The Effects of Improved Transportation Links on Dutch Cities

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1. Introduction

Cities are prime locations of economic activities. They become increasingly important to policy makers and researchers. Different types of economic integration affect growth of cities by changing their market access. In Brakman et al. (2012) we analyzed the effects of integration through abolition of national border barriers and through international town twinning (TT) on cities growth. In this paper, we look at the third type of integration through abolition of transportation barriers and its effects on cities. This paper is based on research with in cooperation with the cities of Almere and Lelystad.[3]

The economic wellbeing of a city depends, among other things, upon its own characteristics such as sector-structure, the population size and its skilled population (see Glaeser et al. (1995)). Moreover, it depends on the city's location relative to other cities and transportation routes. Economic activities tend to cluster in large urban areas owing to positive agglomeration effects do not exist in small towns. There are, however, other factors or repulsion forces that make large cities less attractive and may lead to spreading of economic activities. These include higher wage and other production costs, higher living costs such as housing, and congestion. The size of these economic activities can be reflected in the size of cities. The size and distribution of cities are determined by the relative strength of such positive forces of attraction to agglomerated location and the repulsion forces (Krugman 1991a, 1995; Fujita and Mori 2005; and Fujita et al. 1999).

Very high or very low trade costs favors the dispersion of economic activities, while agglomeration would emerge for intermediate values of these costs once the spatial mobility of workers is low (Fujita and Thisse, 1996). Various natural as well as policy induced interventions can change the center of balance between the two forces. Depending on the degree of the shift in the balance this may trigger relocation of economic activities, mainly firms and workers which, in turn, affects the size of the cities. The outcomes are either further agglomeration or dispersion of economic activities. An example of such intervention is the construction of new or improving

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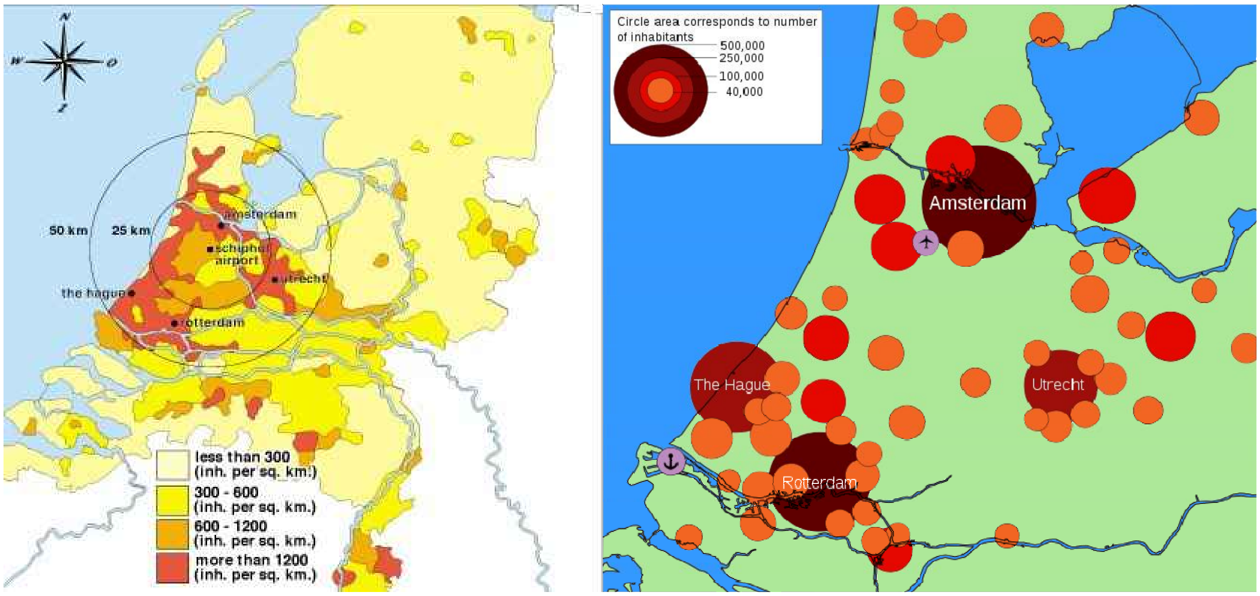
existing transportation routes connecting the cities. Such investment reduces transportation or trade costs between the cities or regions.

In this paper, we use simulations approach to analyze the long-run effects of four transportation projects in the Netherlands using the New Economic Geography (NEG) model based on Krugman (1991a), Helpman (1998) and Hanson (1998). We specifically use the Core-Periphery (CP) model and by mainly focusing on its extension called the Core-Periphery Congestion (CPC) model of the New Economic Geography with interregional factor mobility by Krugman (1991a).

Figure 1: Randstad, the Netherlands



We analyze the long-run implications of four road and railway projects that are aimed at improving transportation between the large cities in the west of the Netherlands called Randstad and nearby smaller municipalities in Flevoland (e.g. the new towns Almere and Lelystad). With the simulation analysis we try to answer the following questions. Does this intervention lead to relocation of firms and workers into the municipalities near the projects at the expense of the other municipalities? Do all municipalities benefit from this intervention? or do only large municipalities gain over the small ones in the vicinities of the projects? Does the intervention lead to divergence or convergence between the large and small cities as well as between the municipalities in the Randstad and the cities outside? How do the effects differ across municipalities of different sizes and across municipalities that are at different distances from the project locations?

The rest of this paper is arranged as follows. In Section 2 and 3 we discuss the NEG models that we use in our analysis. In Section 4 we discuss alternative policy scenarios. We use four potential policy interventions that are aimed at reduction of travel time and so transportation cost within Randstad area of the Netherlands and the transportation routes connecting them with smaller neighboring municipalities. The simulation results of the policy intervention are given in Section 5. Section 6 gives summary and conclusions.

2. The Models

Various models have been used over time to analyze the spatial distribution (agglomeration versus spreading) of economic activities and the effects of policy interventions. In this paper we use the New Economic Geography (NEG) model based on Krugman (1991a), Helpman (1998) and Hanson (1998). In the NEG model there are two opposing forces one leading to agglomeration and the other leading to spreading of economic activities. The existence of such forces affects the outcome of man-made or natural disasters or constructive investment in infrastructure. A number of papers in economic geography investigate this using models that involve the combination of Dixit and Stiglitz (1977) monopolistic competition and 'iceberg' transport costs. In a world characterized both by increasing returns and by transportation costs, there will, obviously, be an incentive to concentrate production of a good near its large markets, i. e., agglomeration (Krugman 1991a). The consequence of the agglomeration according to Krugman is that economically strong regions (core) become increasingly strong and the weak regions (periphery) become increasingly weak. Home market effect (the ability to sell large proportion of products in the same place of production) emerges in cities and agglomerated regions which are densely populated by people who have a preference for a varied supply of products and services called love-for-variety (see Brakman et. al. (2009)). Large scale production for such market helps the firms to reduce production costs and make profits. Agglomeration also provide wide range of employees with various skills called labor market pooling. These further attract more firms to large cities and agglomerated areas. Furthermore, Davis and Weinstein (1999), for instance, show positive effect of agglomeration on the economic growth of cities.

However, according to Hanson (1998) such agglomeration process has limits. After some level of agglomeration, economic centers become too crowded, resulting in a situation in which the agglomeration becomes disadvantage owing to high wages, traffic congestion, and high housing prices. If such agglomeration disadvantages outweigh the agglomeration advantages the concentration of economic activities may stop growing and start to disperse to the cities outside the economic centers (see Brakman et al. 2009). Similarly, expansion of manufacturing activities in such markets increases wage cost which leads to relocation of the firms to the areas with lower wage and other input costs (Puga and Venables 1996). In addition to such congestion forces, some external shocks can also break the pattern detected by Krugman (1991a). These shocks can be destruction of cities infrastructure during conflict (for example see Brakman et al. 2004a), or positive shocks of policy interventions such as construction of housing that reduces housing costs or transportation routes that reduces congestion. This paper focuses on the later, i. e., construction of roads and railways. Ceteris paribus, improved transportation between the core and the periphery may lead to relatively higher both population and economic growth of the periphery. Models that involve the combination of Dixit and Stieglitz (1977) monopolistic competition and 'iceberg' transport costs are often used in analyzing related issues. In these models, agglomeration is caused by the desire to overcome transport costs when selling ones product or making purchases. This similar desire on the side of producers and consumers leads to a feedback loop, resulting in self re-enforcing agglomeration (see Knaap 2004). The precise form of the loop and the resulting degree of agglomeration differs between models. These models often lead to too much agglomeration than real world distribution of economic activities, agglomeration bias. In the NEG it is possible to account for real geographical factors and congestions factors that are resistant to full agglomeration and produce more realistic distribution of economic activities.

We use the Core-Periphery (CP) model and mainly its extension namely the CP model with congestion (CPC) model of the New Economic Geography with interregional factor mobility by Krugman (1991a) to investigate the long-run implications the four road and railway projects to improve transportation between the large cities in the west of the Netherlands called Randstad and nearby smaller municipalities (see section 3 for detail). The general CP model for *M* municipalities is given by equations (1) through (4). See Brakman et al., (2009) for the detailed derivation of the equations and some normalization process to get the compact form of the model.

$$Y_a = \delta\lambda_a W_a + (1-\delta)\phi_a \tag{1}$$

$$I_a = \psi_a^{1/(1-\varepsilon)} \text{ and } \psi_a = \sum_i \left(\lambda_i T_{ai}^{1-\varepsilon} W_i^{1-\varepsilon}\right) = \sum_i \left(\lambda_i T^{D_{ai}(1-\varepsilon)} W_i^{1-\varepsilon}\right) \tag{2}$$

$$W_a = \Phi_a^{1/\varepsilon} \text{ and } \Phi_a = \sum_i \left(Y_i T_{ai}^{1-\varepsilon} I_i^{\varepsilon-1}\right) = \sum_i \left(Y_i T^{D_{ai}(1-\varepsilon)} I_i^{\varepsilon-1}\right) \tag{3}$$

$$T_{ai} = T_{ia} = T^{D_{ai}} \tag{4}$$

Equations (1) through (3) for each municipality $a = 1, 2, \ldots\ldots, A$ together determine the income level Y_a, price index I_a, and wage rate W_a for each municipality *a*. The economy has two sectors. One is the manufacturing sector with employment share of λ_m and the other is the agricultural sector with employment share of ϕ_m for each municipality. $\sum_i \lambda_s = \lambda_1 + \lambda_2 + \ldots + \lambda_a = 1$ and similarly, $\sum_i \phi_s = \phi_1 + \phi_2 + \ldots + \phi_a = 1$. A household spends δ fraction of income spent on manufacturing goods and the remaining $(1-\delta)$ on agricultural commodities, i.e. food. $T_{ai} = T_{ai} = T^{D_{ai}}$ is the iceberg transport costs indicating the number of units needed to be shipped from municipality *a* so that one unit of the good arrives in municipality *s* and the vice versa; where D_{ai} is the unit of distance between municipality *a* and *i*, for instance road distance in kilometers or travel time in minutes. $\varepsilon = 1/(1-\rho)$ is the elasticity of substitution between manufacturing goods where $\rho \in (0,1)$ is the substitution parameter representing love-of-variety effect in the aggregate consumption function of manufacturing goods (see Brakman et al., 2009):

$$C = \left(\sum_{j=1}^{N} c_j^{\rho}\right)^{1/\rho} \tag{5}$$

The derivation of the CP model is based on production function of the form:

$$l_j(w_j) = w_j(\alpha + \beta x_j) \tag{6}$$

and the demand for variety $x_j = \theta p_j^{-\varepsilon}$ where $l_j(w_j)$ is the amount of labor required to produce x_i units of manufacturing output depending on real wage cost; and α and β are the fixed and marginal labor input requirements, respectively; p_j is unit price of the variety and θ is a constant. The real wage rate in municipality *a* is defined as $w_a = W_a I^{-\delta}$. Given the *L* total labor force of the economy, the model assumes that a fraction $\gamma \in (0,\ 1)$ of the proportion of the labor force work in the manufacturing sector whereas the remaining $(1-\gamma) \in (0,\ 1)$ work in the food sector. As opposed to some research works evaluating the impacts transportation infrastructure (for instance Knaap (2002)), we assume that the wage rate varies across the municipalities. However, we adopt similar assumptions with such works on several aspects. For instance, like many other works, we assume that there are no constraints in labor supply. This means that each community has a sufficiently large pool of unemployed to use in times of increased labor demand.

We extended the CP model by accounting for congestion cost and obtain the congestion (CPC) model. The CP and CPC model are more or less the same except the use of congestion parameter in the CPC model; and we can call both CP models. The CP model, in general, explains agglomeration (and spread) of economic activities in terms of demand linkage (Forslid and Ottaviano, 2003). When a firm moves its production facilities to a new site, local market is affected through two channels. (i) Given the trade costs, the presence of a new competitor reduces local prices, this reduces demand per firm (market crowding effect) and increases consumer surplus (cost-of-living effect). (ii) local expenditures grow increasing the demand per firm (market size effect) if the extra income generated by the new firm is locally spent. The first effect discourages geographical agglomeration whereas the other two effects encourages it by creating circular causation among firms' and workers' location decision. This is based on assumption of employing only local workers and labor is the only factor of production and this is solely the case in the CP model whereas the CPC models reveals some additional effects. In the CPC model, we see extra spreading force of congestion cost that can be seen as second force that discourages agglomeration. The congestion model is based on the idea that it is disadvantageous to locate production in an already crowded area by other firms or an increase in cost as more and more firms locate in one place and raise to the incentive to relocate to less crowded areas. The size of congestion depends on the number of manufacturing firms N_a located in municipality *a*. The extra cost due to congestion is reflected on the production function of the variety x_j given as:

$$l_{ja}(w_j) = N_a^{\tau/(1-\tau)} w_j (\alpha + \beta x_j) \qquad (7)$$

where $\tau \in (-1,\ 1)$ is the congestion parameter. Note that the labor requirement $l_{ja}(w_j)$ for each unit of x_j differs for each municipality depending on congestion. $\tau = 0$ means no congestion and the model remain the same as the CP model; $\tau \in (0,\ 1)$ means the cost increases as more and more firms locate in the same area and so congestion is harmful; whereas $\tau \in (-1,\ 0)$ means firms benefit from locating together. Note that the difference in all the CP, CPC and FE models arise from the cost of production and reflected in the production function (see below for more on the FE model). After incorporating the production function with congestion, equation (1) above remains the same whereas the right hand expressions of equations (2) and (3) become equations (8) and (9).

$$I_a = \psi_a^{1/(1-\varepsilon)} \text{ and } \psi_a = \sum_i \left(\lambda_i T_{ai}^{1-\tau\varepsilon} W_i^{1-\varepsilon} \right) = \sum_i \left(\lambda_i T^{D_{ai}(1-\tau\varepsilon)} W_i^{1-\varepsilon} \right) \tag{8}$$

$$W_a = \Phi_a^{1/\varepsilon} \text{ and } \Phi_a = \lambda_a^{-\tau} \sum_i \left(Y_i T_{ai}^{1-\varepsilon} I_i^{\varepsilon-1} \right) = \lambda_a^{-\tau} \sum_i \left(Y_i T^{D_{ai}(1-\varepsilon)} I_i^{\varepsilon-1} \right) \tag{9}$$

In the CPC model with positive congestion parameter, some places gets less attractive since the degree of competition increases as number of number of firms locating there increases. Thus, the new comers or even some of the existing firms may locate in new and less populated locations. Similar argument holds for consumers as well. Living cost is higher in more crowded locations and thus consumers prefer to live outside such locations. Thus, the CPC model has spreading effect and is more realistic than the CP model where all the firms tend to end up in one location. Papageorgiou and Thisse (1985) describe the process of interaction between the two classes of agents as follows: "Households are attracted by places where the density of firms is high because opportunities there are more numerous, and they are repulsed by places where the density of households is high because they dislike congestion. Firms are attracted to places where the density of consumers is high because there the expected volume of business is large, and they are repulsed by places where the density of sellers is high because of the stronger competition. So by adopting congestion model we add additional spreading factor (see also Bosker et al. 2007b) to the core-periphery model where agglomeration is most likely stable long-run equilibrium. High transportation costs representing all kinds of barriers (see Brakman et al., 2009) are also spreading factor. Before the simulation of the effects of the actual policy scenarios we will have a closer look at the effects of transportation cost and congestion in multiple region scenario.

3. Agglomeration and Spreading effects of Transportation cost and Congestion

The agglomeration/Spread effects of transportation cost and congestion in simple two-regions model are well-known. High transportation cost as well as high congestion leads to spreading equilibrium (see Brakman et al., 2009). In this sub-section we analyze the effects of different transportation cost and different level of congestion in the case of multiple locations. We use actual population size of the 418 municipalities of the Netherlands representing the size of economic activities in 418 different locations or regions. The Figure 2a below shows the results for changing transportation cost at a given level of congestion factor. It shows that at very high congestions factor as $\tau = 0.30$ or $\tau = 0.20$, positive and increasing transportation cost (for instance from T_{ij} = T_{ai} = 1.01 to T_{ij} = T_{ai} = 1.30) leads to more spreading. Moreover, perfect spreading becomes the long-run equilibrium when the transportation is totally free (T_{ij} = T_{ai} = 1.00). In general finding of the changes in transportation cost and congestion factor are in line with theory. The absence of congestion and low transportation costs lead to agglomeration indicated by steep or fast falling curves. The lower the congestion, the higher the agglomeration (fast falling curves) even with positive transportation cost. With positive congestion and positive transportation cost, higher transportation cost leads to much further spread (flatter curves). Moreover, with any positive congestion $(\tau > 0)$, free transportation always leads to spreading equilibrium. With free transportation and zero congestion the initial distribution remains a long-run equilibrium (no redistribution).

Figure 2a: Changing Transportation T_{ij} = T_{ai}, fixed Congestion factor (tau, τ)[4]

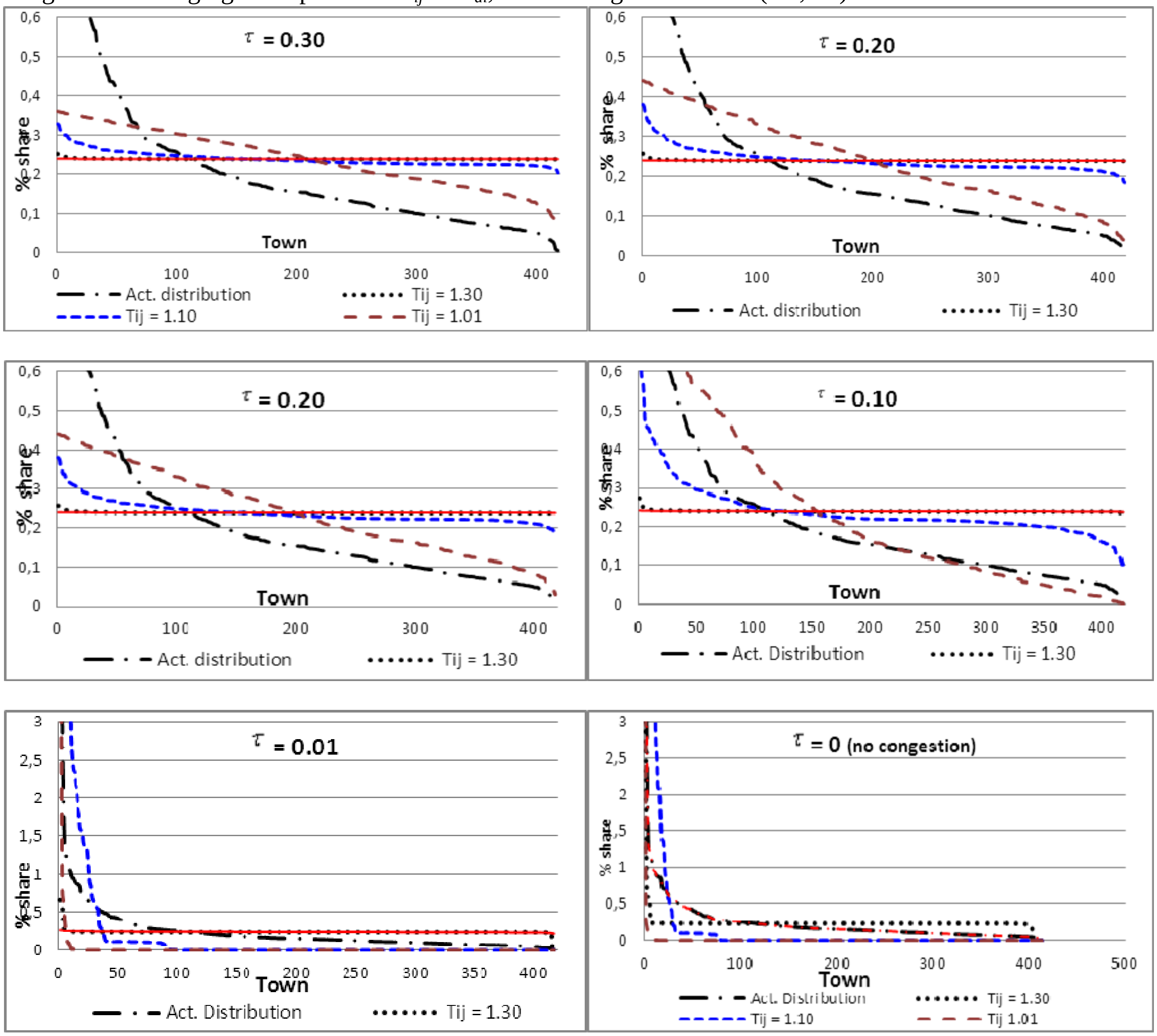
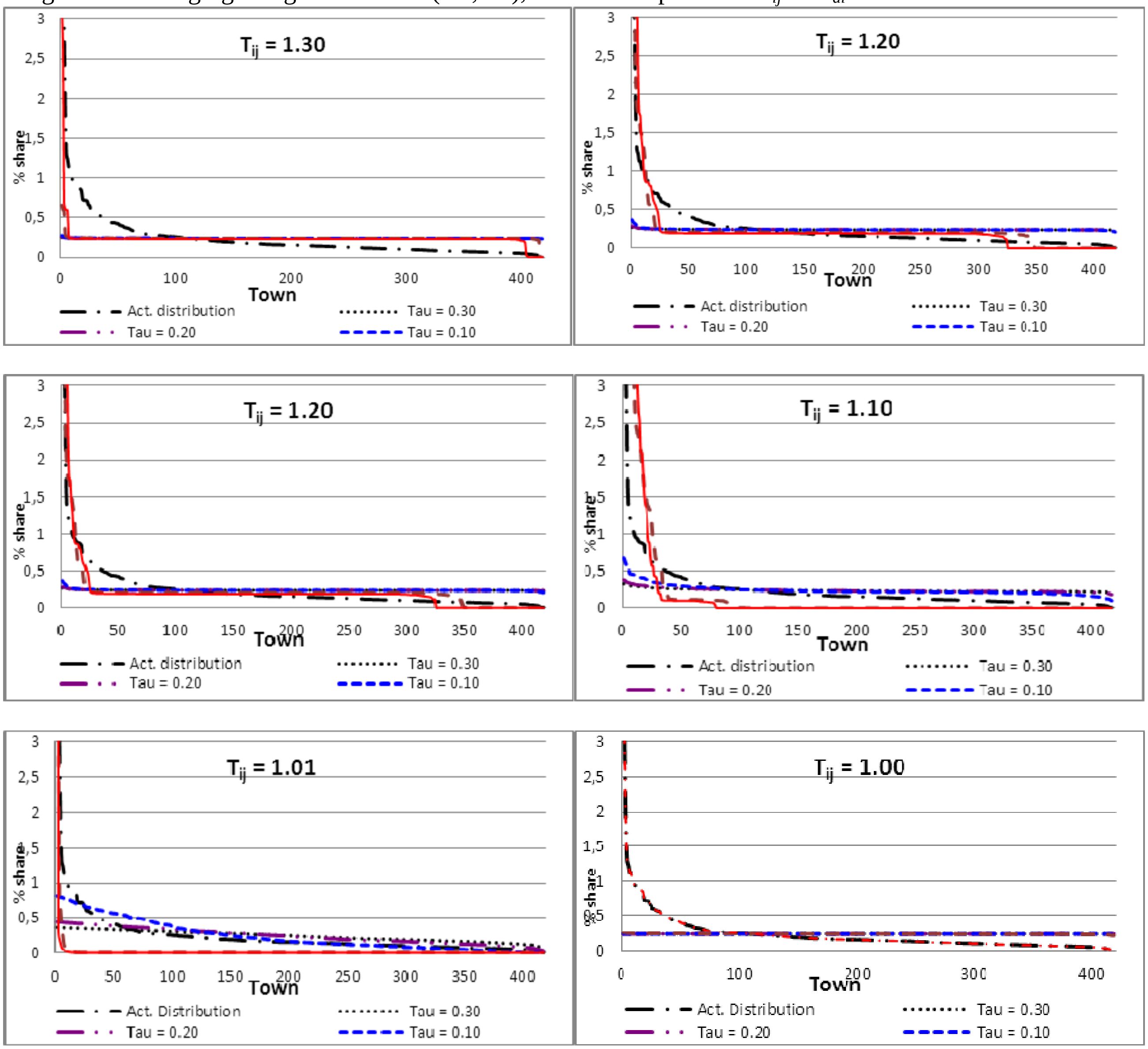


Figure 2b shows the results for changing congestion factor at a given level of transportation cost. With positive transportation cost, higher congestion always leads to spread. However, the lower the positive transportation cost the smaller congestion as 0.01 leads to agglomeration (see τ = 0.01 curve as we go from figure for T_{ij} = T_{ai} = 1.30 to T_{ij} = T_{ai} = 1.20 to T_{ij} = T_{ai} = 1.10 and to T_{ij} = T_{ai} = 1.10). Absence of congestion and lower transportation costs lead to

4 $T_{ai} = T_{ia} = T$ in the equations and T_{ij} in the figures are the same and measures the iceberg transportation cost.

agglomeration (fast falling curves). The lower the congestion, the higher agglomeration (fast falling curves) even with some positive transportation costs. With positive congestion and positive transportation cost, higher transportation costs lead to spread (flatter curves). Similarly, with positive congestion, free transportation also leads to spreading equilibrium. With high transportation, absence of congestion leads to agglomeration whereas positive, small as well as high, congestion leads to spread.

Figure 2b: Changing Congestion factor (tau, τ), fixed Transportation $T_{ij} = T_{ai}$



Bad transportation infrastructure can account for 40 to 60 percent of transport cost; and obviously, improved transportation infrastructure reduces transport cost (see Limao and Venables, 2001); and so does the reduction in travel time through the projects aimed at improving the transportation infrastructure. New infrastructure may lead to further agglomeration in the core area and dispersion to the nearby smaller municipalities. Although it is argued that dispersion is usually bad as compared to agglomeration, from a welfare point of view, dispersion necessarily takes place when the transportation cost is sufficiently low (Tabuchi 1998). Dispersion also exist at very high transportation cost. Baldwin et. al.,(2003) also show that infrastructural developments have non-linear effects in the presence of agglomeration effects. Very high or very low trade costs would favor the dispersion of economic activities, while agglomeration would emerge for intermediate values of these costs once the spatial mobility of workers is low (Fujita and Thisse, 1996).

4. The Policy Scenarios: Abolition of Traffic Congestion

The Dutch government and the municipalities have recently been working on policies that are aimed at developments and integration of cities by reducing or abolishing traffic congestion among these cities. These development initiatives may have different outcomes for different cities. Whether cities benefit from such projects depends on whether the cities are competitive or complementary (example see Tabuchi 1998). If the cities are complementary, all the cities will gain from the intervention. However, if they are competitive, some cities may gain at expense of the others. It is also possible that the policy intervention may change the competitive position of the Randstad compared to the other cities in the country, as well as large cities compared to smaller cities.

In this paper we focus on the distribution effects of the projects in terms of population. The projects change the transportation and trade costs that lead to relocation of firms and workers. This means that some municipalities inevitably loose whereas others gain. In the projects that we are analyzing in this paper, the improvement in infrastructure implies reduction in traffic congestion as well as reduction in trade cost among municipalities that use the particular transportation routes. The questions that we try to address are the following. Does this intervention lead to more agglomeration in the Randstad at the expense of the other cities? Do only large cities in the Randstad and in its vicinities gain over the small ones or the vice versa? Does the intervention lead to divergence or convergence between the large and small cities? This intervention may benefit smaller cities in close range with the improved transportation links over the large ones since people can live in cheaper cities and easily access the large city for work, recreation and shopping. In this paper we focus on simulation analysis of long term population effects on the municipalities resulting from four road and railway construction projects aimed at reduction or elimination of traffic congestions at selected trajectories within the Randstad area and in its vicinities: conurbation

a) Railway Construction (OVP1), [De aanleg van de Hanzelijn]

b) Road Widening (AUTOP2), [De verbreding van de A1/A6]

c) Railway Construction (OVP3), [De IJmeerverbinding]

d) Road Widening (AUTOP4), [De verbreding van de A27/AGU]

The first project (OVP1) is the construction of a new railway from Lelystad through Dronten till Zwolle which opened at the end of 2012. This project will shift, at least part, the traffic between the Northern Netherland cities and Amsterdam to through Dronten, Lelystad and

Almere as opposed to the former route, through Amersfoort. These municipalities along this route are expected to grow relatively faster if the reduction in transportation cost due to this project is higher than the benefit of agglomeration in the Amsterdam area. The second project (AUTOP2) is widening the highway road between Almere and Amsterdam. This project is also expected to benefit smaller nearby municipalities connected to Amsterdam through this road if the reduced transportation cost is large enough. The third project (OVP3) is construction of railway at the trajectory from Schiphol through Amsterdam and Almere to Lelystad. This is aimed at improving the economic wellbeing of the cities by better integrating with the main Randstad area. In this project, we look at the effect of such further integration of Lelystad and Almere into the Randstad in comparison with expectation of the cities. Thus, we try to answer whether these cities benefit as intended by such measures or the cities in the Randstad become more competitive and capture the benefit. The fourth project (AUTOP4) is about increasing the width of the existing road between Utrecht and Almere through the Gooi region. The aim of this project is also to better integrate Almere and other cities in the area with the Randstad by improving transportation through Utrecht.

To simulate the effects of these projects we use the road distance data between all municipalities of the Netherlands and their population data in 2009. Changes in travel time due to these projects were constructed with the kind cooperation of the cities of Almere and Lelystad, two of the cities who are expected to benefit most from these projects in terms of attractiveness. The new route of the first project (OVP1) reduces the travel time of 161 municipalities who would travel through this route to other cities (see table 1 below summary of all the projects). Similarly, the projects AUTOP2, OVP3, and AUTOP4 change, respectively, the travel times of 133, 55, and 161 Dutch municipalities to others. The largest reduction in travel time by project 1 is about 71 % which is between Dronten and Zwolle; whereas the smallest reduction is 0.012 % between Schiermonnikoog and Maassluis. The largest change due to AUTOP2 is about 10.9% (between Diemen and Muiden) whereas the smallest change is approximately 0,002 % (between Amsterdam and Dongeradeel). The largest and the smallest change due to OVP3 is 37.1% (between Almere and Diemen), and the largest change due to AUTOP4 is 23.3% (between Eemnes and De Bilt. All the projects are located on transportation routes within the Randstad area and its vicinity. We analyse the implications of these for different cities within and in the vicinities of the Randstad such as Almere, Lelystad and Dronten in terms of population distribution. Moreover, we investigate whether there are different implications for smaller cities compared to large cities and for cities that are far away from the project locations compared to nearby cities.

Table 1: Summary of the projects travel time (T_{rs}) effects

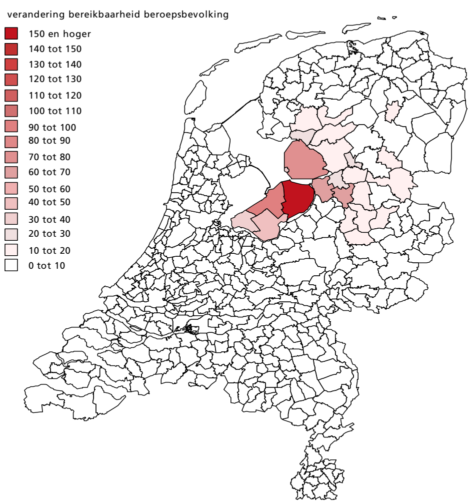
Projects	pair of affected roads(T_{rs})	Affected municipalities	the largest change in T_{rs}	the Smallest change in T_{rs}	Mean sum change in T_{rs}
OVP1	4790	161	0.71122	0.000122	1.624446
AUTOP2	3401	133	0.10877	0.000020	0.361751
OVP3	204	55	0.37103	0.032050	0.100537
AUTOP4	4630	161	0.23277	0.000150	1.166299

For the empirical analyses and simulations we use the spatial data that include indicators of spatial location of 427 Dutch municipalities and the degree of agglomeration of cities and urban regions. Before we go to the simulation of the long run effects, we show the description of the short run effects of the projects on market potential based on Harris (1954). We calculate the changes in the market potential due to the changes in travel time following the different projects. The change in the market potential for municipality m is calculated as $\Delta MP_a = \sum_{i=1}^{N}\left(\frac{Q_a}{T_{ai(t=1)}}\right) - \sum_{i=1}^{N}\left(\frac{Q_a}{T_{ai(t=0)}}\right)$; where, $T_{ai(t=0)}$ and $T_{ai(t=1)}$ are travel times between two municipalities m and s before and after the projects, respectively; Q_a is a measure of economic size, for instance population, of municipality m; and (*N = 427* in this case) is the number of municipalities in the sample. In this way, the short run effects of infrastructural interventions policy can be calculated. The emphasis here is not on the effects on transport flows but on the impacts on the spatial allocation of economic activities measured by population distribution. Figure 3 shows the map of the changes in the market potential in terms of population and employment under each project.

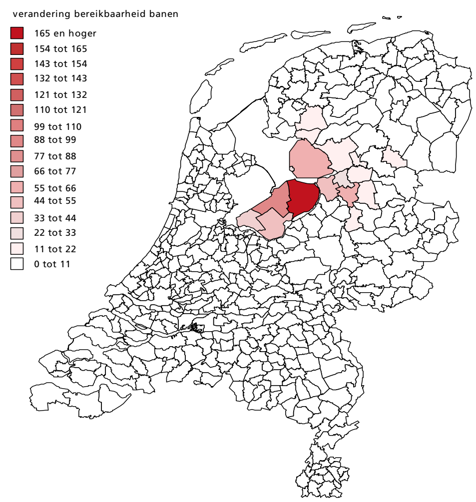
Figure 3: Changes in the Market Potential

Project 1 (OVP1)

Q_a = population

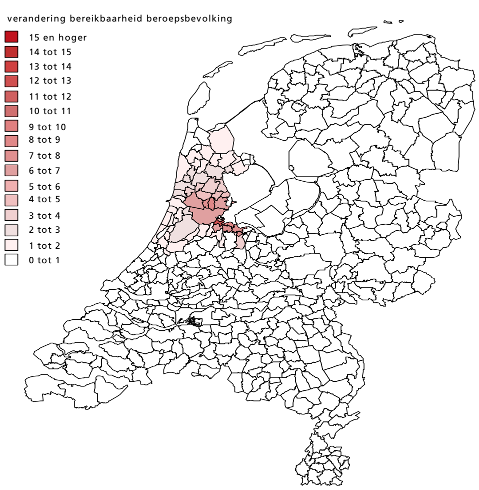


Q_a = job(employment)

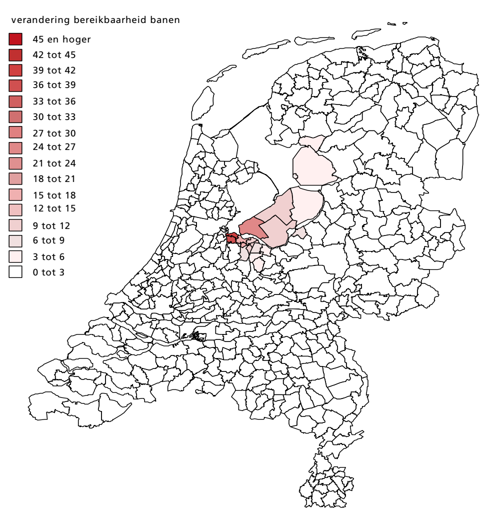


Project 2 (AUTOP2)

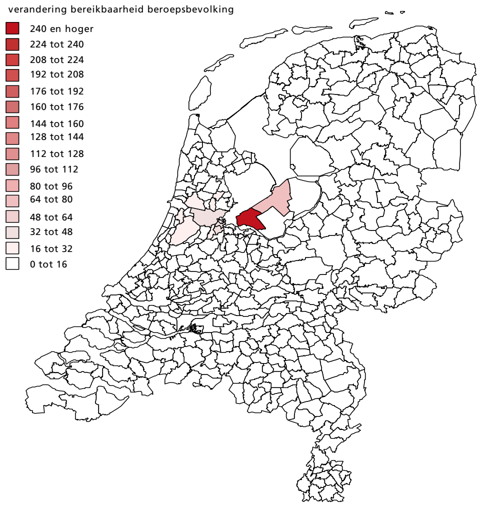
Q_a = population

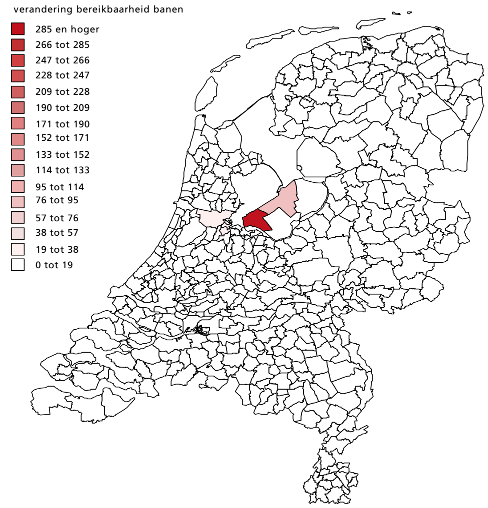


Q_a = job(employment)

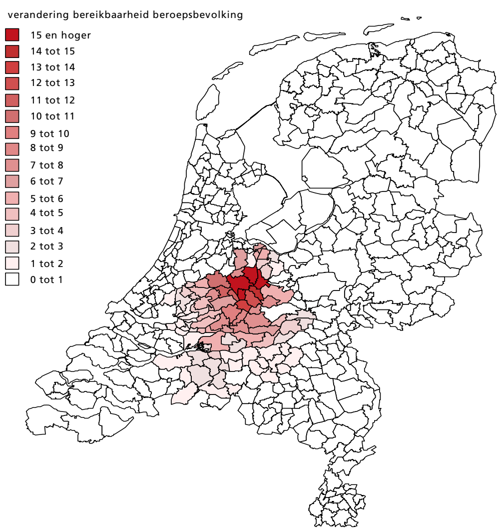


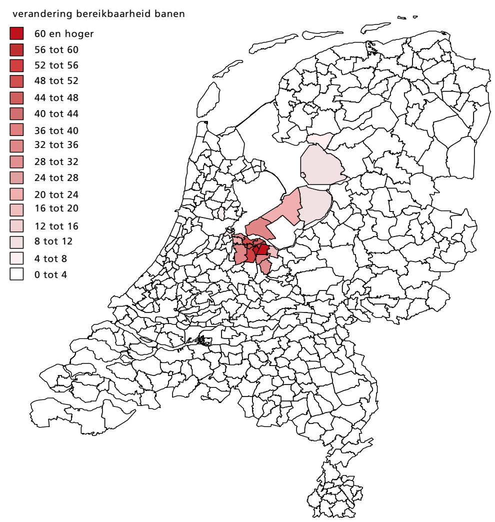
Q_a = population **Project 3 (OVP3)** Q_a = job(employment)





Q_a = population **Project 4 (AUTOP4)** Q_a = job(employment)





The darker red the shade of the maps in the figure, the larger the gain in the market potential. These changes are short-run gains in the market potential as the result of immediate changes in the travel time in the denominator of the market potential. The gains in terms of population and employment are slightly different, but both are the largest at and near the location of the projects since these places also experience the largest reduction in the travel time to other municipalities. The gain in the market potential in terms of population implies improved access of the firms to households, i.e., consumers; whereas the gain in the market potential in terms of job implies easier access of the household to companies due to improved transportation. The improved transportation changes the transport cost of both firms and workers.

The above figures show only short run effects without relocation of firms or workers. However, the changes may also lead to relocation of the firms and the workers in the long run since transportation cost is one of the major determinants of firms location with respect to the location of the workers and consumers (for instance see Krugman and Venables 1995; Tabuchi and Yoshida 2000; Puga and Venables 1996; and Wen 2004). Obviously, reduced travel time through improved transportation means reduced transportation cost and lower trade cost.

Moreover, lower trade cost means less agglomeration (Puga 2002) because with lower trade cost some firms relocate from industrial agglomeration to regions with lower wages (see Krugman and Venables 1995). Therefore, these projects aimed at reducing travel time and transportation cost may lead to less agglomerated municipalities. Thus, next, we need to look at the long-run effects using simulation approach based on NEG long-run equilibrium model discussed above in section 2.

5. The Long-run Effects

Here we use computer simulation of the long-run effects of the proposed projects based on NEG model described in the earlier section. This baseline simulation analysis is based on 427 municipalities of the Netherlands. Many estimation and simulation works based on NEG models use straight line distances between two locations (for instance, see Stelder, 2005). However, we use the shortest path road network and actual travel times between municipalities since this is a better measure of distances the commodities and workers travel. Obviously the shortest path road distance between two municipalities are the same whether we measure it from city *a* to city *i* or from city *i* to city *a*, i.e., $D(a, i) = D(i, a)$. We also assume that the travel time of going and return between two municipalities are the same, i.e., $T(a, i) = T(i, a)$. This assumption is realistic for almost all pairs of municipalities in the Netherlands since most part of the country's topography is almost flat. In case of mountainous countries, driving up the hill and driving down the hill may take different travel times between the same two municipalities. However, travel times between two cities can differ when congestion is only in one direction (e.a. Almere-Amsterdam) and not in the other direction (e.g. Amsterdam-Almere). In this analyses we do not account for that possibility.

Moreover, both the road distance and travel time include the internal (within a municipality) distance and/or travel time since the municipalities cover the area of more than a city in almost all the cases. As described in the earlier section, there are two types of the projects, namely the road projects and rail way projects. We use the road network to account for changes in distance and travel time effects of both types of projects since the complete rail road connecting all the 427 municipalities is not available. This means that we assume that everyone travels by car or train, depending on the shortest ravel time of either of these modalities.

Finally, we assume the initial distribution of manufacturing workers is proportional to the initial distribution of the population. For instance, if the municipality of Amsterdam accounts for 5 percent of the total Netherlands population, the municipality also accounts for 5 percent of the national manufacturing workers.

In the simulation process we start with parameter configuration that reproduce the current level of agglomeration as close as possible. We use four different combinations of the models and different distance options. These are two core model (CP) options one with distance in kilometers and another with distance measures by travel time in minutes; and two congestion (CPC) model options with positive congestion parameter (τ) in combination with the two distance options. The parameters combination (given in table 2 below) are chosen in such way that different parameters configurations reproduce the actual distribution as close as possible under different model options. For instance, at low or medium transport cost, the fact that there is no congestion problem in core model leads to agglomeration at one place as the long-run equilibrium, agglomeration bias. Thus, ceteris paribus, an approximate real distribution of the cities is possible only at high iceberg transportation cost of about 33% with travel time as a measure of distance and of about 40% with actual road distance. On the contrary, under the congestion model, the closest realistic distribution happens even at very low transportation cost of about 5%. Figure 4 below shows the approximated distribution under the congestion model.

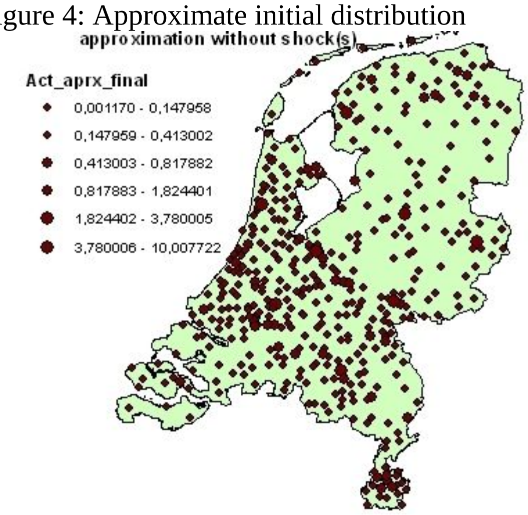
Table 2: the parameters configuration

Model	**Distance options**	**Parameters configuration**			
		$\gamma(=\delta)$	$\varepsilon(=\rho)$	T	τ
Core model (no congestion)	road distance (in kilometers)	0.5	5(0.8)	1.40	0
	Travel time (in minutes)	0.5	5(0.8)	1.33	0
Congestion model (positive tau, $\tau > 0$)	road distance (in kilometers)	0.5	5(0.8)	1.05	0.10
	Travel time (in minutes)	0.5	5(0.8)	1.05	0.10

Note: Tolerance = 0.001; and the number of regions/municipalities *M* = 427 in all the model scenarios.

Moreover, we fix some parameters in advance according the definitions of the models (for instance $\tau = 0$ in the core model by definition). Moreover, the proportion of manufacturing workers remain the same throughout the model options. Thus, largely, we use the iceberg transportation level that reproduce close distribution with the real agglomeration level based on 2009 population. High transportation cost of up to 40% is required to keep spread near actual distribution. However, consistent with falling transportation cost (example see McCann and Shefer 2004), very low cost as 5 percent is sufficient for this with congestion model. The proportion of the labor force working in the manufacturing sector γ = 0.5 is also assumed to be equal with the proportion of the income spend on manufacturing goods (δ). The elasticity of substitution $\varepsilon = 1/(1-\rho)$= 5 is calculated from the substitution parameters $(\rho = 0.8)$ meaning the consumption goods are substitutes but less than perfect. The transportation parameter $(T > 1)$ implies that more than 1 unit of goods should be shipped from one municipality so that 1 unit arrives in another municipality. The congestion parameter $(\tau = 0)$ and $(\tau > 0)$ represent the absence of congestion effect and existence of congestion with negative effects on firms and workers, respectively. The tolerance level of 0.001 is used as a cutting point. It is the ratio of the difference between the real wage in a current location of a worker and another location to the current real wage the worker is receiving; i.e., $((w_i - w_a)/w_a)$, where $(w_i > w_a)$, w_a is a real wage that a worker is receiving in municipality *a* and w_i is the real wage in municipality *s*. This ratio should be large enough to motivates the workers to relocate to the higher real wage municipality. In other words, this means that when the ratio is too small the workers stay with their current job and the long run equilibrium is reached. Tolerance = 0.001 $\equiv ((w_i - w_a)/w_a) < 0.001$ means that it is no more attractive for a worker to relocate when the ratio falls below 0.001. Figure 4 shows the relative size distribution of the municipalities after the replication. We checked for the effect of changing the tolerance level from 0.001 to 0.00001 and the results remain very much the same. Changing the tolerance level only leads relatively different length of times to reach the long run equilibrium. The final distribution and other relationships, for instance between the distribution effects and changes in travel time or distance from the project locations as discussed below (example see table 5 and table 7), generally remain robust. We further discuss the simulation results of the two model options based on discussion in section 2 above, namely the core model and the congestion model.

Figure 4: Approximate initial distribution



In all the model options the long-term equilibrium is achieved through mobility of firms due to changes in transportation and trade costs and mobility of workers from one municipality to another due to differences in real wage. The workers migrate to municipalities with higher real wage. This higher supply of labor reduces the real wage in that municipality below that of another municipality which triggers another wave labor migration to those municipalities with higher real wage. This process continues until the real wage becomes the same in all the municipalities and there is no further incentive to migrate. Thus, the long-term equilibrium is achieved when the real wage becomes very much similar in all the municipalities. The simulation results are summarized in table 3 and table 4.

Table 3: Summary: Mean gains within each model option and across the models

Model	Distance options	Mean/net gains?			
		OVP1	AUTOP2	OVP3	AUTOP4
Core model (no congestion)	road distance	yes	no	yes	yes
	Travel time	no	no	no	no
Congestion model (positive tau)	road distance	yes	yes	yes	yes
	Travel time	no	yes	yes	no
"net number of gains/affirmative"		0	0	3	0

Note: the distance option are that road distance is in kilometers and travel time is in minutes in all cases.

Table 3 shows the mean effects of each project on the final distribution of the municipalities size as whole under different model options. The value is '*yes*' if the sum of the changes in the municipalities population share following each project is positive and '*no*' otherwise. This can happen due to large increases of only couple of municipalities or small increases in several municipalities. Table 4 gives the number of municipalities with positive effects following the projects simulated implementation under the different model options. The detailed individual effects of selected models based on travel time distance option are also given by geographical map demonstrating of the effects (see figures 6.5a and 6.5b for the core model and congestion model, respectively). The size of circular balls shows the percentage gain for the gaining municipalities. The figures show a wide range of results showing different effects of different projects simulated using the two models. The code model (Figure 5a) demonstrates its high agglomeration effects, even with such high transportation cost as 33% compared to the congestion model (Figure 5b) with 5% transportation cost still resulting in stronger spreading effect.

Figure 5a: Changes in the cities size (Core-Periphery model)

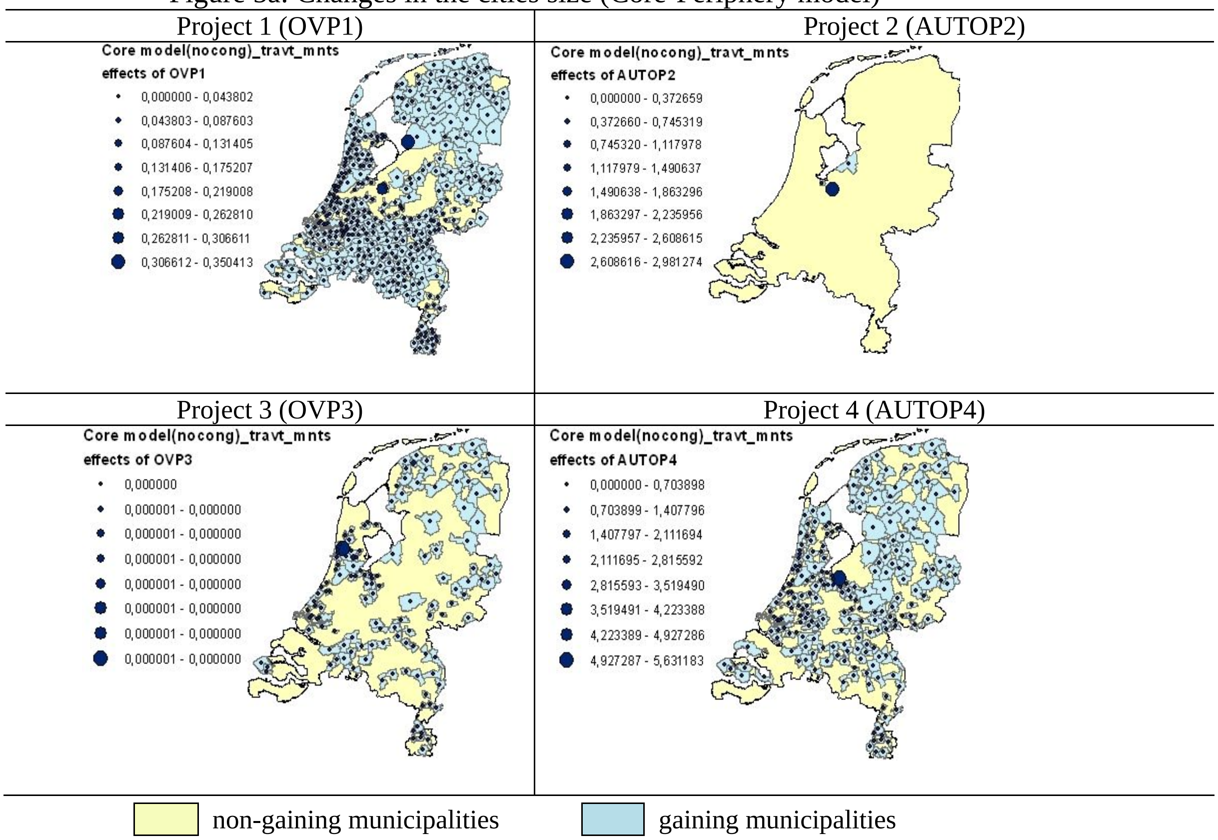
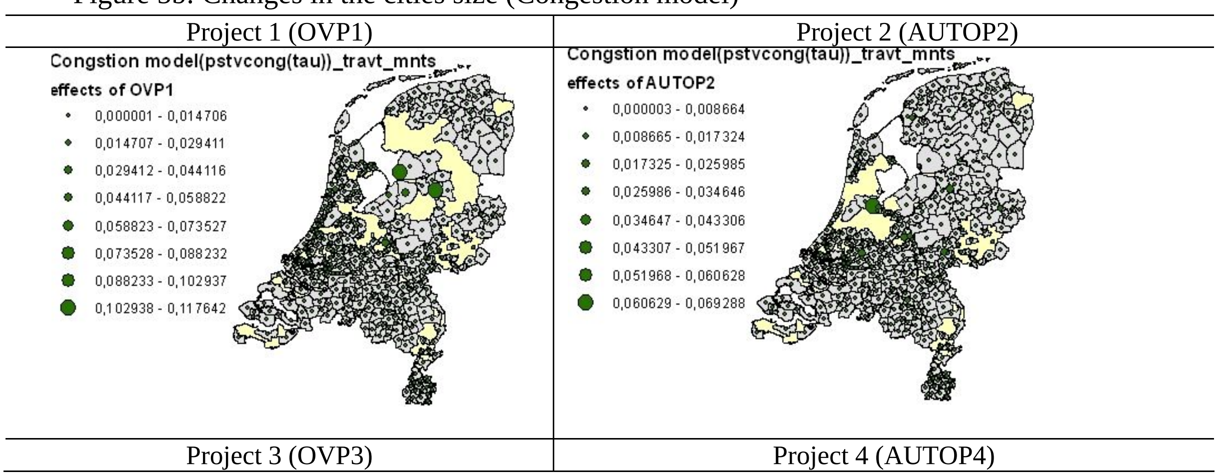
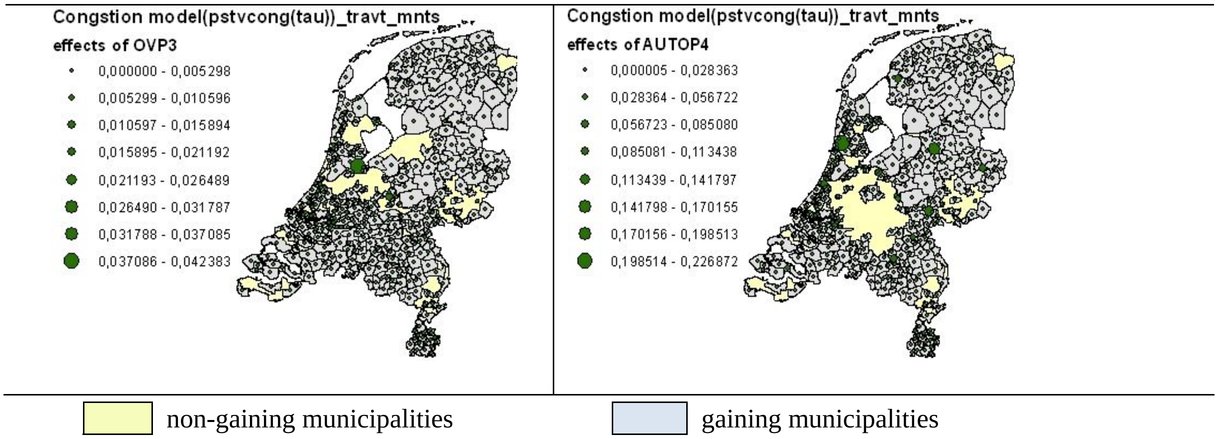


Figure 5b: Changes in the cities size (Congestion model)





The summary table 3 shows that project OVP3 is the best in terms net gain (all municipalities average effect) whereas table 4 shows that OVP3 and AUTOP4 are the top in terms of the number of individual municipalities gaining from the projects.

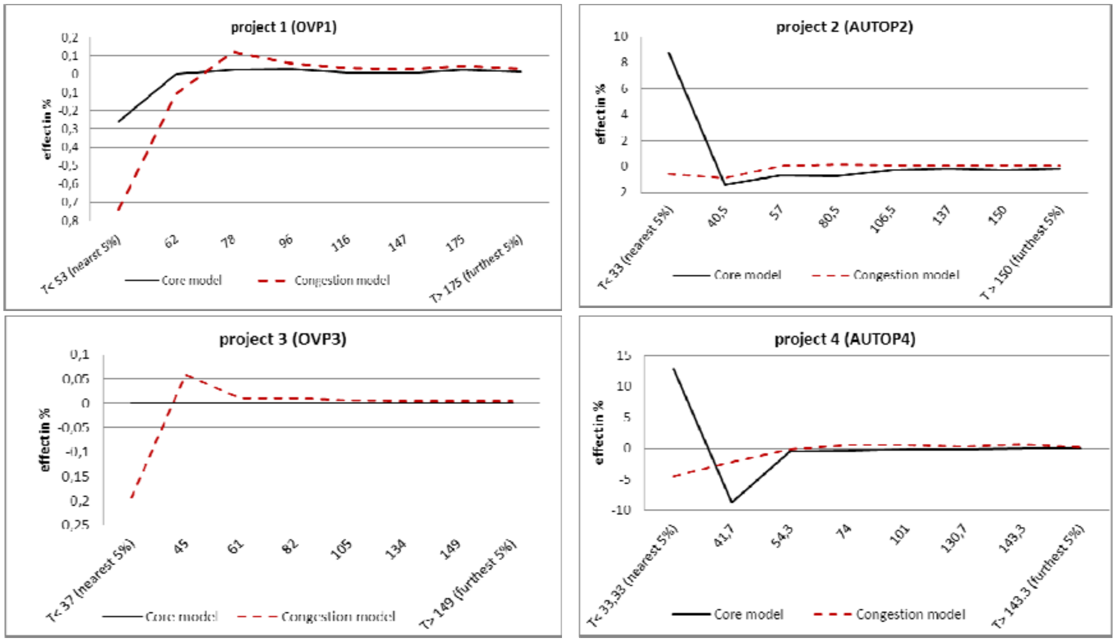
Table 4: Number of net gaining municipalities within each model option and across the models

Model	Distance options	Number of municipalities with net gain					
		OVP1	AUTOP2	OVP3	AUTOP4	OVP5	AUTOP6
Core model	road distance	3	4	408	416	333	417
(no congestion)	Travel time	391	3	136	223	23	222
Congestion model	road distance	59	62	373	390	25	23
(positive tau)	Travel time	381	378	380	363	58	80
"mean number of gaining municipalities"		209	112	324	348	110	186

Note: the distance option are that road distance is in kilometers and travel time is in minutes in all cases.

For a better reading and interpretation of the results, next we look at a more detailed aspects of selected two models, as suggested in earlier section in a comparative way. These two versions of the NEG model are the most commonly used ones. Other forms of the model are closely related to either of them. Moreover, the effect under the congestion model is much in line with what we would expect in reality from such projects. For instance, the results under this model reflects that a number of municipalities gain marginally as opposed to big flow of firms and workers creating big changes in one or few municipalities. This is because the real world is more complex than these models and there are a lot of resistance factors to triggering relocation. Both the core and the congestion models have some limitation. For instance they do not take into account such issues the value of amenities such as landscape, climate; no region has a superior resource base or technology; there are no intermediate goods and so on (see Schmutzler 2002). The major difference between the core and the congestion model is that there are no direct negative externalities between firms under the core model assumptions, e.g. due to pollution or congestion in the former. In general, the simulated results for the congestion model show spread away from the project locations specially when the big municipalities such as Amsterdam are part of the location of the project. On the contrary, the agglomeration in bigger municipalities is relatively higher under the core model (see Figure 6). The figures show the changes in the municipalities size following the simulated interventions under the two models over different distance ranges. Under each project the congestion model (the red-dashed curve) lies below the core model result (the black solid line) near the project locations, but the opposite at further distances from the project locations. This implies that the projects aimed at integrating the randstad with the municipalities in the vicinities, in general, benefit more the municipalities outside the project locations in the randstad. These results are more realistic compared the core model because the former accounts for the congestion factor and since it is also based on more realistic transportation cost of around 5% compared to above 30% in the core model.

Figure 6: Long-run effects of the projects (T = travel time in minutes)



We break down this investigation between the large and small municipalities to check whether the these results are derived by the project location or by the size of agglomeration at the project location compared to the neighboring or the rest of the country. Table 5 gives the pair-wise correlation of the simulated effects of the projects with travel time from the project location for small and large municipalities separately. The congestion model shows that, in general, small municipalities grow as we move away from most of the project location whereas the large municipalities shrink. This implies that the reduction in transportation cost is large enough in those cases to lead to spread. In these results there are some exceptions (for example see AUTOP4) where large cities gain significantly as we travel far away from the project locations.

Table 5: correlation between changes in the population share and travel time from the projects location

the projects	(1) Core model (τ=0)	(2) Congestion model (τ>0)	(4) Core model (τ=0)	(5) Congestion model (τ>0)
OVP1	0.0528	0.1235*	-0.1114	-0.1439**
AUTOP2	-0.0435	0.1203*	-0.0132	-0.0661
OVP3	0.0102	0.0977	0.0094	-0.1013
AUTOP4	-0.0167	0.1205*	0.0847	0.1487**
sample	small municipalities[5]		large municipalities	

[5] Small municipalities are those with less than median population whereas large municipalities are those with larger population than median population

Note: *, ** and *** show significance at 10%, 5% and 1%, respectively

In this case one can argue that the reduction in the transport costs are not sufficient to lead to spread. The effects of infrastructure depends on several factors (example see McCann and Shefer 2004). Cities own characteristics including size and composition of its activities. We look at further detail of these projects by dividing cities into more groups based on their size instead of just two groups, small and large (see table 6). The results show that the significant gainers are not the top large municipalities, rather they are medium size municipalities. We also look at the correlation of the effects of simulated projects with the sum[6] of changes in travel time of a municipality to other municipalities and population size or population density as a measure of agglomeration.

Table 6: detailed version of table 5 for AUTOP4

	(1)	(2)
sample	Core model (τ=0)	Congestion model (τ>0)
smallest 5%	-0.1715	-0.1085
next 5%	-0.3073	-0.3073
next 15%	0.3361***	0.2967**
next 25%	0.1233	0.0781
next 25%	0.1232	0.2405**
next 15%	0.1472	0.0908
next 5%	-0.7703***	0.3592
largest 5%	0.4605	-0.1572

Note: *, ** and *** show significance at 10%, 5% and 1%, respectively

Although there are some slight variation across the projects, the total population and population density have similar relationship with the project effects within each project. This because there is high correlation between the total population and density themselves; i. e., the municipalities with high total population are also densely populated municipalities. The more important thing we want to look at here is the relationship between the sum of changes in the travel time (so transportation cost) and the effects on the city sizes.

Table 7: correlation of % effects of projects with the change sum in the travel time and agglomeration

		(1)	(2)
the projects	variables	Core model (τ=0)	Congestion model (τ>0)
	sum of % changes in travel time	0.0636	0.1098**
OVP1	population	0.0073	0.0549
	population density	0.0684	0.0382
	sum of % changes in travel time	0.1953***	0.1289***
AUTOP2	population	-0.0084	0.0158
	population density	-0.0282	0.0900
	sum of % changes in travel time	0.0223	0.0739
OVP3	population	0.0107	0.0284

[6] Sum of changes in travel time of municipality *A* is the sum of all changes in travel time between the municipality *A* and any other municipality *B* if the travel time changes. The larger this value, the higher degree of improvement in connection of the city with other cities.

	population density	0.0443	0.0097
AUTOP4	sum of % changes in travel time	-0.1810***	0.0058
	population	-0.0140	-0.0115
	population density	-0.0094	-0.0189

Note: *, ** and *** show significance at 10%, 5% and 1%, respectively

This help us to check whether or not the cities with the largest reduction transport cost measured in terms of reduction in travel time are also those who gain the most. The answer is affirmative for all the projects (see table 7 column 2). Given the spread to small and medium municipalities above, this means that much of the spread are to the better connected nearby municipalities. Looking at a more detailed aspects we discover communalities among all the results. Here also we look at the results by dividing the sample in two different ways. First, we divide the sample into losing and gaining municipalities following the simulated interventions (see table 8).

Table 8: more detailed version of table 7

the projects	variables	(1) Core model (τ=0)	(2) Congestion model (τ>0)	(3) Core model (τ=0)	(4) Congestion model (τ>0)
OVP1	sum of % change in travel time	0.2634	0.3892***	-0.0326	-0.2033***
	population	-0.5447	0.1785	0.1241**	0.0234
	population density	0.9299	0.0512	-0.0543	0.0402
AUTOP2	sum of % change in travel time	1.0000***	0.3404***	-0.0793	-0.0530
	population	-0.6843	-0.0302	0.0723	0.0646
	population density	-0.5669	0.1578	-0.0432	-0.0142
OVP3	sum of % change in travel time	0.0804*	0.1037**	0.0706	0.1237
	population	-0.0387	0.0057	0.1098	0.1856
	population density	0.0681	0.0690	0.1794	-0.0653
AUTOP4	sum of % change in travel time	0.1149**	0.2831***	-0.4526	-0.0251
	population	-0.0902*	-0.0571	0.3091	-0.0834
	population density	0.0273	0.0719	0.0920	-0.2596
	sample	gaining municipalities		losing municipalities	

Note: *, ** and *** show significance at 10%, 5% and 1%, respectively

Table 9: more detailed version of table 7

the projects	variables	(1) Core model (τ=0)	(2) Congestion model (τ>0)	(3) Core model (τ=0)	(4) Congestion model (τ>0)
OVP1	Sum of % change in travel time	-0.0644	0.2739***	0.0941	0.0375
	population	0.0682	0.0114	-0.0254	0.0362
	Population density	-0.4361***	-0.0661	0.0583	0.0239
AUTOP2	Sum of % change in travel time	0.2689***	0.1937***	0.0723	0.0741
	population	-0.0814	0.0783	0.1109	-0.0209
	Population density	-0.0501	-0.0166	-0.1375	0.0957
OVP3	Sum of % change in travel time	0.0024	0.0526	0.0537	0.0768
	population	0.0935	0.0723	-0.0394	0.0031
	Population density	0.0275	-0.1135*	0.0458	-0.0010
AUTOP4	Sum of % change in travel time	-0.2478***	0.1205*	-0.0742	-0.1211*
	population	0.0014	-0.0266	0.0010	0.0228
	Population density	-0.0153	0.1155*	0.0260	-0.0213
	sample	small municipalities		large municipalities	

The detailed results show more consistent changes. In general, the larger the reduction in transport cost, i. e., travel time, the higher the gains are among the gaining municipalities (see column 2) whereas the larger the reduction in transport cost the higher the losses are among the losing municipalities (see column 4). This holds across both the core model and the congestion model. Second, we divide the sample into small and large municipalities (see table 9). Here again focusing on the congestion model, the results show that, in general, the larger the reduction in transport cost following the simulated policy intervention the higher the gains in the city sizes among the smaller municipalities (see table 9, column 2). On the contrary, the larger the reduction in transport cost following the projects the higher the loss in the city sizes among the large municipalities (see column 4).

Baldwin et. al., (2003) show that, in the core-periphery equilibrium for instance, small improvement in infrastructure within less agglomerated regions has no effect if the difference in public infrastructure between the core and periphery is large or if the trade cost between the two is already very low. This is because it does not make investment in the periphery profitable. The results in core model are, in general, in agreement with this line of argument. The level of spread from the large to the smaller municipalities implied by the results from congestion model leaves large municipalities large and small ones small. According to Baldwin et. al., (2003) better public infrastructure in the more agglomerated core compared to the periphery is one of the reason for the disparity to remain to exist.

Table 10: Correlation between changes in the cities size and sum of % changes in travel time

the projects	(1) Core model (τ=0)	(2) Congestion model (τ>0)	(3) Core model (τ=0)	(4) Congestion model (τ>0)
OVP1	0.0129	0.1242*	-0.0944	-0.0724
AUTOP2	0.0777	-0.0722	0.1047	-0.0476
OVP3	0.0336	0.0698	0.00031	-0.00107
AUTOP4	0.1232*	-0.2317***	0.0693	-0.0430
location	near (*T*< median travel time)		far (*T* > median travel time)	

The effects of the simulated projects have different level of changes in the travel time for different municipalities. The municipalities that are closer to the project locations have larger reduction in the travel time and so transportation cost. The effect of the policy intervention on the cities size and its relationship with the change in sum of % reduction in transportation cost can also be different. The core model results in table 10, in general, show increase in and near improved transportation locations; whereas the results from the congestion model, in general, show spread from better connected locations. Figure 7 below show the long-run effects of the simulated projects on the size of the large and some municipalities in the polder area based on the congestion model. The right hand panel of the figure is just a more zoomed to the axis view of the same figure on the left to show a more detailed view of smaller changes. Much more pronounced changes are observed among the smaller municipalities in the polder. The changes resulting from different projects are mixed depending on the level of the changes in the travel time and location of the projects. Most of these cities near the project locations and in the polder area all gained population under at least three of the four projects.

Figure 7: Long-run effects of the projects on large and polder municipalities

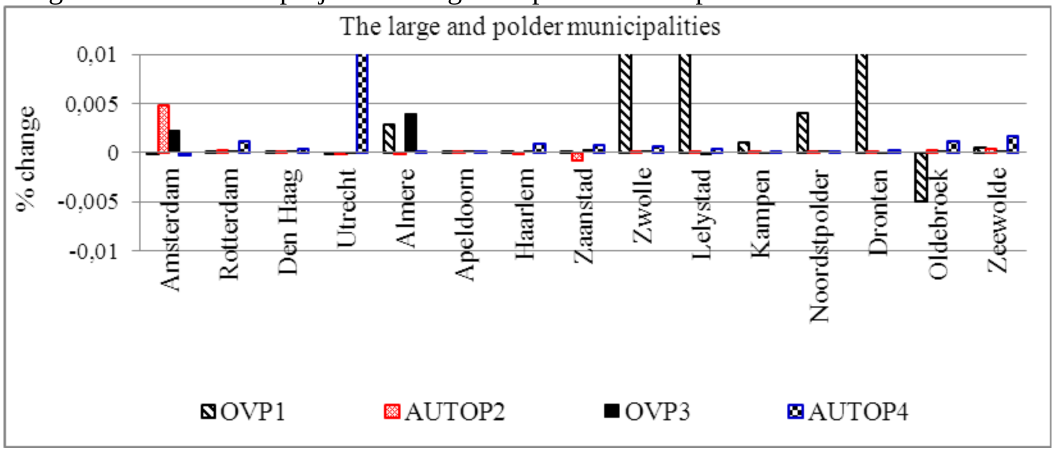
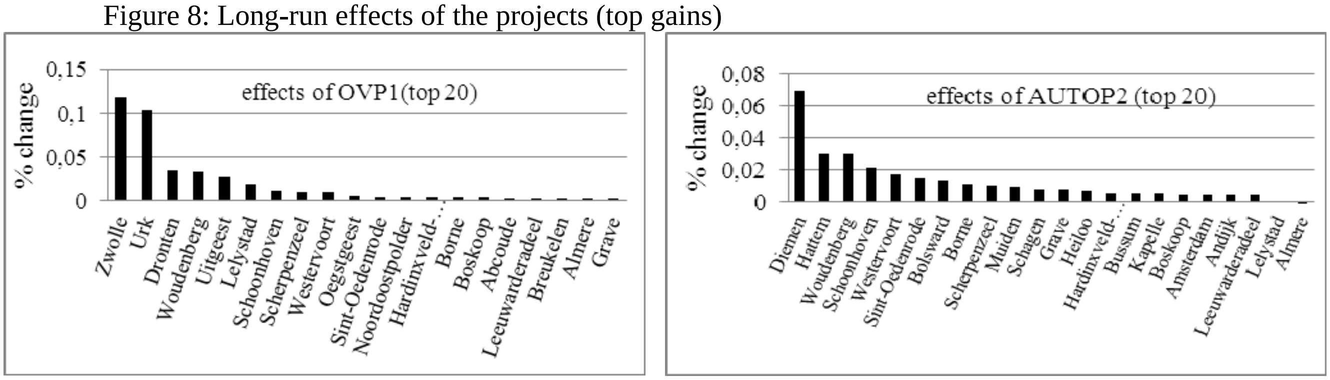
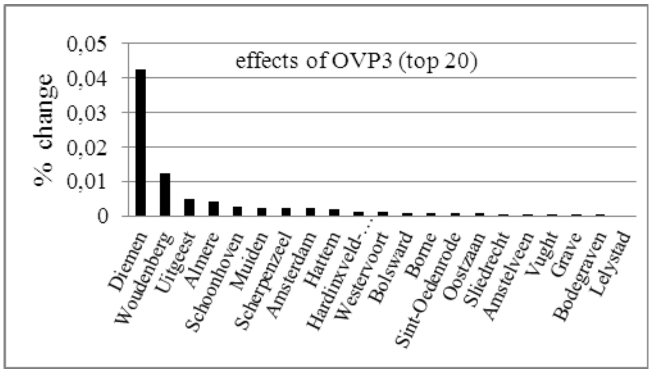
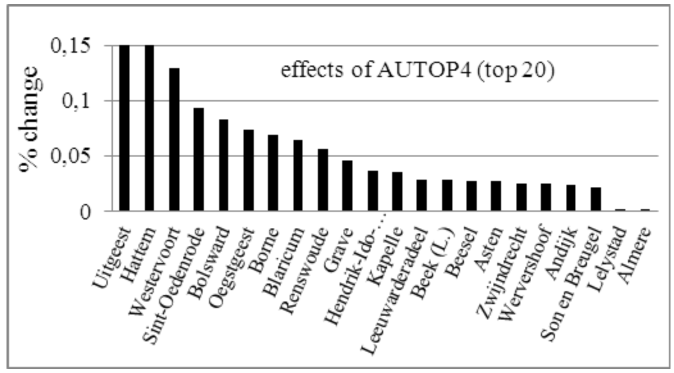


Figure 8 shows the percentage change in the population size of the municipalities that have gained the most under the four projects. These top gaining municipalities are the municipalities that are, in general, located within close distance to the project locations. However, this doesn't mean that all the municipalities that are located closer to the project locations gain at the expense of other municipalities. Rather, as we have discussed earlier in this section, considerable proportion of the relocation process takes place between the municipalities that are within closer range of the project locations. Thus, the municipalities with the most loss are also within closer range of the projects. Since we use congestion model, municipalities with low population, as proxy for low congestion, would gain as long as they are not too far from the locations of improved transportation projects. For example, see Woudenberg in Figure 8 below. This implies that commuting from such place through the old as well as the improved transportation links to the larger markets would be cheap enough or more optimal for some of the workers. This is one of unintended consequences of such projects. Moreover, the realization of such gain by such municipalities depends on the municipalities capacity to provide housing and public amenities for the new residents.

Figure 8: Long-run effects of the projects (top gains)







6. Conclusions

In this paper we analyze the long-run effects of improved transportation on the Netherlands municipalities. We use the population data of the 418 municipalities of the Netherlands as indicators of the distribution of economic activities. We mainly use congestion model of the NEG model in simulating the effects. Our first task was testing for the theoretical effects of changing transportation cost and congestion factor in the case of multiple regions. The results are consistent with the two regions results from earlier studies and consistent with the theory. These include that very high congestions factor as well as positive and increasing transportation cost leads to more spreading of economic activities. Moreover, perfect spreading becomes the long-run equilibrium when the transportation is totally free ($T_{ij} = T_{ai}$ =1.00) as long as there is some positive congestion factor. With free transportation and zero congestion (τ=0), equivalent of the core model, the initial distribution remains a long-run equilibrium (no redistribution). With zero or positive transportation cost, the lower the congestion factor the higher the agglomeration and the opposite, i.e., further spread, the higher the congestion factor. After establishing this, we simulate the improved transportation links. Improved transportation facilities generally benefits the municipalities the are located reasonably close to the projects locations, but not necessarily the locations of the projects themselves, i.e., the gains measured by higher agglomeration occur neither too close to nor too far from the project locations. Previous works find that the cities closest to the integration line, for example national borders, gain the most from the integration. In this paper, i.e. along the improved transportation links, this holds in general but not always. The cities closest to the transportation locations are not always who gains the most. We see spreading effects to near distance cities, but not too far. In this sense, the projects may also have unintended consequences, for the stalk holders, of spreading away from the target municipalities. This is so likely because of some reasons. First the use of the congestion model leads to spreading to smaller municipalities. Another reason is that traveling from outside large agglomerations while living in cheaper places to commute for work in the big cities becomes quite easier following the improved transportation links. Third, such further integrating projects of already very agglomerated areas seems to result in spreading effect than if it happens in less agglomerated areas such as border locations as the case in the earlier studies.

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