Welfare economic impacts of transportation improvements in a peripheral region

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Abstract

We set out to investigate whether transportation improvements can trigger welfare economic impacts in a peripheral region. The paper addresses this issue through the development of a general equilibrium labor market model with a transportation component. The model is implemented to a set of 101 core and peripheral cities in Israel. Numeric simulations are carried out to test the research hypotheses regarding positive relationship between improved accessibility and enhanced economic welfare. Economic welfare is measured in terms of efficiency and equity impacts. The results of the simulations show that transportation improvements in the form of auto travel time reductions may lead to substantial welfare benefits in the peripheral region considered in terms of increased output, productivity and wages.

Keywords: Travel time; Wage differentials; Productivity; Output; Transportation improvements.

1. Introduction

In recent years there has been a growing interest in the mechanisms linking a barrier-free geography and economic efficiency and equity. A common claim put forward by many urban economists, transportation planners and regional scientists is that transportation improvements extend the borders of labor markets, thus contributing to enhanced welfare by widening the scope of opportunities for consumers and producers alike.

Transportation investments have been identified in the literature as one of the main contributors to regional development and to the enhancement of economic growth. Although the strength and causation of the transport-growth relationship is a highly controversial issue in regional science, there is a general consensus amongst researchers that underserved regions with development potential are likely to benefit from such improvements (Frederiksen, 1981; Deno, 1988; Martin, 1998; McCann and Shefer, 2004).

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The motivation for this research stems from the need to provide theoretical and empirical underpinning for the short-term effects of transportation improvements on the generation of equity and efficiency (welfare) benefits in a peripheral region. Over the past decades, existing modelling frameworks dealing with the urban and regional arena (e.g. land-use transportation models, micro-simulation models) have focused primarily on the long-term implications of transportation improvements (e.g. effects on land use, jobs, population, and land market). Short-term implications such as the impact of enhanced accessibility on wage convergence between core and peripheral regions have not been adequately addressed.

The terms "equity" and "efficiency" have multiple meanings and can be attributed to a variety of issues dealing with fairness and justice. In the transportation context, equity is usually used to describe the accessibility of individuals to jobs, opportunities and services. In this work, equity is used to describe the effect of decreasing spatial friction on the enhancement of wage rate. Economic efficiency is defined as achieving higher levels of productivity and output per worker.

The study region encompasses 101 core and peripheral cities in Israel. We take a particular interest in the welfare-economic impacts of transportation improvements on several small impoverished peripheral cities located in the southern part of the country.

The methodological framework chosen to investigate these impacts is a welfare economic model built from three sub-models – a commuting model, a production model and a general equilibrium model. Model 1 (equity) is designed to represent the commuting scene and to show how reduction in travel time encourages commuting and thus contributes to wage increase in peripheral cities. Model 2 (efficiency) is designed to reproduce the mutually-re-enforcing impact on productivity that is induced by diminishing travel time. Model 3 combines Models 1 and 2 and reproduces both impacts.

The balance of the rest of the paper is made up of additional eight sections: Section 2 examines previous work. Each of the following three sections 3, 4, and 5 is dedicated to one of the three models. Section 6 describes the study region. The data for the models and their application to the study region is presented in Section 7. Section 8 reports the findings of the numerical simulations dealing with the impacts of improved accessibility on economic indicators. Section 9 concludes the paper with discussion of the research findings.

2. Previous research

Transportation improvements are often called upon as a means to revive a region's economic competitiveness, particularly that of a depressed region. This stems from the desire to remove spatial impediments such as poor accessibility which constrain the market and slow-down economic development.

It is widely believed that regions that are most likely to benefit from transportation improvements, in terms of increased economic efficiency and equity, are those which are found in a transitional stage of development. Due to investment in transportation infrastructure capital, these regions are likely to experience greater growth in wages and jobs, and show faster convergence than regions which are found in a more advanced stage of development (Thill *et al.*, 2001)

Transportation improvements can contribute to the enhancement of economic efficiency in under-served peripheral regions by integrating distant markets and cities (Fox and Porca, 2001). Diminishing spatial friction between neighboring cities intensifies the economic interaction between them, thus enabling them to enhance each other's productivity (see Dekle and Eaton 1999; Banister and Berechman, 2001). This in turn allows the generation of positive spatial externalities – agglomeration effects become region-wide.

Transportation improvements may also have a profound impact on the reduction of spatial disparities and the promotion of economic equity. The enhanced accessibility created by transportation improvements extends the borders of the labor market, allowing people who live in underserved peripheral regions to work closer to the core and enjoy the higher wages offered there (Garrison and Souleyrette, 1996; Blum *et al.*, 1997; Button, 1998). Thus, reduced commuting time may lead to a process of socio-economic convergence, where wage levels in the core and in peripheral cities move closer to each other.

A wide range of models and techniques are used for evaluating the impacts of transportation improvements on economic growth. Two of the most commonly used methods include the production function approach (see Aschauer, 1989; Munnell, 1990; Eberts, 1990; Tatom, 1991) and general equilibrium models with transportation as a component (Dekle and Eaton, 1999; Banister and Berechman, 2001).

2.1 Efficiency related studies

One of the most cited studies on the impact of public infrastructure on economic efficiency is Aschauer's (1989) seminal work on the contribution of public infrastructure (mostly highways) to productivity growth in the United States. His findings suggest that a 1% increase in the public capital stock could raise total factor productivity by 0.39%. Aschauer's work has produced a voluminous research activity, both at the national and regional levels. Munnell (1990) employed aggregate time series data with a constant returns production function. She reports figures close to Aschauer's estimations, with elasticities of output with respect to changes in infrastructure near 0.34. Fritsch and Prud'homme (1995) using cross-sectional data (1973-1989 period) from 20 different regions in France showed that the impact of road infrastructure on the productivity of both labor and capital seems quite strong, with elasticities also in the 0.08-0.12 range. A few studies however found the relationship between public infrastructure and productivity to be relatively small – at the 0.03-0.08 elasticity range (see Eberts, 1990; Duffy-Deno and Eberts, 1991; RESI Study, 1998) or insignificant (see Tatom, 1991).

Banister and Berechman (2001) present a spatial production economy model with transportation infrastructure effects. Their model tackles the question of whether transportation improvements between two production units (firms, cities, etc.) can contribute to enhancement of their productivity. The model assumes that productivity at location 1 is positively affected by the level of output in location 2 (and vice versa), and that this influence weakens with distance. By applying numerical simulations to their model, Banister and Berechman reach the conclusion that transportation helps, but not overwhelmingly.

Another multi-location model with transportation as a component is Dekle and Eaton's (1999) prefectural production and land rents model. Their model uses wage and land rent data from 46 Japanese prefectures to estimate the magnitude and the geographical range in which agglomeration effects diminish with distance in the financial services and manufacturing industries. The authors find that the extent of agglomeration economies in both industries is significant, but that their effect decays much faster with distance in the financial services sector than in the manufacturing sector.

2.2 Equity related studies

Additional strand of literature examines the effects of transportation investments on equity and income inequality. Ferreira (1995) presents a model of public-private capital complementarity in which expanding public investment reduces inequality. His model shows that infrastructure helps poorer individuals and underdeveloped areas to get connected to core economic activities, thus allowing them to access additional productive opportunities (Estache, 2003). Another study conducted by Estache and Fay (1995) found that enhanced access to roads is a key determinant of income convergence for the poorest regions in Argentina and Brazil (Calderón and Servén, 2004).

Deno (1988) found that highway capital has its greatest effect on manufacturing output in distressed cities. An earlier and similar research conducted in Mexico by Looney and Frederiksen (1981) shows that road transportation is effective in intermediate regions but not in underdeveloped regions. These results are consistent with the hypothesis suggested by Hansen (1965) that the best candidates for highway development investment are regions in an "intermediate" stage of development.

In the next three sections, we develop a framework that constitutes the focus of the paper: a general equilibrium multi-city model that focuses on labor-force, commuting, productivity and agglomeration effects.

3. Model one: workforce, labor supply and demand, and employment

Consider a simulation region with n cities $i=1, 2,\ldots,n$, specifying for each city i a location within geographic space. Each city is endowed with workforce F_i, physical capital K_i, and a Cobb-Douglas production function with two inputs: human and physical capital, with α as the share of employment. An origin-destination travel time matrix summarizes the geography and transportation system of the region. Symbols used include: city i, employment E_i, wages w_i, rates of return on capital ρ_i and the amount of inter-town commuting, F_{ij}.

3.1 Commuting and labor supply

We assume in this short-run model that capital is immobile while labor is quasi mobile. During the short run workforce does not respond to structural shocks by inter-city migration, but it can choose to offer its services either in its residence city or at any other reachable city. We also assume that workers decide to commute based on two major considerations and several secondary factors ζ_{ij}. The major two considerations are: (1) a comparison of wages between residence city and candidate work city; (2) travel time between residence city and the candidate work city. The choice mechanism is stochastic: for equidistant cities, a higher wage improvement (over what the residence city offers) will lead to a higher probability of choice. For cities offering an equal wage hike, a shorter travel-duration will dominate choice. However, the choice mechanism should suppress travel to a city offering less than the residence-city. The discrete choice function is presented in Equation 1:

$$\Omega_{ij}(w,T) = \frac{Exp\left[\beta_1\left(\frac{w_j}{w_i}\right) - \beta_2 t_{ij} + \sum \beta_k \zeta_{ij}\right]}{\sum_{k=1}^{n} Exp\left[\beta_1\left(\frac{w_k}{w_i}\right) - \beta_2 t_{ik} + \sum \beta_k \zeta_{ik}\right]} \tag{1}$$

Commuting probability Ω_{ij} is applied to workforce F_i to compute the number of workers in city i who offer their labor services in city j. Summing up over all i's yields the work supply in city j:

$$\breve{E}_j = \sum_{i=1}^{n} \Omega_{ij} F_i = \sum_{i=1}^{n} E_{ij}(w,T) \tag{2}$$

3.2 Production and labor demand

Since capital is assumed to be immobile, rates of return ρ_i must be endogenous. This leads to the following optimum conditions:

$$w_i E_i = \alpha Y_i \tag{3}$$

$$\rho_i K_i = (1-\alpha) Y_i \tag{4}$$

where Y_i represents the value of the local product. Equations 3 and 4 yield the demand function for labor, i.e., the optimum number of employees sought by producers at city i:

$$\hat{E}_i = \frac{\alpha}{(1-\alpha)} \cdot \frac{\rho_i}{w_i} K_i \tag{5}$$

3.3 Equilibrium

To close the model, each labor supply is set to equal labor demand and the solution vectors of wages and capital costs are sought:

$$\hat{E}_i = \breve{E}_j \tag{6}$$

The labor demand and supply equations thus obtained form a logically consistent and complete representation of the simulation region's labor market. Furthermore, they satisfy the necessary and sufficient conditions for the existence of equilibrium, namely: (1) they are continuous in prices w and ρ; (2) they are homogeneous of degree zero in prices; and (3) they satisfy Walras' Law.

4. Model two: agglomeration spillovers in production

Model 2 builds an additional layer onto model 1. The labor supply sub-model loses the commuting section, and local employment equals local workforce. The production environment changes in the following way: Productivity at each city i may be enhanced by the proximity of economic activity at other cities *j*, provided that the cities are not too far away in terms of travel time. The specific model is a generalization of a similar model by Banister and Berechman (2001) whose model is shown in Equation 7. Banister's and Berechman's model is a system of 2 Cobb Douglas production units 1 and 2, at a distance of d_{12} from each other. Productivities A_1 and A_2 are the following functions of product levels Y_2 and Y_1:

$$\tilde{A}_1 = A_1(1+\gamma e^{-\lambda t_{12}} Y_2) \text{ and } \tilde{A}_2 = A_2(1+\gamma e^{-\lambda t_{12}} Y_1) \tag{7}$$

where $\tilde{A}$ is the agglomeration-impacted productivity and A is the stand-alone productivity. This is clearly a case leading to mutually dependent product levels. We develop a multi-city version as follows:

$$\tilde{A}_i = A_i\left[1+\gamma\sum_{j\neq i}^{n} e^{-\lambda t_{ij}} Y_j + \sum_l \theta_l Z_{jl}\right] \tag{8}$$

It increases the number of cities from two spatial units to *n* units and it includes the impact of local characteristics variables *Z*. The local product is:

$$\tilde{Y}_i = \tilde{A}_i E_i^{\alpha} K_i^{1-\alpha} = A_i\left[1+\gamma\sum_{j\neq i}^{n} e^{-\lambda t_{ij}} Y_j + \sum_l \theta_l Z_{jl}\right] E_i^{\alpha} K_i^{1-\alpha} \tag{9}$$

Expression 9 is a system of linear equations equivalent to the following matrix equation:

$$\begin{bmatrix} \frac{1}{A_1\hat{E}_1^{\alpha}K_1^{1-\alpha}} & -\gamma e^{-\lambda t_{12}} & \cdots & -\gamma e^{-\lambda t_{1n}} \\ -\gamma e^{-\lambda t_{12}} & \frac{1}{A_2\hat{E}_2^{\alpha}K_2^{1-\alpha}} & \cdots & -\gamma e^{-\lambda t_{12}} \\ \vdots & \vdots & \ddots & \vdots \\ -\gamma e^{-\lambda t_{n1}} & -\gamma e^{-\lambda t_{n2}} & \cdots & \frac{1}{A_n\hat{E}_n^{\alpha}K_n^{1-\alpha}} \end{bmatrix} \cdot \begin{bmatrix} \tilde{Y}_1 \\ \tilde{Y}_2 \\ \vdots \\ \tilde{Y}_n \end{bmatrix} = \begin{bmatrix} 1+\sum_l \theta_l Z_{1l} \\ 1+\sum_l \theta_l Z_{2l} \\ \vdots \\ 1+\sum_l \theta_l Z_{nl} \end{bmatrix} \tag{10}$$

For a small enough *γ*, Equation 10 has a strictly positive solution set where each *Y* is a linear combination of all other *Y*'s and is strictly greater than the stand alone *Y*. The size of λ is of course crucial since it governs the attenuation of mutual productivity re-enforcement over space.

5. Model three: agglomeration and commuting

This section combines sub-models 1 and 2 in order to obtain a multi-city general equilibrium solvable model. This model, when perturbed to reflect a transport system upgrading, is expected to show improvement in efficiency (higher product and productivity) as well as equity (higher wage levels in spatially disadvantaged regions).

Combining models 1 and 2 is achieved by adding matrix Equation 10 to Equations 1 through Equation 5 and by substituting the labor supply E_i values of Equation 2 for the labor demand E_i within the matrix equation. Solving this matrix equation is equivalent to matching supply and demand, as was done previously in Equation 2. An equilibrium solution is guaranteed to exist because the three necessary and sufficient conditions described in model one still hold. The application of the combined model to a real system of cities, characterized by a core-periphery structure, is presented in the next sections.

Figure 1: Study Area.

6. Study area

The study area (Figure 1) encompasses 101 cities in Israel with population above 2000 residents. We are particularly interested in two regions: the Core region of central Israel (Tel – Aviv metropolitan Area) and the Near Negev (Greater Beer-Sheva Region) – a peripheral region located at the southern part of the country. These two regions are known for their acute socio-economic contrast. The Core region which includes Tel-Aviv and its surrounding satellites (e.g. Ramat-Gan, Giv'atayim, Herzeliyya) is socio-economically successful and draws the best businesses and the most skilled workforce. It suffers from typical "rich-man's problems" plaguing central areas – traffic congestion, demographic problems and environmental pressures (Gat, 2004). The southern periphery is comprised of one central city (Beer-Sheva), several Jewish small cities (e.g. Sederot, Netivot, Ofaqim, Arad), and Bedouin-Arab villages. It continuously suffers from severe “poor man’s problems" - chronic unemployment, low quality education and low skilled workers. The southern cities are poorly connected to each other and to the Core region. The low socioeconomic background of the southern cities has contributed to their transformation into conspicuous pockets of deprivation and poverty (Yiftachel, 2000). Due to their low residential and employment densities, these cities lack the scale economies necessary for creating producer and consumer amenities.

Statistical data show considerable differences between these small peripheral cities and core region cities in almost all socio-economic parameters. These disparities are best reflected by wage and socio-economic level variations. Table 1 shows acute differences (1000-1500 NIS) in the average proposed wages between the Beer-Sheva metropolis cities and Tel-Aviv. Sharp disparities can be also observed in the socio-economic cluster rankings of these two regions. This index, supplied by the Israel Central Bureau of Statistics (CBS) is based on demographic, economic and standard of living variables such as dependency rate, years of schooling, occupation, unemployment, motorization rate, average income per capita etc. The cluster ranking index ranges from 1 to 10, where a measure of 1 denotes very low socio-economic level and a measure of 10 indicates a very high socio-economic level. As can be observed from the table, all southern cities with the exception of Arad are characterized by medium to very low socio-economic level, as opposed to most core cities which are characterized by high to very high socio-economic level.

Table 1: Socio-economic level and size of selected cities.

Location	*City*	Average Wage in 1995 NIS *(1US$=3.5 NIS)*	*Socio Economic Cluster Ranking (1-10 Scale)*	*Population 1995 (in Thousands)*
Core	Tel Aviv - Yafo	4850	8	348.3
	Rishon LeZiyyon	5195	8	163.3
	Ramat Gan	5140	9	128.0
	Herzeliyya	5950	9	82.8
	Giv'atayim	5220	9	48.9
	Nes Ziyyona	5090	7	21.8
Southern periphery	Be'er Sheva	3825	5	149.4
	Qiryat Gat	3625	3	43.8
	Ofaqim	3230	2	20.6
	Arad	3775	6	20.3
	Sederot	3205	3	16.6
	Netivot	3350	3	14.4

Source: Israel Census, 1995

Table 2 presents a travel time matrix that shows auto trip lengths (in minutes) at AM peak hours between selected cities in the Beer-Sheva Metropolitan area and Tel-Aviv. As can be observed from the table, trip lengths between Beer-Sheva and its surrounding satellite cities range between 27-44 minutes, whereas trips lengths between the various Beer-Sheva Metropolis cities and Tel-Aviv (including other core cities) are in the 65-111 minute range. The city of Beer-Sheva, and the cities of Netivot, Ofaqim and Sederot would clearly be within a commuting range to the core if improvements will be made in the transportation network. The census data shows that less than 2% of residents living in the peripheral cities commute to the core cities.

Table 2: AM peak hours auto travel time (in minutes) matrix (2003) for selected cities.

Origin / Dest.	*Arad*	*Beer-Sheva*	*Netivot*	*Ofaqim*	*Sederot*	*Tel-Aviv*
Arad	-	44	64	64	65	111
Beer-Sheva	44	-	31	27	39	90
Netivot	67	31	-	18	13	71
Ofaqim	66	28	19	-	27	86
Sederot	69	39	13	27	-	65
Tel-Aviv	110	88	67	81	61	-

7. Model application

In this section, we present the application of the models to real world data. A brief description of the data is provided in Section 7.1. Parameters values are reported in Section 7.2. The simulation results are presented in Section 8.

7.1 Data

The commuting and agglomeration spillovers in production sub-models were estimated with data extracted from two main data sources. Socio-economic and labor-force data for the 101 city system were collected from the 20% sample of the 1995 Israel Census of Population and Housing. This detailed disaggregated database supplies information on the social and demographic characteristics of the population. The data used from this source include geographic and employment variables.

Travel time data were extracted from a national travel time matrix prepared for the Israel Ministry of Transport (A.B. Plan, 2004). This matrix was obtained from a traffic assignment model outputs for AM peak hour demand matrices for the year 2003. Representative travel times between the 101 cities were calculated by extracting the centroid of each city polygon and computing the respective times between two centroids. For the purposes of this paper, it is safe to assume that the travel time data represent the magnitude of the spatial friction between the cities.

Additional data pertaining to the proportions of labor, physical capital and annual net return per capital used in the agglomeration spillovers in production, were extracted from two secondary data sources. The Israel Central Bureau of Statistics (CBS) publishes every year the annual net return per capital unit (interest rate ρ). A division of this input by 12 yields the average monthly interest rate. In 1995 the annual interest rate was 10.2%, or 0.85% in monthly terms. The values of the labor and physical capital coefficients $(\alpha, 1-\alpha)$ were obtained from CBS publications and from an empirical production function study conducted by the Bank of Israel and the International Monetary Fund (Scacciavillani and Swagel, 1999). Both sources have estimated that in 1995, the share of labor equaled approximately 2/3 and the share of physical capital equaled 1/3.

7.2 Parameter Values

The parameter values used in the simulations presented in the next section are based on the estimation results of two studies. The coefficient values for the first sub-model (commuting) were obtained from Leck *et al.* (2007), and the parameters for the second sub-model (agglomeration spillovers in production) were extracted from Leck (2008).

The estimation results of the commuting (discrete choice) model reported in Leck *et al.* (2007) include three parameters - wage ratio $(\beta_1=0.00198)$, auto travel time differences $(\beta_2=-0.10341)$, and employment differences $(\beta_3=0.00316)$. The latter coefficient is a local variable representing the size or economic robustness of the city. The estimation of the commuting model yielded the expected signs, where offered wage ratio larger than 1 and a large job supply contribute to utility of selecting a particular work city, and long travel time is a disutility in the selection process. All of the estimated coefficients were significant at the 0.001 level.

The estimation of the agglomeration spillovers in production model (Leck, 2008) was conducted in two stages. In the first stage, the element $e^{-\lambda t_{ij}}$ (see Equation 8) was regressed against the dependent variable (log local productivity $\tilde{A}_i$) and the coefficient denoting the weight of travel impedance λ was estimated. The estimation of travel impedance coefficient was carried out by an iterative process which involved the search for the λ value that maximizes the percentage of variance explained by the log-linear model. The maximum R^2 was attained in the log-linear model, when λ was set to equal 0.78.

In the second estimation stage, the remaining parameters were estimated by the least squares method. These parameters include stand alone (base) productivity A (A=285), a parameter labeled as "sum access" reflecting the economic impact of all other cities j on the product of a specific city *i* (γ=6.63E-11), and three additional parameters representing the local characteristics of a city *i*: average years of schooling ($\theta_1=0.021$), a dummy variable for location in the southern district ($\theta_2=-0.069$), and the number of trains departing from a particular city ($\theta_3=0.001$). The "sum access" coefficient parameter is positive, indicating that the higher the sum access, the higher the productivity level of a particular city.

The estimation results also highlight the importance of high quality human capital in contributing to higher productivity. This finding is consistent with the results of many econometric studies which probed the relationship between human capital enhancement and productivity growth (see Romer, 1990; Grossman and Helpman, 1991; Gemmell, 1995; Ranis *et al.,* 2000, and others). The coefficient indicating the number of trains departing from a particular city to other cities is also positive, signifying the important role of high-quality rail service in impacting productivity. It is important to indicate however that this particular variable is a function of the centrality or economic importance of the city, and big cities are better served than small ones. The coefficient sign of the dummy variable indicating location in the southern district is negative. This estimation result is not surprising given the low socio-economic conditions existing in the peripheral cities which subsequently lead to poor economic performance and lower productivity rates. All of the estimated coefficients were significant at the 0.01 level.

8. Policy simulations

The empirical tool chosen to address the research question regarding the impact of decreasing spatial friction on the enhancement of economic equity and efficiency is a set of policy simulations based on the results of the general equilibrium model. Two types of simulation scenarios were carried out and are described in the following paragraph:

- *Base scenario*: reflects initial equilibrium or current conditions (prior to any changes in the transportation system or local city variables).
- *Highway improvement scenario*: estimates the impact of auto travel time reduction. In this scenario, auto travel times between cities are multiplied by 0.8 to reflect a "flat" 20% improvement in travel time throughout the 101 city system.

8.1 Equity impacts

Figure 2 presents the impact of transport improvements on absolute wage growth in core and peripheral cities. The simulation results show that the core cities are expected to only slightly benefit from auto travel time improvements. As can be seen from the figure, the average wage in Tel-Aviv is projected to increase by 0.7% compared to the base scenario. Higher wage increases are projected in Nes-Ziyyona (2.5%) and Givatayim (1.8%). The relatively high wage increase in Givatayim (Tel Aviv suburb) is mainly due to the high socio-economic profile of the commuters in this city. These commuters, who are highly skilled and educated, earn particularly high salaries outside their own locality. When an improvement is being made in the highway system, the share of workers residing in Givatayim and working in other cities increases. This sequentially leads to an increase in the average wage. A possible explanation for the stronger showings of Nes-Ziyyona may be related to its relatively small population and location in the outer metropolitan ring, making her more sensitive to transport improvements.

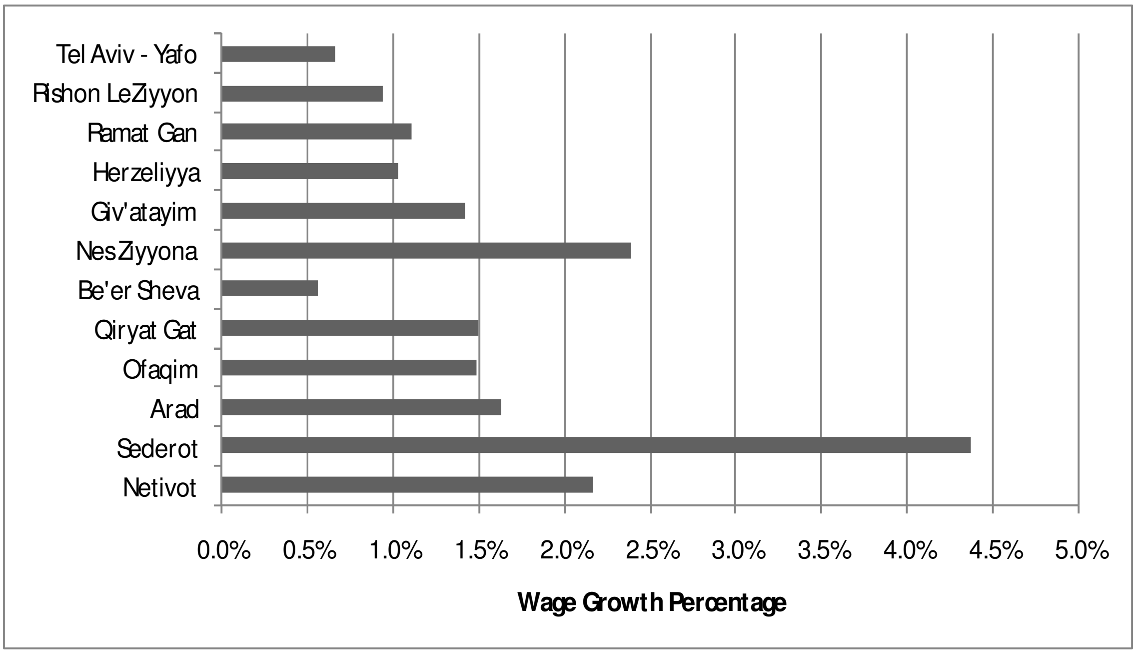

Figure 2: Wage growth in the auto travel time improvement scenario compared to base scenario.

According to theory, wages should slightly decrease in the Core due to higher supply of labor. So, why is this not the case? The reason for this stems from the impact of decreasing spatial friction on the ability of neighboring cities to enhance their output and productivity level (see first summation in the right hand side of Equation 8). This impact is much stronger in the core cities due to strong agglomeration effects stemming from the proximity of the core cities to one another and because of their large output level. Due to the fact that in the general equilibrium model wage level w_i is dependent on local product Y_i $[w_i=(\alpha\ Y_i)/E_i]$, when the local product in the core cities increases, so does the wage level.

Improvements in the highway system are expected to generate slightly higher equity benefits in the peripheral cities. Average wages are expected to rise by 4.4% in Sederot, 2.2% in Netivot and 1.6% in Arad. The higher wage increase in Sederot is explained by the fact that this town is the closest amongst the peripheral cities to the Core region, so even a relatively small reduction in auto travel time significantly increases the utility of Sederot residents' to work in the core cities. Beer-Sheva, the largest city in the southern periphery is much less sensitive to auto travel time changes than the smaller cities and is virtually unaffected by transportation improvements.

8.2 Efficiency impacts

The efficiency related simulations cover two economic indicators - output per worker and productivity. Figure 3 presents the output per worker in 1995 NIS in the base and auto travel time improvement scenarios. As can be seen from the figure, the core cities are expected to moderately benefit from highway improvements. Output per worker is projected to rise in Nes-Ziyyona by 2%, and in the other core cities by approximately 1%. Although these benefits do not seem to be large in relative terms, they are quite substantial in absolute terms (total output).

Figure 3: Output per worker (1995 NIS) prior and following transportation improvement.

In the southern periphery, the impact of transportation improvements on output enhancement is predicted to be much higher. Output per worker is projected to be boosted by 5% in Sederot, 4% in Qiryat Gat, 3.5% in Netivot and by 2.5% in Ashdod. The explanation for the especially large increase in output per worker in the peripheral cities is primarily due to the significant decrease in employment (out-commuting).

Figure 4 presents the percentage growth in agglomeration-impacted productivity compared to the base scenario in core and peripheral cities. As can be seen from the figure, the agglomeration-impacted productivity is expected to rise in all core cities by no more than 0.3%-0.8% as a result of highway improvements. The city of Nes-Ziyyona is the only city that is expected to enjoy higher productivity growth (1.5%).

Productivity enhancement in the peripheral cities is projected to be substantially higher than in the Core. The agglomeration-impacted productivity is projected to be enhanced in Sederot by more than 3% and in Qiryat Gat by approximately 2.5%.

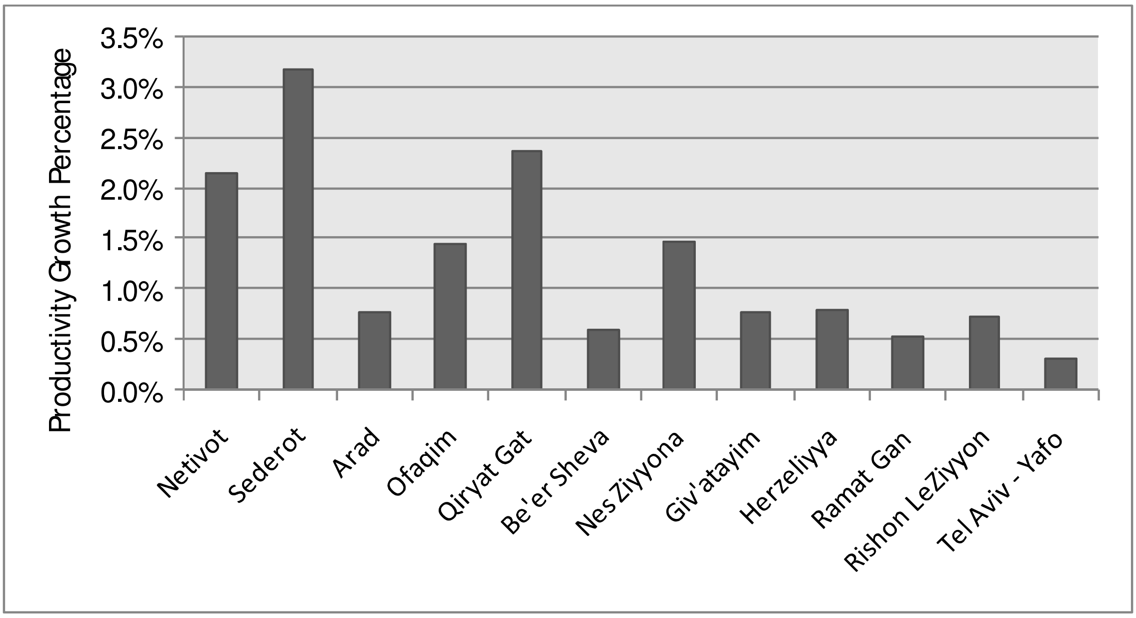

Figure 4: Productivity growth compared to base scenario.

A clear dichotomous trend regarding the source of welfare enhancements can be observed from the analysis of the simulation results. While welfare improvements (growth in wages, productivity and output per worker) in the peripheral cities are primarily due to enhanced commuting benefits and decreased labor supply, the source of these improvements in the core cities largely derives from the fruits of agglomeration. Agglomeration effects are much more substantial in the Core due to the large size of cities and the short distances between them. As spatial friction between the core cities diminishes as a result of transportation improvements, these agglomeration effects become even stronger giving rise to productivity enhancements. Higher productivity level in a particular city contributes to increased output and consequently to higher wages.

9. Conclusions

In this paper, the effects of transport improvements on economic welfare have been demonstrated by the employment of several numerical simulations. The outcomes of the simulations illustrate the existence of a significant relationship between reduced spatial friction and enhanced economic welfare. The magnitude of the welfare impacts in relative terms was found to be quite small in the core cities, and moderate in the peripheral cities. Cities located in the outer Tel-Aviv metropolitan ring were found to be more sensitive to accessibility improvements than other cities located in the inner ring or in the core.

The agents impacting welfare enhancement in the core and peripheral cities are not identical. Welfare enhancement in the peripheral cities is mostly due to changes in the work destination of commuters. Workers in the peripheral cities change their workplace choice in favor of the core cities that offer higher wages and other amenities. In contrast to the peripheral cities, welfare enhancement in the core is mainly due to mutual productivity effects of neighboring cities. The large size of the core cities, combined with decreasing spatial friction due to transport improvements enables them to further reinforce their own productivity level.

The research has focused on the short-termed equity and efficiency benefits of transportation improvements. Prospective research should be aimed at investigating the long termed welfare economic impacts by including additional urban sub-systems in the integrated model, especially land market and land use.

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