

A Structural Econometric Model of Spatial General Equilibrium

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Structural economic models of spatial general equilibrium are scarce in the regional economics literature. In this paper a structural spatial econometric model for 9 regions of Israel is estimated using nonstationary spatial panel data during 1987 -2010. The model focuses on the relation between regional labor and housing markets when there is imperfect internal migration between regions and when building contractors operate across regions. The model is used to characterize empirically spatial general equilibrium in regional housing and labor markets by solving for wages, house prices and population in the 9 regions. The model is used to simulate the temporal and spatial propagation of regional shocks induced by housing policy, capital investment, amenities etc. It is shown that shocks are spatially state dependent because of heterogeneity in spatial dependence. They are also highly persistent because of longevity in housing.

Keywords: spatial general equilibrium, regional labor markets, regional housing markets, spatial econometrics.

Introduction

Spatial general equilibrium (SGE) theory is concerned with the joint determination of regional wages, employment, population and house prices through the study of the relations between markets for labor, output, capital and housing within regions and between them. Theoretical models of SGE have been proposed by Roback (1982) in which real estate markets play a central role in the spatial distribution of economic activity, and by Krugman (1991) in which the spatial distribution of economic activity depends on transport costs and pecuniary scale economies induced by home market effects. The latter has formed the backbone of the New Economic Geography (NEG) model, which occupies a central place in the study of economic geography (Brakman, Garretsen and van Marrewijk 2009, McCann 2013, and Combes, Mayer and Thisse 2012).¹

As usual, empirical study of SGE has lagged behind theoretical developments². Nevertheless, there have been a number of empirical studies of the relation between real estate markets and regional employment (Vermeulen and Ommerman 2009, Glaeser and Gottlieb 2009, Greenwood and Stock 1990 and Johnes and Hyclak 1999) as well as empirical studies of the home market effect on wages and investment (Hanson 2005, Head and Mayer 2004, Davis and Weinstein 2003). These studies have, on the whole, been non-structural partly because key data have not been available. For example, Vermeulen and Ommerman and Greenwood and Stock did not have data for house prices or rents. Johnes and Hyclak did not have data on housing stocks. In the absence of regional house price data or data for housing construction, it is of course impossible to estimate structural models of regional housing markets. More recently, Bushinsky, Gotlibovski and Lifshitz (2014) investigated the co-determination of residential location, employment location, occupational choice and labor market outcomes for immigrants in Israel. However, this is carried out in a partial equilibrium setting because house prices and native

¹ We differentiate SGE from computable general equilibrium (CGE) models in regional economic research (Partridge and Rickman 1988, Giesecke and Madden 2013) and dynamic stochastic general equilibrium (DSGE) (Brandsma, Kancs, Monfort and Rillaers 2013).

² There have been numerous partial equilibrium empirical studies of components of the NEG model. See e.g. chapter 12 in Combes, Mayer and Thisse (2008) for a critical (and downbeat) review. Brakman and Garretsen (2006) also comment on the gap between theory and empirics in NEG research.

wages are assumed to be independent of immigration. By contrast these variables are endogenous in spatial general equilibrium.

We agree with the assessment of Combes, Mayer and Thisse (2008) that, “..despite significant and marked progress, empirical studies still fall short of the theoretical research that calls for general-equilibrium models.” (p 303). Moreover, “..it appears that *the structural approaches, directly rooted in specific theoretical models, are often more convincing than the reduced forms that are traditionally used.*” (p 340, italics in original). Furthermore, “There is no question that future empirical studies must move beyond testing hypotheses within a simple bilateral linear relationship, as is so often characteristic of existing studies.” (p 341) Similar methodological criticisms have been voiced by Brackman, Garretsen and van Marrewijk (2009, p 243) who argue that empirical results from partial equilibrium settings might cease to apply in general equilibrium, and that there is a need to use spatial econometrics methods to allow for spatial spillover between regions (pp 350 – 355).

In this paper we respond to these methodological challenges. We have constructed a database which incorporates essential regional data (such as house prices, housing stocks and capital stocks), which are not generally available. We use spatial econometric methods that allow spatial spillovers between regions. The model and its estimation are conceived in general equilibrium. Also, we go beyond bilateral analysis because the model has nine regions. We investigate empirically the joint determination of regional population, wages and house prices. These outcomes are determined in a structural econometric model of regional housing markets in Israel estimated using spatial panel data during 1987 – 2010. The housing sector of the model draws on our previous work (Beenstock, Felsenstein and Xieer 2014) in which the key variables are housing starts, housing completions, housing stocks and house prices. The labor sector of the model determines regional wages and employment. Specifically, we extend previous work (Beenstock, Ben Zeev and Felsenstein 2011) in which we showed that regional wages vary directly with regional capital – labor ratios. Given everything else, therefore, regional wages vary inversely with employment in the region, but they vary directly with regional capital stocks. We also find evidence of an agglomeration effect in regional labor productivity; wages are higher in regions in which capital per worker was larger in the past.

We present new results on internal migration, which suggest that locations are imperfect substitutes because people have regional preferences (Beenstock and Felsenstein 2010). In this model regional population shares vary directly in the long-run with relative regional wages and inversely with relative house prices. Given everything else, people prefer to live in regions where wages are higher and housing is cheaper. We show that this simple model gives a satisfactory empirical account of population shares in several regions of Israel.

However, there are locations such as Tel Aviv and Jerusalem where this simple model does not apply. In fact, their population shares vary inversely with relative real wages and directly with relative house prices. We suggest for these regions that the demand to reside in them depends on unobserved amenities, which are estimated implicitly using the principle of compensating wage differentials. By assumption, therefore, the population shares in these regions vary directly with relative wages and inversely with relative house prices, and they vary directly with relative amenities. However, we show that the time series properties of these implicit amenities satisfy theoretical restrictions suggested by amenity theory. Indeed, these restrictions are used to inform about the effects of relative wages and house prices on regional population shares.

As noted by Glaeser and Gottlieb (2009), SGE theory is traditionally based on a trinity of arbitrage conditions: “..workers must be indifferent between locations, firms must be indifferent about hiring more workers, and builders must be indifferent about supplying more housing.” This trinity is based on the simplifying assumption that firms, workers and builders regard alternative locations as perfect substitutes. We have shown elsewhere (Beenstock and Felsenstein 2015) that this assumption does not apply to building contractors. We show here that it does not apply to workers³. It remains to be seen whether it applies to firms, and whether capital is perfectly mobile⁴.

³ See also the assessment of Combes, Mayer and Thisse (2008) that internal migration is insufficient to equate regional wages (p 341).

⁴ As Baldwin and Martin (2004) point out, capital mobility is a stabilizing factor that works against catastrophic agglomeration. This is because production shifting does not necessarily induce demand shifting. Additionally capital mobility is not synonymous with the mobility of capital owners. Capital moves without its owners. Profits are repatriated to the region where capital owners are located. Capital owners may have regional preferences. The regional share of capital is thus endogenous and is not determined by arbitrage conditions.

Since population, wages and house prices increase over time the spatial panel data that we use to estimate the model are nonstationary. Moreover, because the data are spatial, the units in the panel may not be independent. As noted by Brakman, Garretsen and van Marrwijk (2009) it is ironic that most empirical work in economic geography ignores spatial dependence. We may add to this criticism that they usually treat the data as if they were stationary⁵. We take both of these phenomena into account by using spatial econometric methods designed for nonstationary panel data. Specifically, we use spatial panel cointegration tests to estimate the model.

In summary, this paper touches on four separate but related literatures; spatial general equilibrium, regional labor markets, regional housing markets, and the spatial econometric analysis of nonstationary panel data. What results is possibly the first structural econometric SGE model.

Theory

Here we summarize the model's main theoretical features by assuming that a region is “small and open” so that what happens in the region depends on what happens outside it, but not the opposite way around. In the econometric model, by contrast, all regions are inter-dependent. The region is open to trade and internal migration. Although for the present, regional capital stocks are exogenous, the model may be extended to take account of internal capital mobility. Land is zoned for residential or commercial purposes, and because housing density is endogenous the supply of housing space varies directly with residential land and house prices, and inversely with building costs. Although housing is immobile, regional housing markets are related on the supply side because building contractors operate in different regional housing markets, and on the demand side because of internal migration. If it becomes more profitable to build elsewhere, building contractors will reduce their activity in the region. The demand for housing space varies directly with population and wages in the region and inversely with house prices. House prices in the region are determined by market clearing where the demand for housing equals the stock of housing.

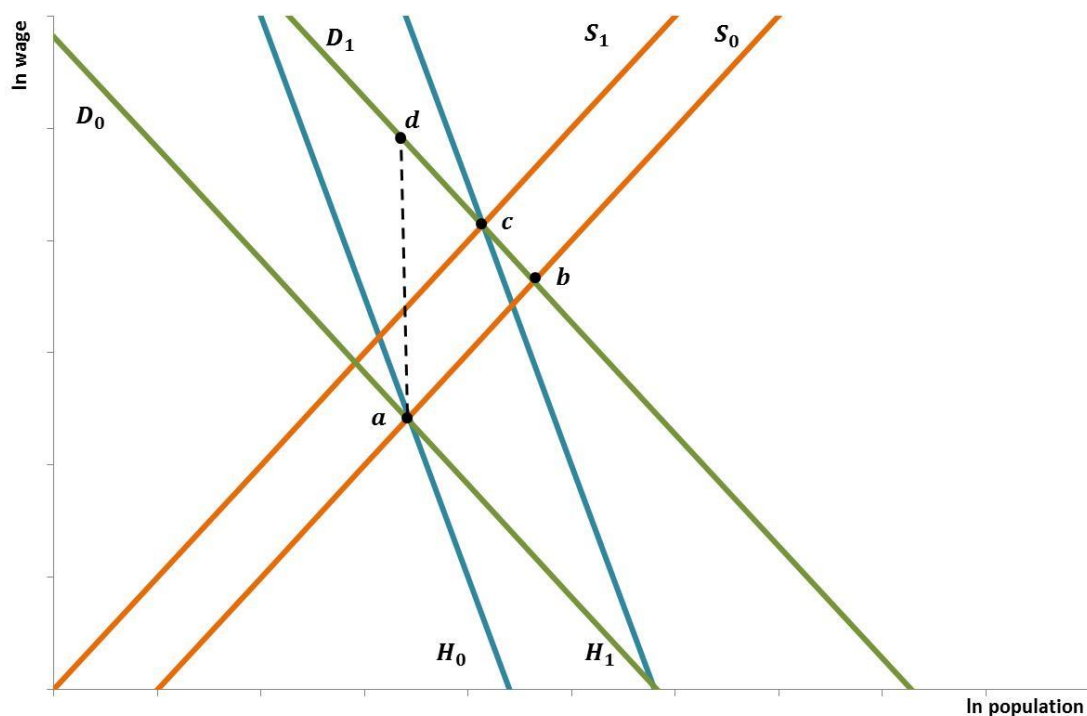
We follow Roback rather than NEG by assuming that product markets are competitive rather than monopolistic, and that zoning rather than transport costs

⁵ For example, Vermeulen and Ommerman (2009) estimate spatial error correction models but do not use critical values calculated by Westerlund (2007) for nonstationary panels. They also assume that regions in Holland are independent. The same applies to the numerous empirical relationships in Glaeser and Gottlieb (2009).

matter for SGE. Labor demand in the region varies directly with the capital stock and land zoned for commerce, and it varies inversely with real wages. The population share of the region varies directly with relative wages, and inversely with relative house prices. Therefore, the supply of labor is wage elastic due to internal migration. However, because the participation ratio is exogenous labor supply is wage inelastic within regions.

In Figure 1 the logarithms of wages and population are measured on the vertical and horizontal axes. For simplicity, regional participation ratios are assumed to be wage inelastic. Schedule D_0 therefore denotes the regional demand schedule for labor. It slopes downwards, and its location varies directly with land zoned for commercial purposes, the capital stock and TFP. Schedule S_0 denotes the regional supply schedule of labor; it slopes upwards because internal migration varies directly with wages, and its location contracts if wages increase elsewhere, or if house prices become relatively expensive. The region's share of the national population varies directly with real wages in the region relative to real wages elsewhere.

Figure 1: Spatial General Equilibrium: an Increase in the Demand for Labor



Schedule H_0 plots the combinations of wages and population that support regional house prices at P_{H_0} . It slopes downwards because the demand for housing varies directly with wages and population, and is flatter the greater the income elasticity of demand for housing space. Above schedule H there is an excess demand for housing, which would raise house prices and which causes schedule H to shift upwards by an extent which varies inversely with the price elasticity of demand for housing. Schedule H shifts upwards if land zoned for housing increases, because P_{H_0} is supported by larger combinations of wages and population. Schedule H shifts downwards if house prices and land zoned for housing increases elsewhere because builders prefer to construct elsewhere.

Spatial general equilibrium (SGE) occurs at point a in Figure 1, where the housing market is in equilibrium, and the supply of labor equals the demand for it. Relative real wages are defined as:

$$RRW = \frac{w}{\bar{w}} \left(\frac{\bar{P}_H}{P_H} \right)^\phi \quad (1)$$

where bars denote variables elsewhere, and ϕ is the share of housing in consumption. If $RRW = 1$, real wages adjusted for living costs (house prices) are equated. But there is no reason why RRW should equal 1 unless labor is perfectly mobile.

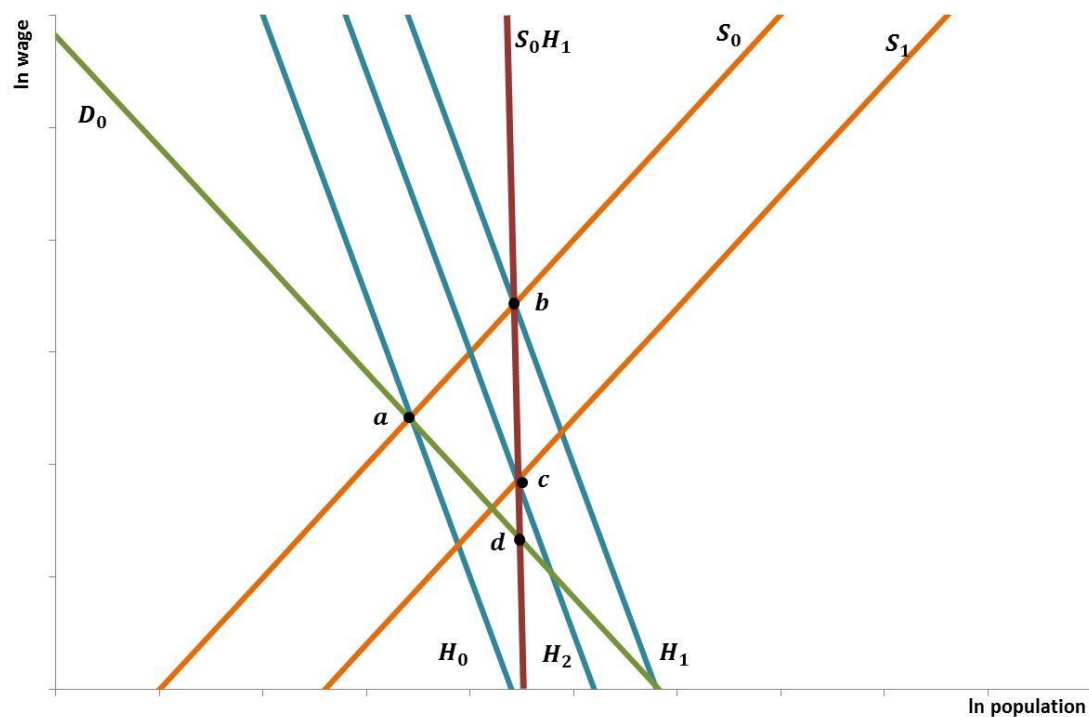
An increase in TFP in the region raises the demand for labor to D_1 . At point b (intersection between D_1 and S_0) there is an excess demand for housing. The increase in house prices shifts schedule H_0 to H_1 and schedule S_0 contracts to S_1 . The new SGE is at a point such as c (intersection of schedules D_1 , H_1 and S_1).

Notice that at c the population does not necessarily increase relative to a . This will happen if schedule S contracts by more than schedule H expands when house prices increase. Nor must schedule H be steeper than schedule D . These slopes are unrestricted by theory. Indeed, there is an entire taxonomy of SGEs so that the response of population, wages and house prices to e.g. TFP shocks is indeterminate. SGE occurs on schedule D_1 to the north-east of point b . If SGE occurs on segment db population, wages and house prices increase. If SGE occurs to the north-east of d wages and house prices increase, but population decreases. This indeterminacy increases when the regions are mutually dependent, and when the schedules featured in Figure 1 are asymmetric. For example, schedule H may be flatter than schedule D in some regions but steeper in others. The scope for indeterminacy naturally increases

with the number of regions. As noted, Brakman, Garretsen and van Marrewijk (2009) have criticized theory derived for two region models for predicting what happens in N regions. This criticism holds a fortiori if the regions are asymmetric. In our case $N = 9$, which naturally increases the potential for spatial state dependence in which the propagation of shocks in housing, land, and labor markets depends on where they occur.

An increase in land zoned for housing would raise schedule H_0 to H_1 (Figure 2). House prices along schedules H_0 and H_1 are the same (P_{H0}). At point a there is an excess supply of housing, which lowers house prices, thereby contracting H_1 to H_2 and expanding S_0 to S_1 . Schedule S_0H_1 plots the locus of intersections between schedules S and H as house prices decrease (below b) or increase (above b). House prices continue to decrease until the new SGE is reached at point d at which wages and house prices are lower and population is higher. This result does not depend on whether schedule D is flatter than schedule H .

Figure 2: Spatial General Equilibrium: an Increase in Land Zoned for Housing



Data

We have developed an annual database for nine regions in Israel (see map) during 1987 – 2010. These regions have been selected because house price data have been published for them since the early 1970s by the Central Bureau of Statistics (CBS). In the absence of regional income accounts we have constructed annual panel data for these 9 regions for such variables as housing starts, completions and stocks, wages, employment, schooling, capital, population etc. Since we have described this database elsewhere (Beenstock and Felsenstein 2008, 2015) we provide minimal details here. Figures 3 – 8 plot key variables over time and space. Population has risen everywhere on the background of the arrival of a million immigrants from the former USSR during the 1990s. Also the natural rate of increase in the national population is relatively high (about 2% pa). The population increased from 4.5 million in 1987 to 8 million in 2012. Notice that despite the fact that GDP per head grew at an annual rate of about 1.8% pa, wages did not grow during the 1990s and grew only slowly subsequently. The last two decades have favored capital at the expense of labor partly because demographic factors have increased labor supply.

House prices doubled in real terms during the wave of immigration from the former USSR in the early 1990s. However, Figure 3 shows that the increase in house prices was not uniform. The same applies to population (Figure 4). Figure 5 shows that with the exception of the early 1990s when the wave of immigration crested, housing construction kept pace with the rate of population growth so that housing space per capita increased. However, there is substantial regional variation in this measure of housing density. Finally, Figure 6 plots capital stocks; it shows that capital grew more slowly in capital abundant regions, such as North, and more rapidly in capital scarce regions, thereby inducing beta and sigma convergence in capital stocks.

The Israel Land Authority (ILA) is a unique institution in which approximately 90 percent of land in Israel is vested. The balance is owned privately⁶. ILA auctions land for housing construction (and commercial purposes) to building contractors, who sell completed housing in the private market to the public. Home-owners are given 50-year leaseholds with ILA, which are renewable at zero cost. The main purpose of ILA is political; to give the government ultimate control over land ownership. ILA is highly politicized. It is currently answerable to the Minister of Housing and Construction (MOHC), and land for housing construction is frequently

⁶ Mainly by churches and freeholds dating back to Ottoman rule which ended in 1918.

made available by ILA on a partisan basis. We estimate that ILA currently holds enormous land reserves for housing equal to all the built-up land in Israel. Unfortunately, these reserves are in locations where residential demand is low. Figure 6 plots land auctioned for residential purposes by ILA⁷. It shows that land for housing has been sold-off mainly in the periphery. These land sales constitute a major instrument of regional policy, and play a central role in the econometric model for identifying housing supply.

Figure 8 plots population shares against relative real wages (RRW) for each of the nine regions. The data points are joined chronologically so that the first point refers to 1987 and the last to 2010. The population shares in Center, Dan and Krayot vary directly with relative real wages, as expected. Over the entire period South's population share and its relative real wage increased, however, the latter preceded the former. In two regions, North and Haifa, population shares increased but relative real wages zig-zagged without increasing. In Sharon relative real wages increased but its population share did not change. Finally, in Tel Aviv and Jerusalem the relationship between population shares and relative real wages slopes the "wrong" way. In Tel Aviv relative real wages increased but its population share decreased. The opposite happened in Jerusalem; relative real wages decreased but its population share increased.

Panel Cointegration

In spatial panel data unit roots that induce nonstationarity in the data may arise from either or both of two reasons. There may be temporal unit roots that arise in nonspatial data, and there may be spatial unit roots (Yu, de Jong and Lee 2012, Beenstock and Felsenstein 2012) induced by unit eigenvalues in W or by unit SAR coefficients. We have established elsewhere that our panel data are nonstationary for the former reason. Since parameter estimates may be spurious in nonstationary panel data (Phillips and Moon 1999) we use panel cointegration tests due to Pedroni (1999, 2004). Specifically we use the grouped ADF statistic (GADF) for the residuals. Pedroni's critical values assume that cross-section units are independent. Banerjee and Carrion-I-Silvestre (2011) have calculated critical values for strong cross-section dependence and Beenstock and Felsenstein (2015) show that Pedroni's critical values

⁷ In CBS publications these data are referred to as "housing starts under public initiative".

are salient for weak (spatial) cross-section dependence for SAR coefficients less than 0.4. These critical values are indicative only because they have not as yet been calculated for cointegration in spatial panel data models. For example, Banerjee and Carrion-I-Silvestre report that the critical value of GADF at $p = 0.05$ is -2.57 when $N = 10$, $T = 20$ and there are three cointegrating variables. The model is cointegrated and the results are not spurious if the estimated residuals are stationary, i.e. GADF is smaller than its critical value ⁸.

Because the structural equations of the model are estimated using panel cointegration, the model refers to long-term relations between the state variables. We do not estimate the error correction models associated with these cointegrating relations because economic theory is more restrictive about long-term behavior than about short-term behavior. Therefore, the model ignores short-term dynamics. More generally, it ignores stationary components of the state variables such as the role of expectations (especially of house prices and inflation) and partial adjustment mechanisms (especially in wage determination and housing construction).

The equations in the model have the following generic spatial Durbin specification:

$$\begin{aligned} Y_t &= \alpha + \beta X_t + \gamma \tilde{X}_t + \lambda \tilde{Y}_t + u_t & (2) \\ \tilde{X}_t &= WX_t & \tilde{Y}_t = WY_t \end{aligned}$$

where Y , X and u are column vectors of length N , α is an N -vector of fixed regional effects, tildes denote spatially lagged variables, and W is an $N \times N$ spatial connectivity matrix row-summed to one, with zeros along the leading diagonal, and with eigenvalues less than 1. Since Y and X are difference stationary, so are spatial lagged variables difference stationary because W does not generally constitute a matrix of cointegrating vectors. Panel cointegration requires that u be stationary⁹. If u is stationary when $\gamma = \lambda = 0$, equation (2) is “locally cointegrated” because cointegration is induced within spatial units. If u is stationary when $\beta = 0$, equation (2) is “spatially cointegrated” because cointegration is induced between spatial units. If none of these

⁸ We do not use estimators for spatial cointegration proposed e.g. by Yu, de Jong and Lee (2012) because the unit roots in the data are temporal rather than spatial.

⁹ The 1st order error correction model associated with equation (2) is

$$\Delta Y_t = a + bu_{t-1} + c\Delta Y_{t-1} + d\Delta X_{t-1} + e\Delta \tilde{Y}_{t-1} + f\Delta \tilde{X}_{t-1} + \varepsilon_t$$

where $b < 0$ is the error correction coefficient and ε is iid. As mentioned, we do not estimate error correction models.

restrictions apply, then equation (2) is “generally cointegrated” because cointegration is induced within and between spatial units¹⁰.

The solution for Y_t from equation (2) is:

$$Y_t = A(\alpha + u_t) + BX_t \quad (3)$$

$$A = (I_N - \lambda W)^{-1} \quad B = A(\beta i_N + \gamma W)$$

in which case the spatial propagation of X in region j on Y in region i is $b_{ij} = \beta a_{ij} + \gamma c_{ij}$ where $C = AW$. The counterpart for innovations is a_{ij} .

In cointegrated time series models the parameter estimates are super-consistent (Stock 1987) in which case potential reverse causality from Y to X in equation (2) would not affect the consistency of β , although it may be biased in finite samples (Banerjee et al 1993). Matters are different in nonstationary panel data because the bias induced by cross-section dependence between state variables does not tend to zero with N (Phillips and Moon 1999). However, if N is fixed as it is in spatial panel data, it may be shown that this bias tends to zero with T (Beenstock and Felsenstein 2015). This means that model covariates, such as X in equation (2) are weakly exogenous¹¹, in which case the parameter estimates are consistent.

Similar reasoning applies to λ , which in stationary panel data must be estimated by maximum likelihood (Elhorst 2003) since dependent variables and spatial lagged dependent variables are jointly determined. In nonstationary panel data OLS estimates of SAR coefficients are consistent (Beenstock and Felsenstein 2015) provided the model is panel cointegrated; because $\tilde{Y} \sim I(1)$ and $u \sim I(0)$ are asymptotically independent.

We do not report equation standard errors because estimates of cointegrating vectors generally have non-standard distributions. Instead, tests of parameter restrictions are carried out by imposing the restrictions and using the cointegration test statistic to evaluate them. For example, if the model ceases to be cointegrated when a restriction is imposed, the restriction is rejected. If, however, the p-value for cointegration does not depend on the restriction, the restriction is accepted.

¹⁰ Notice that Y and \tilde{Y} and X and \tilde{X} are not generally cointegrated with each other.

¹¹ Since the covariates are integrated to order 1 and the residuals are integrated to order zero, there can be no asymptotic relation between the covariates and the residuals. In spatial panel data super-consistency depends on the number of time series observations (T) not the number of cross-section observations (N).

The spatial weighting scheme is given by equation VIII in Table 1. It varies inversely with distance (d) and it is asymmetric unless the average populations of i and j happen to be the same¹². Therefore, bigger neighbors have a greater spatial weight than smaller neighbors. Agglomeration (A) at the beginning of period t is defined in equation IX. It varies directly with “capital experience” as measured by the capital-labor ratio (k) in period $t-1$, and it depreciates by 5 percent per year. The time series properties of A are therefore the same as those of k . Using capital creates new knowledge through learning-by-going, which increases TFP.

The Model

The empirical model described in this section is based on the theoretical model described in section 2, but in bringing theory to data a number of extensions are required. First, there are nine dependent regions rather than only one “small” region. However, each region may be characterized as in Figure 1; there are supply and demand schedules for housing and labor. Second, whereas the theoretical model did not articulate the gestation lag in housing construction, the empirical model specifies the dynamic relation between housing starts and completions. Because the housing stock is quasi-fixed in the short-run but variable thereafter the empirical model distinguishes between temporary and permanent (steady state) equilibria. Third, the Israel Land Authority, which was ignored in the theoretical model plays a central role in the empirical model as the source of land zoned for housing construction. Fourth, amenities which had no role in the theoretical model are specified in the empirical model.

The main equations of the model are reported in Table 1. Housing starts (S) are determined by Equation I according to which starts vary directly with house prices (P) and construction incentives provided by the Ministry of Housing and Construction (Z), inversely with building costs (C), as well as spatial lags of these variables¹³. These spatial lag coefficients are negative because there is spatial substitution in housing construction. The spatial lagged dependent variable is positive (0.557) due to spatial spillover in housing construction. The overall price elasticity of housing starts is 0.28. Equation II relates completions to starts and is multi-cointegrated (Granger

¹² Note that W does not depend on t because it refers to the sample average.

¹³ See Beenstock and Felsenstein (2015) for details and further explanations for equations I, II, V and VI.

and Lee 1989) with equation I. It ensures that all starts are eventually completed, but completion rates vary directly with starts. Equation III is an inverted demand curve for housing. The price elasticity of demand for housing space is -1.565 (1/0.639), the elasticity of demand with respect to the population is 1.15 (0.724/0.939) and the income elasticity of demand is 0.42 (0.271/0.639). In addition, local house prices vary directly with neighboring house prices and with neighboring populations.

Table 1: The Model

$$I. \ln S_{it} = fe_i + 0.318 \ln \left(\frac{P_{it}}{C_t} \right) + 0.487 \ln \left(\frac{P_t}{C_t} \right) - 0.597 \ln \left(\frac{\tilde{P}_{it}}{C_t} \right) + 1.166 Z_t - 0.439 \tilde{Z}_t + 0.577 \ln \tilde{S}_t$$

$$II. F_{it} = 0.175 U_{it} + 0.544 F_{it-1} + 0.136 S_{it}$$

$$III. \ln P_{it} = fe_i + 0.734 \ln N_{it} - 0.639 \ln H_{it} + 0.271 \ln W_{it} + 1.140 \ln \tilde{N}_{it} + 0.520 \ln \tilde{P}_{it}$$

$$IV. Z_{it} = \frac{S_{Git}}{S_{it}}$$

$$V. U_{it} = U_{it-1} + S_{it-1} - F_{it-1}$$

$$VI. H_{it} = H_{it-1} + F_{it-1} - D_{it-1}$$

$$VII. \ln W_{it} = fe_i + 0.026 \ln k_{it} + 0.122 \ln A_{it} + 0.047 E_{it} + 0.184 Jews_{it} - 2.5 UO_{it} + 0.027 Age_{it} - 0.00063 Age_{it}^2$$

$$VIII. w_{ij} = \frac{\overline{POP}_j}{d_{ij}(\overline{POP}_j + \overline{POP}_i)}$$

$$IX. \ln A_{it} = 0.95 \ln A_{it-1} + \ln k_{it-1}$$

GADF_z: equation I -3.46, equation II -3.4, equation III -3.37, equation VII -2.57

Legend: S starts, S_G starts initiated by MOH (exogenous), F completions, D demolitions (exogenous), P house price index, C construction cost index (exogeneous), N population (exogenous), W wages, U housing under construction, k capital-labor ratio, A capital agglomeration, E average years of schooling, Jews percentage of Jews in population, UO percentage of ultra-orthodox in population, Age average age of population. P $\bar{O}P$ mean population.

GADF_z The z statistic for Pedroni's GADF, Spatial lagged variables are over-scripted with \sim .

Equations IV – VI are identities. According to equation VII wages vary directly with capital-labor ratios and capital agglomeration. Wages also depend on regional Mincer variables (schooling and age) and are higher in regions with more Jews and lower in regions where there are more ultra-orthodox Jews. There is no spatial spillover in equations II and VII.

Internal Migration

Schedule S in Figure 1 is estimated by regressing population shares on relative real wages (RRW) for each region, i.e. separate regressions are carried out using the data in Figure 8 to estimate:

$$\frac{POP_{it}}{POP_t} = \pi_i + \theta_i RRW_{it} + p_{it} \quad (4)$$

Where p is a residual and RRW is calculated assuming $\phi = 0.22$ in equation (1), i.e. housing is 22 percent of consumption according to CBS estimates. However, in only four regions (Krayot, South, Center and Dan) is there a positive relation between population shares and RRW. The OLS estimates of the slope coefficient on RRW (θ) are 0.032, 0.12, 0.288 and 0.709 respectively, implying that internal migration is largest in absolute terms for Dan and smallest for Krayot. The residuals (p) for these four regions are stationary with $GADF = -2.3$.

By contrast, in the other regions such as Tel Aviv the data seem to slope the “wrong” way; population shares vary inversely with relative real wages. For these irregular regions we assume that θ is 0.8 in Tel Aviv, 0.6 in Jerusalem, 0.3 in Haifa, and 0.5 in Sharon. Since the population shares sum to one, the North is chosen as the Nth region. For these irregular regions amenities are imputed by assuming that they are equal to p in equation (4) with $\pi = 0$. The choices of θ for these irregular regions is made to smooth the estimates of p which are plotted in Figure 9. The level of these estimates capture regional fixed effects (π) which is largest in North and smallest in Haifa and Tel Aviv. More important is the estimated trend in imputed amenities, which is increasing in North and Jerusalem and decreasing in Tel Aviv, Sharon and Haifa. Indeed, these estimated amenities are nonstationary. Jerusalem and North have become increasingly attractive, whereas the opposite has happened in Tel Aviv, Haifa and Sharon.

Model Properties

To illustrate the properties of the model a full dynamic simulation (FDS) is calculated during 1987 – 2010 in which the state variables (population, employment, wages, house prices, housing construction and stocks in the nine regions) are solved in terms of the exogenous variables (capital, housing construction initiated by the Ministry of Housing, amenities, and demographics). The model therefore consists of 45 endogenous variables that are solved in each time period. The FDS serves as a base

run for counterfactual simulation in which the exogenous variables are perturbed in 1994. The model is state dependent temporally and spatially. It is temporally state dependent because it is slightly nonlinear because variables are specified in levels and logarithms. For example, Table I includes housing construction starts (S) in equations IV and V and its logarithm in equation I. Incidentally, this gives rise to temporal dynamics in the model despite the fact that equation I is static; the dynamics are entirely induced by the relations between housing stocks and flows, and by the dynamics of agglomeration (equation IX). This means that the same shock in say 2000 would produce slightly different effects than its counterpart in 1995. The model is spatially state dependent because the spatial weights matrix (W) is asymmetric and because the regions vary in size. Therefore, a given shock will have a bigger effect on a smaller region and it will have a bigger effect if it occurs in regions that are more spatially connected. This means that the spatial diffusion of shocks depends on where they occur, as well as when they occur.

Figure 10 plots the spatio-temporal diffusion on housing starts (top left), population (top right), house prices (bottom left) and wages (bottom right) of a permanent 10% shock applied in 1994 to the capital stock in North. The increase in the capital stock increases labor demand directly through capital deepening which raises labor productivity, and indirectly through agglomeration. The latter effect takes time to build-up so that wages in North eventually increase by 1.3 percent. They would have increased by more, but for inward migration which increases labor supply and which eventually raises population in North by half a percent at the expense of population elsewhere. The population loss is greatest in Dan and smallest in Jerusalem. This does not mean that internal migration is mainly from Dan to North since third regions are involved.

Because population and wages increase in North the demand for housing in North increases inducing an increase in house prices. The opposite happens elsewhere where population has decreased. House prices decrease most in Dan because it has the largest population loss, but they also decrease most in Center. House price diffusion involves spatial dynamics induced by equation III in Table 1, which is why the pecking-order in house price responses does not depend solely on the pecking-order of population responses. Housing construction (starts) increases in North because of the increase in house prices and it decreases elsewhere. The decrease is smallest in Sharon because house prices decrease least there. The decrease in housing starts is

greatest in Krayot despite the fact that house prices do not decrease most there. This pecking-order is also influenced by the spatial dynamics in housing starts (equation I in Table 1). Inward migration into North would have been larger but for the increase in house prices in North and the decrease elsewhere. Finally, wages increase slightly in other regions because labor supply decreases.

The temporal diffusion in Figure 10 is slow. It takes about 7 years for most of the diffusion to occur. Indeed, it takes about 10 years for a temporary shock (not shown) to the capital stock to dissipate. These temporal dynamics are induced by stock-flow effects in housing and by agglomeration effects in labor productivity.

When Figure 10 is calculated for other regions the propagation is qualitatively similar but quantitatively different due to spatial state dependence (not shown). The population response in South, for example, is smaller than in North but as in Figure 10 Dan is the most sensitive region for outward migration. In terms of the theoretical indeterminacy in SGE that was discussed, Figure 10 shows clearly that productivity shocks raise wages and population. In terms of Figure 1 SGE occurs at points such as c which is northeast rather than northwest of a. The population increases in North because relative real wages increase in North. This happens because the increase in house prices is insufficiently large to reduce real wages relative to elsewhere, since the income elasticity of demand for housing is only 0.42.

Figure 11 plots the propagation of a temporary reduction in public sector housing starts of 300m square meters in 1991. Apart from quantifying the propagation of housing supply policy, the simulation is motivated by a counterfactual evaluation of housing policy (see Figure 7). Faced with mass immigration from the former USSR in 1991 the Minister of Housing and Construction (the late Ariel Sharon) built massively in South. At the time this policy was heavily criticized (by the Bank of Israel and the Auditor General) on the grounds that the new housing would remain vacant. Figure 11 simulates what might have happened had this policy not occurred.

Housing starts in 1991 would have decreased by 7-8 percent as a result of which house prices in South would have been about ½ percent higher. The increase in house prices would have induced outward migration from South reducing the population in South by about 0.01 percent. As in Figure 10 Dan is the most sensitive region in Figure 11. The least sensitive is North. The decrease in population in South lowers labor supply, as a result of which wages in South increase. The greatest decrease in wages occurs in Dan.

The simulation shows that although the criticisms of Sharon were unwarranted the quantitative impact of Sharon's housing policy was small because 300m square meters is only a small proportion of the housing stock in South (2.1 percent). Nevertheless, the simulation illustrates how housing supply policy affects the economy in SGE. Land allocated for housing construction by the Israel Land Authority increases the housing stock, which in turn lowers house prices and induces inward migration. The latter increases labor supply, which lowers wages. However, real wages increase because housing is cheaper.

Finally, Figure 12 simulates a permanent increase of 5 percent in amenities in Tel Aviv¹⁴. Inward migration increases the population in Tel Aviv by 1.8 percent. The largest reduction in population occurs in North. This increase in population lowers wages in Tel Aviv by $\frac{3}{4}$ percent and increases house prices by 1.8 percent. The largest reaction occurs in North where wages decrease and house prices increase the least. The increase in house prices in Tel Aviv induces an increase in housing starts of the order of $\frac{1}{2}$ percent. House prices increase everywhere because of the spatial dynamics in equation III in Table 1.

Conclusion

We believe that this is the first time a structural econometric model of spatial general equilibrium has been estimated and simulated. The feasibility of this exercise required the development of a regional database for variables such as capital and housing stocks, which are not normally supplied by the statistical authorities. Since these data are nonstationary and spatially dependent, the model was tested and estimated using panel cointegration methods for spatial data.

The model focuses on the relation between housing and labor markets within and between nine regions in Israel. The supply and demand for housing and the supply and demand for labor are estimated regionally, which are cleared respectively by house prices and wages. Regions are related through internal migration and building contractors who operate across regions. They are also related through internal capital mobility, but for the present regional capital stocks are assumed to be exogenous.

¹⁴ The 1994 amenity value (0.0013) is increased by 5% for all following years, so that 0.0013 is 10% of the 2010 amenity value. In this way a constant value is added rather than a percentage.

In Israel the government has two policy instruments for influencing the spatial distribution of economic activity, the zoning of land for housing construction and commercial purposes, and investment grants and subsidies differentiated by region. The model is used to simulate these policies. For example, increasing land zoned for housing increases housing construction and lowers house prices, which increases labor supply through internal migration. The latter decreases wages and increases the demand for housing. Investment grants which increase capital investment increase labor productivity and wages which induce inward migration. House prices increase because housing demand varies directly with population and income. Housing construction increases because construction is more profitable, which moderates the initial increase in house prices.

These policy instruments are place-based rather than people-based. Glaeser and Gottlieb (2008) think that labor and capital are sufficiently internally mobile to guarantee that spatial factor price equalization occurs within a sufficiently short period of time. Accordingly, they think that place-based policies are redundant, and that people-based policies should be applied to encourage internal mobility. By contrast, Partridge et al (2013) think that place-based policies are justified on second best grounds. Our results are relevant to this debate in three respects. First, the forces of internal migration are insufficiently strong to eliminate regional wage inequality even in the long-term. Second, regional shocks in housing, labor and capital markets are slow to dissipate; they persist even after 10-15 years. Third, agglomeration aggravates this persistence and induces regional divergence rather than convergence. These results suggest a prima facie case for place-based policy. If places matter to the public and to building contractors in a small and young country such as Israel where regional allegiances and cultures are not yet fully developed, they are likely to matter even more in larger and more mature countries.

In the case of Israel, it can be argued that the place-based versus people-based policies dichotomy may be exaggerated. This is because 90 percent of land and almost half of land reserves are vested in the Israel Land Authority. This dominance means that any place-based policy is also inherently people-based. Divestment of these land reserves for housing and commercial purposes inevitably has implications for places as well as people. Since these land reserves are concentrated in the periphery of the country, a regional shock in the form of divestment would benefit the peripheral

regions and attract people and investment away from the congested center of the country.

Map

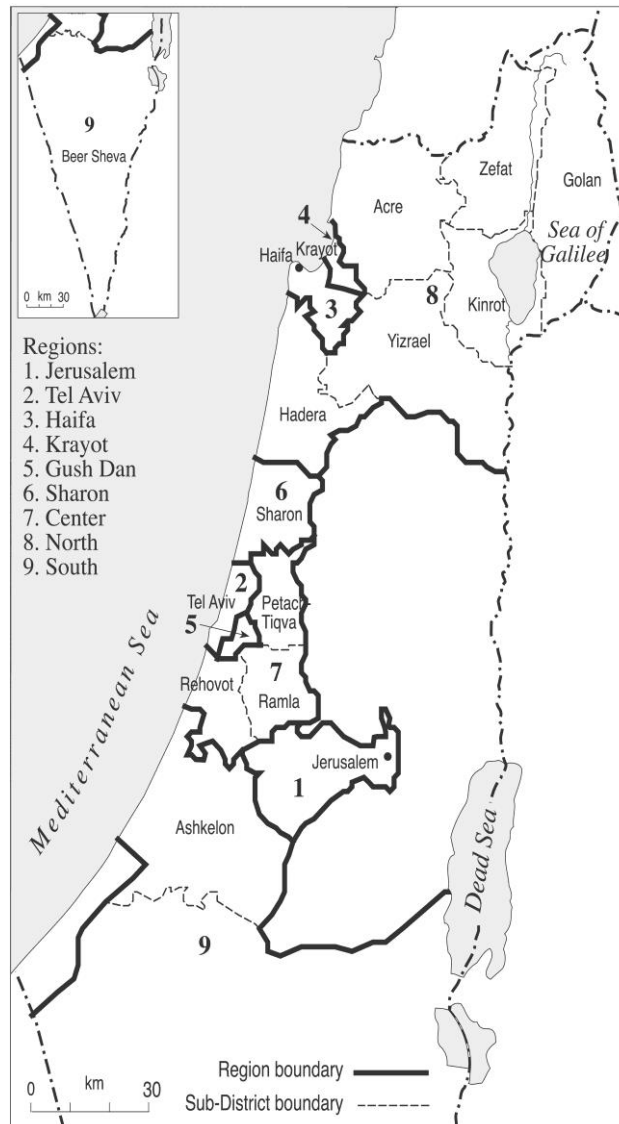


Figure 3 House Prices

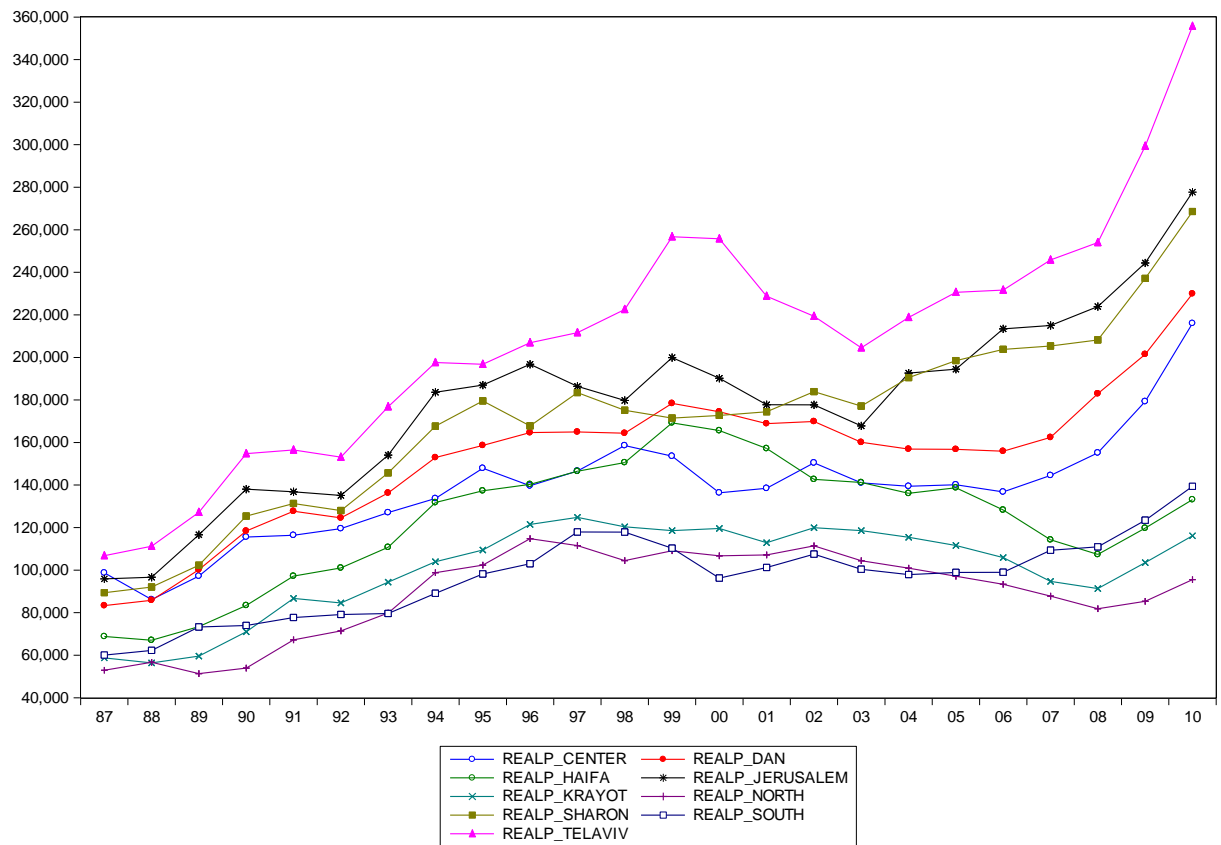


Figure 4 Population

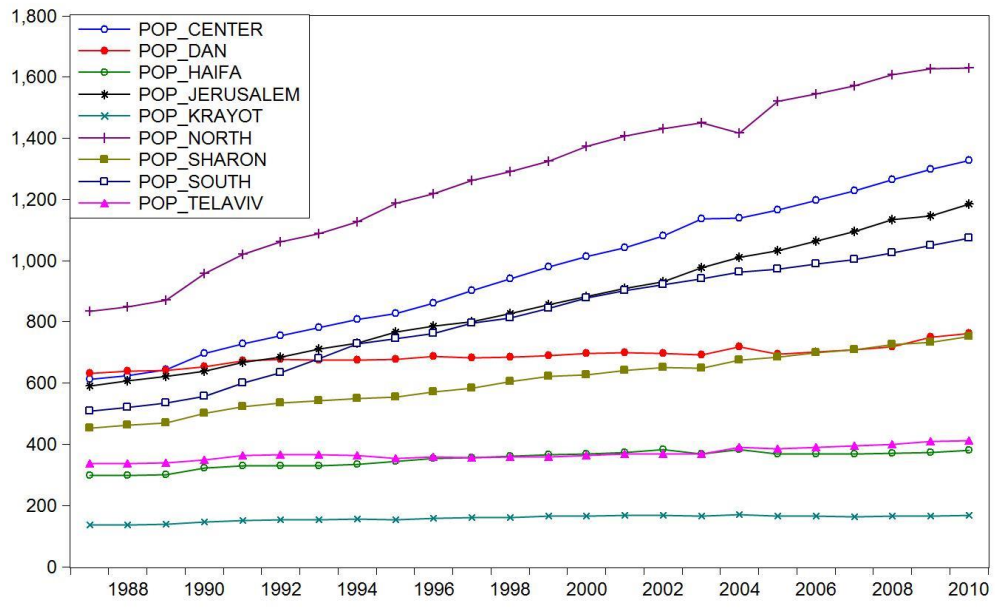


Figure 5 Housing Space per Head

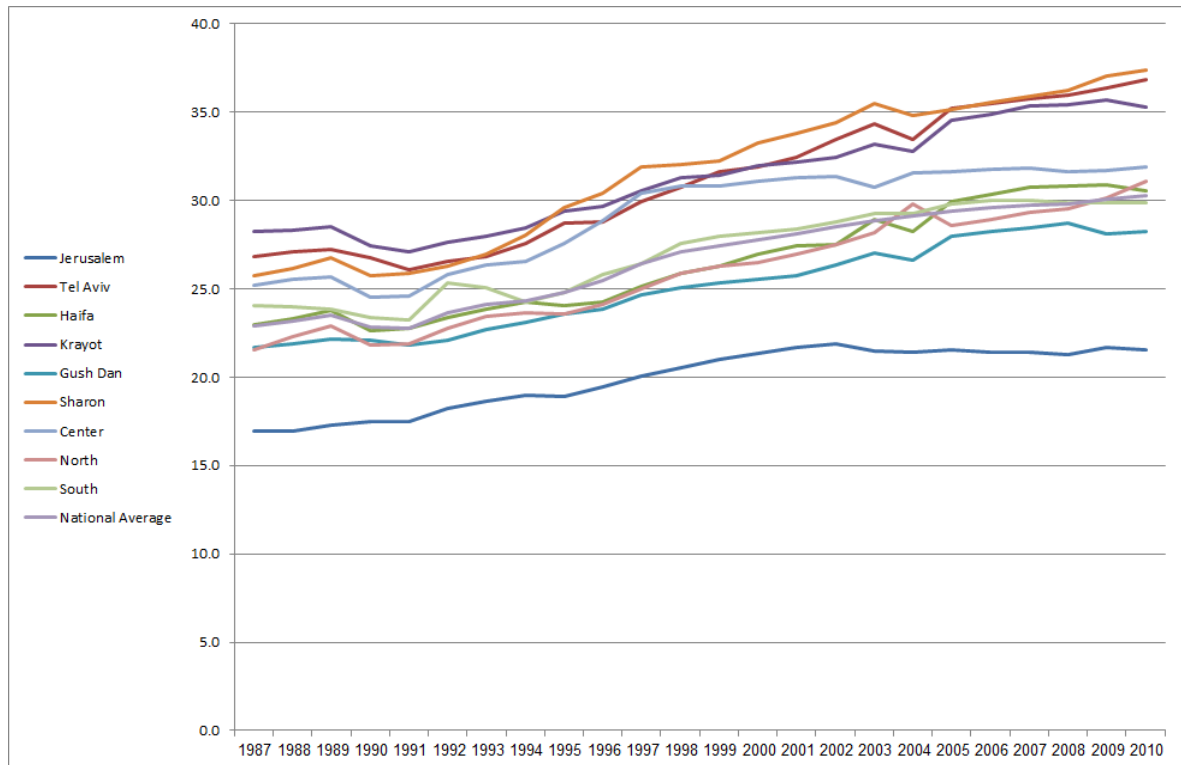


Figure 6 Capital

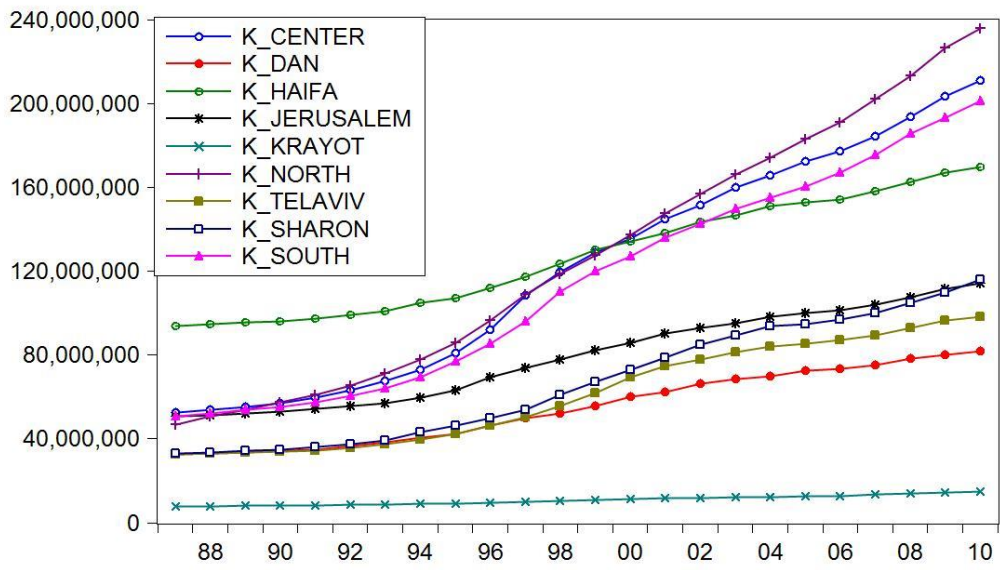


Figure 7

MOH Starts square meters, millions

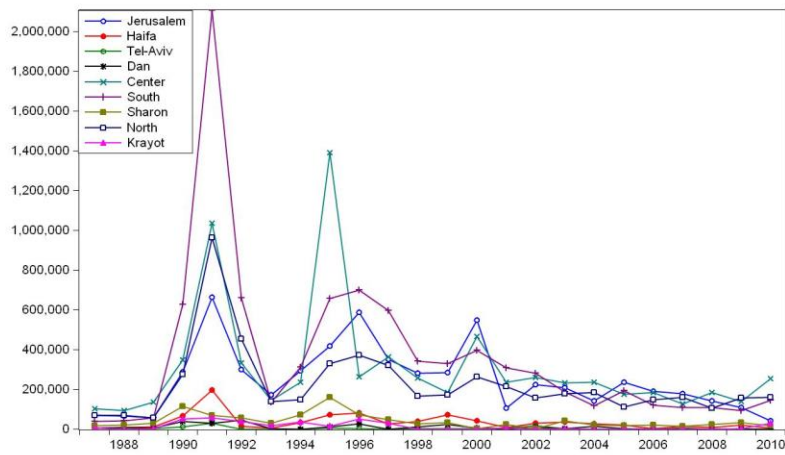


Figure 8 Population Shares and Relative Real Wages

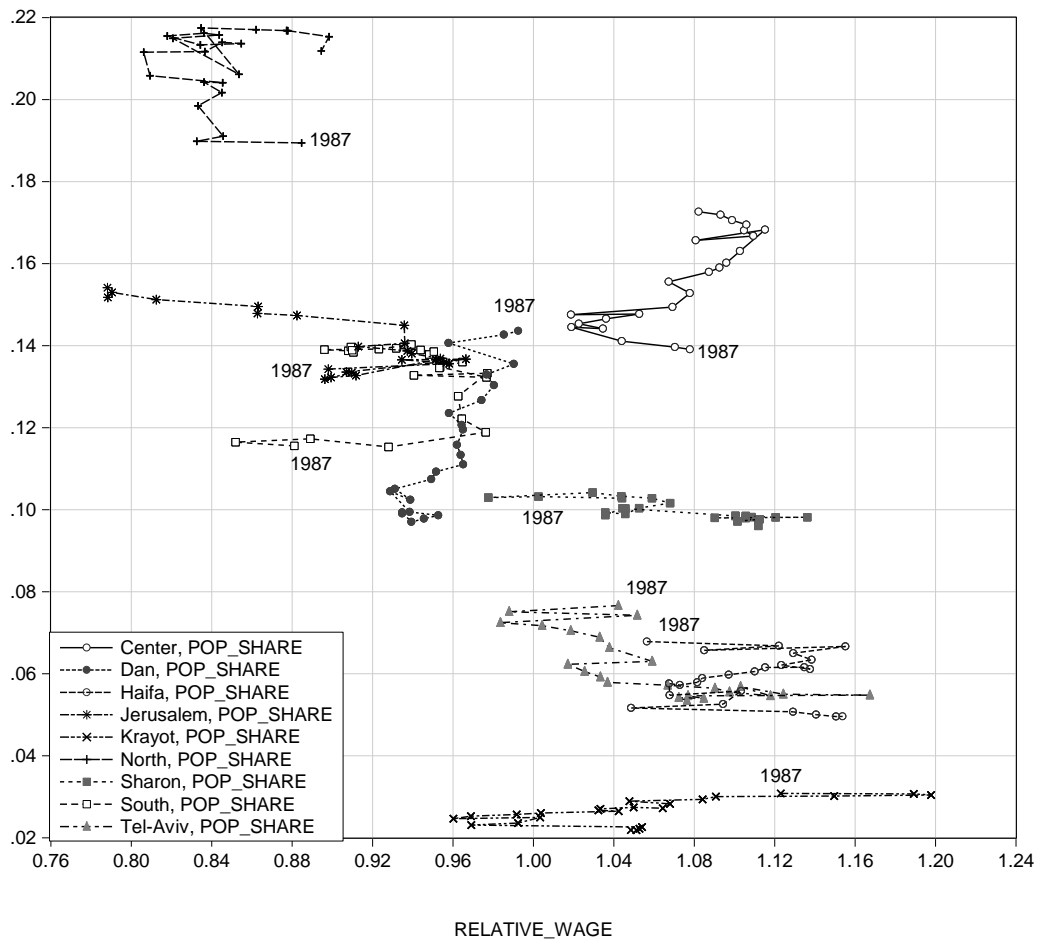


Figure 9 Implicit Amenities

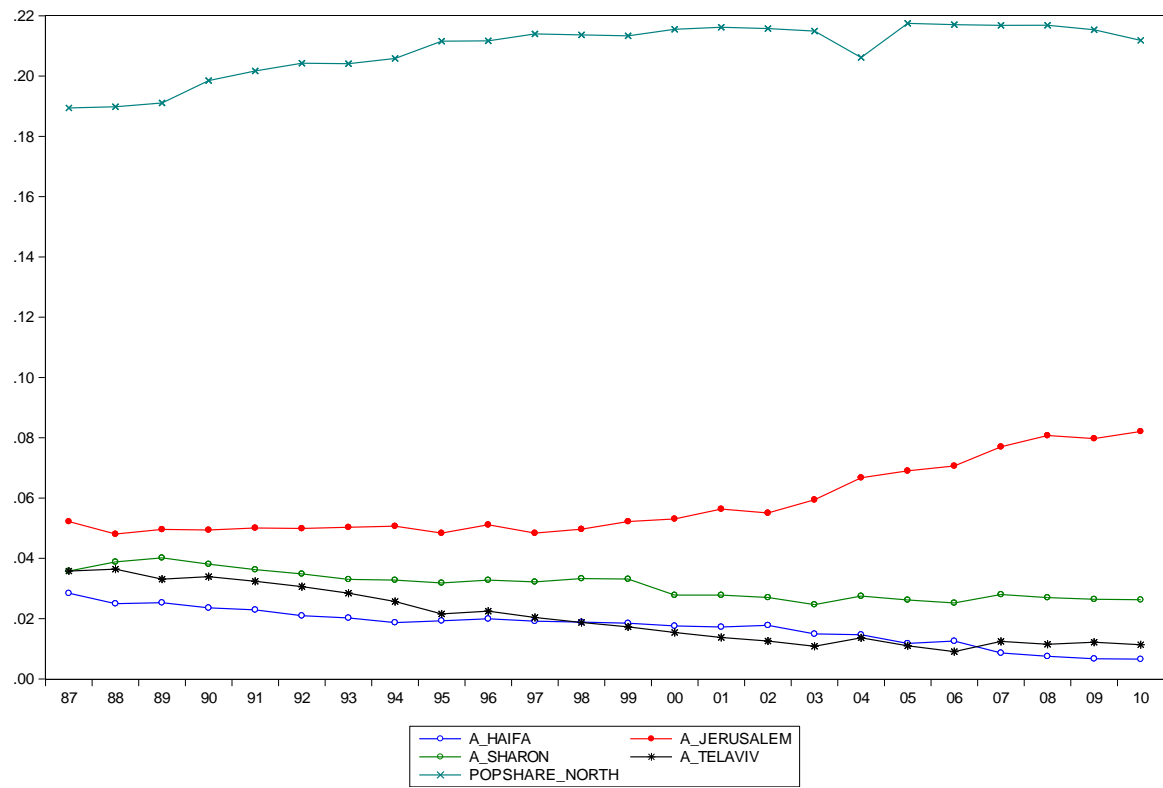


Figure 10: Simulation: Permanent Increase in Capital Stock in North of 10%

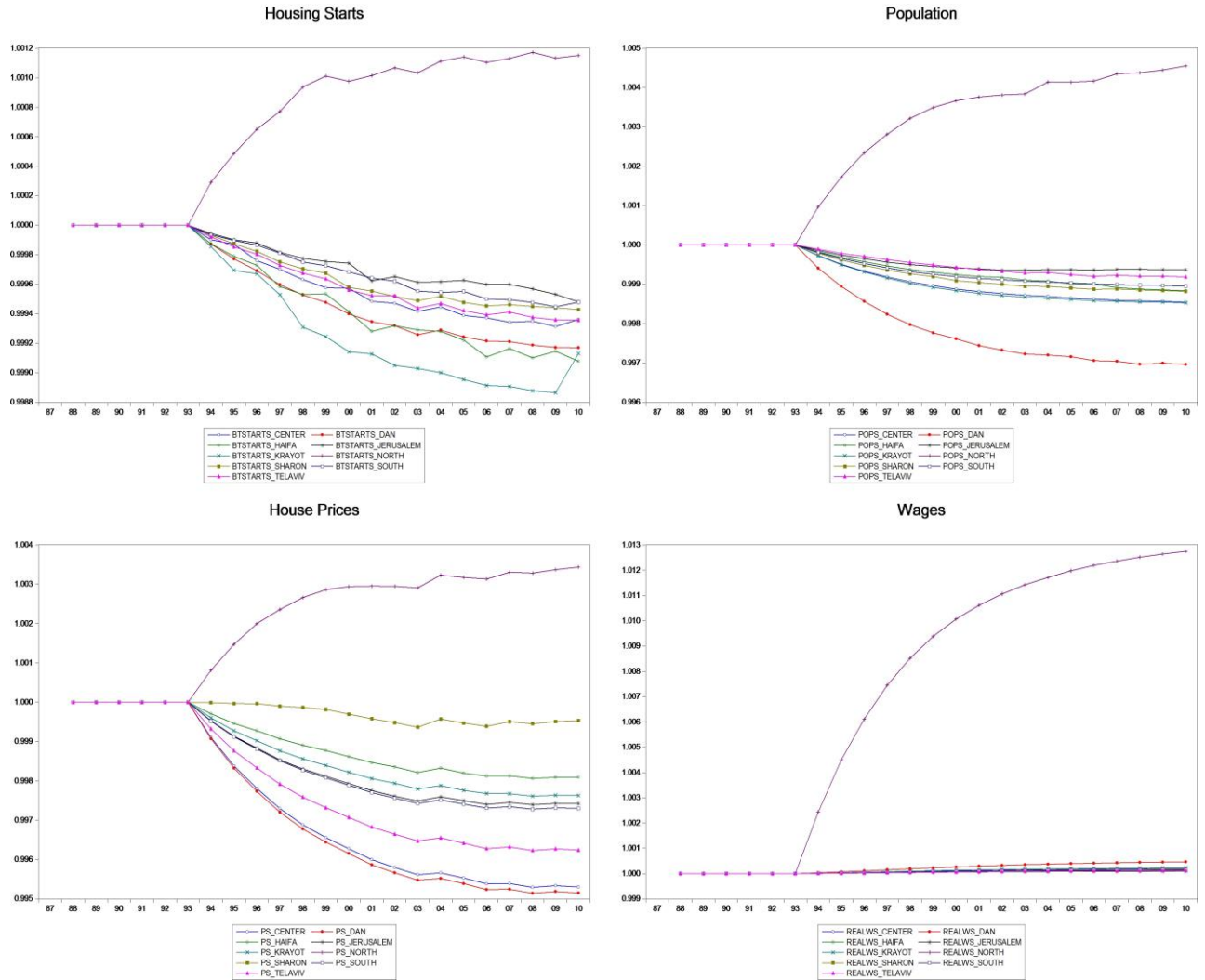


Figure 11: Simulation: Cut of 300m Square Meters in Public Sector Housing Starts in South

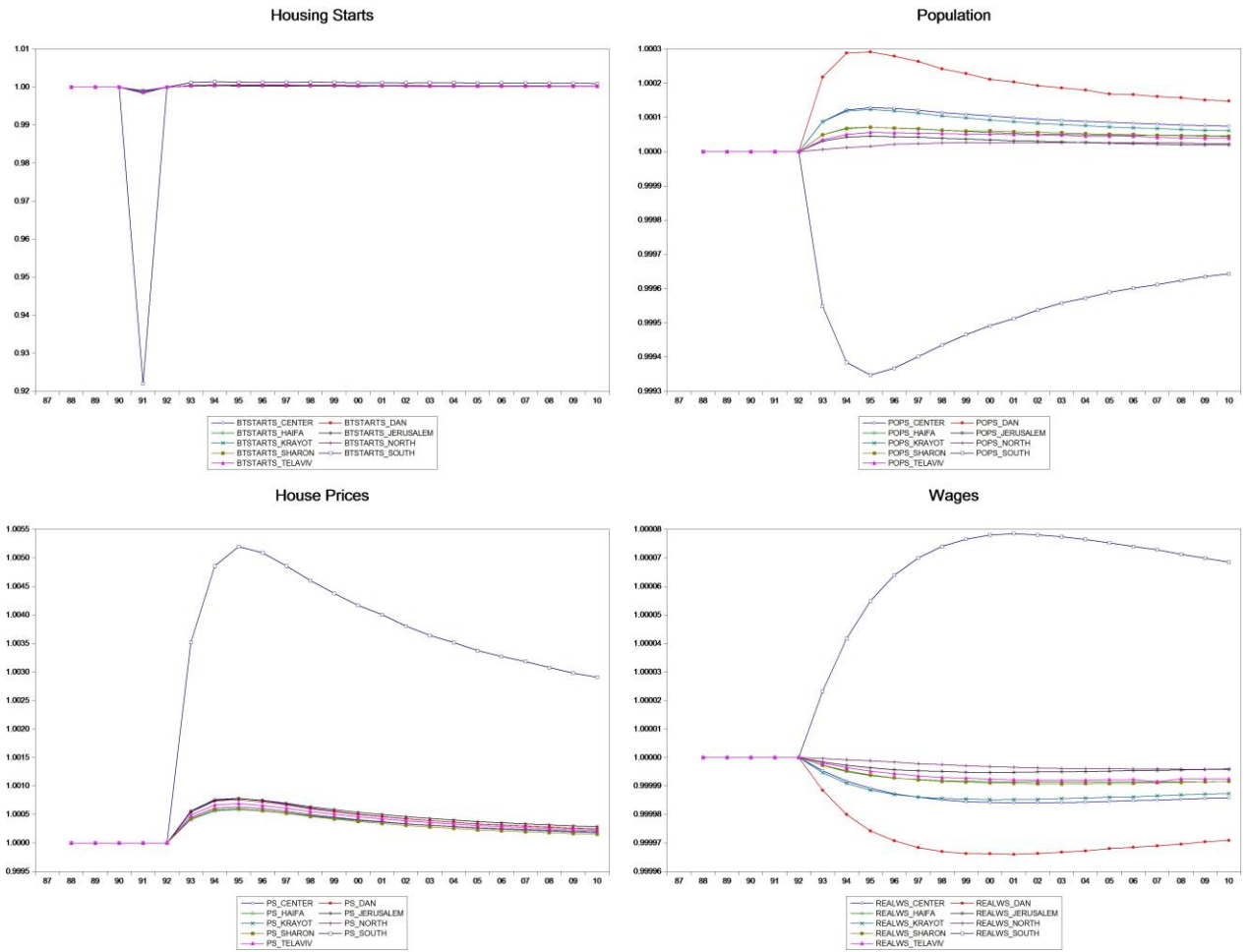
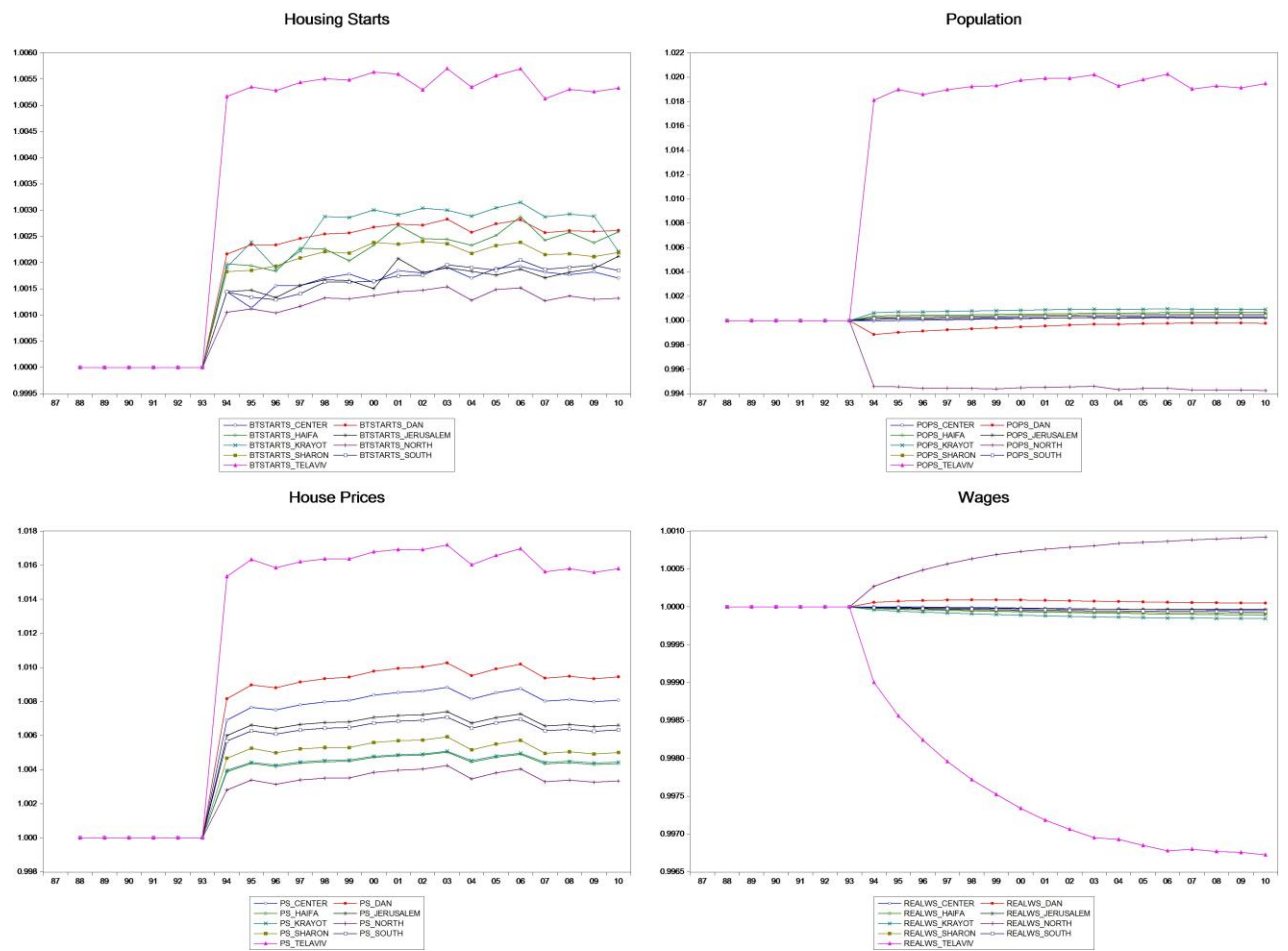


Figure 12: Simulation: An Increase in Amenities in Tel Aviv



References

- Baldwin R.E and Martin P. (2004) Agglomeration and Regional Growth, pp 2672-2711 in Vernon Henderson J and Thisse J-F (eds) *Handbook of Regional and Urban Economics* Vol 4, Elsevier, Holland
- Banerjee A., J. Dolado, J.W. Galbraith and D.F. Hendry (1993) *Cointegration, Error Correction, and the Econometric Analysis of Nonstationary Time Series*. Oxford University Press.
- Banerjee A and Carrion-I-Silvestre J.L (2011) Testing for panel cointegration using common correlated effects estimators. Dept of Economics, University of Birmingham.
- Beenstock M. and D. Felsenstein (2010) Spatial error correction and cointegration in nonstationary spatial panel data: regional house prices in Israel. *Journal of Geographical Systems*, 12: 189-206.
- Beenstock M. and D. Felsenstein (2010) Marshallian theory of regional agglomeration. *Papers in Regional Science*, 89: 155-172.
- Beenstock M. and D. Felsenstein (2015) Spatial spillover in housing supply. *Journal of Housing Economics*, 28, 42-53
- Beenstock M., D. Felsenstein and N. Ben Zeev (2011) Capital deepening and regional inequality: an empirical analysis. *Annals of Regional Science*, 47: 599-617.
- Beenstock M., D. Feldman and D. Felsenstein (2012) Testing for Units Roots and Cointegration in Spatial Cross Section Data, *Spatial Economic Analysis* 7(2), 203-222.
- Beenstock M., D. Felsenstein and D. Xieer (2015) *Spatial econometric analysis of regional housing markets*. Mimeo.
- Brandsma, A, Kancs d'A, Monfort P and Rillaers A (2013) *RHOMLO: A Dynamic Spatial General Equilibrium Model for Assessing the Impact of Cohesion Policy*, EUR 25957 – Joint Research Centre – Institute for Prospective Technological Studies, Publications Office of the European Union, Luxembourg.
- Brakman S and Garretsen H (2006) New Economic Geography: Closing the Gap between Theory and Empirics, *Regional Science and Urban Economics*, 36, 569-572.
- Brakman S., H. Garretson and C. van Marrewijk (2009) *The New Introduction to Geographical Economics*, 2nd edition, Cambridge University Press.

Buchinsky M., Gotlibovski C and Lifshitz O. (2014) Residential Location, Work Location, and Labor Market Outcomes of Immigrants in Israel, *Econometrica*, 82 (3), 995-1054.

Combes P-P., T. Mayer and J-F. Thisse (2008) *Economic Geography: the Integration of Regions and Nations*, Princeton University Press.

Davis D.R. and D. Weinstein (2003) Market access, economic geography and comparative advantage: an empirical assessment. *Journal of International Economics*, 59: 1-23.

Elhorst J.P (2003) Specification and estimation of spatial panel data models. *International Journal of Regional Science*, 25: 244-268.

Giesecke J.A and Madden J.R. (2013) Regional computable general equilibrium modeling pp 377-475 in Dixon P.B and Jorgensen D.W (eds) *Handbook of Computable General Equilibrium Modeling*, Vol 1, Elsevier Holland.

Johnes G and Hyclak T (1999) House prices and regional labor markets, *Annals of Regional Science*, 33, 33-49

Glaeser E. L., Kalko J. and Saiz A. (2001), Consumer City, *Journal of Economic Geography*, 1, 27-50.

Glaeser E.L. and Gottlieb J.D (2008) The Economics of place-making policies, *Brookings Papers on Economic Activity*, 1,: 155–239.

Glaeser E.L. and J.D. Gottlieb (2009) The wealth of cities: agglomeration economies and spatial equilibrium in the United States. *Journal of Economic Literature*, 47: 983-1028.

Granger, C.W.J., Lee, T., (1989) Investigation of production, sales and inventory relations using multi-cointegration and non-symmetric error correction models. *Journal of Applied Econometrics*, 4, S145-S159.

Greenwood M.U. and R. Stock (1990) Patterns of change in the intrametropolitan location of population, jobs and housing. *Journal of Urban Economics*, 28: 243-276.

Hanson G. (2005) Market potential, increasing returns, and geographic concentration. *Journal of International Economics*, 67: 1-24.

Head K and T. Mayer (2004) Market potential and the location of Japanese investment in the European Union. *Review of Economics and Statistics*, 86: 959-972.

Krugman P. (1991) *Geography and Trade*. MIT Press.

Partridge M.D. and Rickman D.S. (1998) Regional computable general equilibrium modeling: a survey and critical appraisal, *International Regional Science Review*, 21, 205-248.

- Partridge M.D.,Rickman D.S.,Rose Olfert M and Tan Y (2013) When spatial equilibrium fails: is place-based policy second best?, *Regional Studies*, <http://dx.doi.org/10.1080/00343404.2013.837999>
- Pedroni P. (2004) Panel cointegration: asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis, *Econometric Theory*, 20: 597-625.
- Phillips P.C.B. and H. Moon (1999) Linear regression limit theory for nonstationary panel data, *Econometrica*, 67: 1057-1011.
- Roback J. (1982) Wages, rents and the quality of life. *Journal of Political Economy*, 90: 1257-1278.
- Stock J. H. (1987) Asymptotic properties of least squares estimators of cointegrating vectors. *Econometrica*, 55, 1035-1056.
- Vermeulen W and van Ommeren J (2009) Does land use planning shape regional economies? A simultaneous analysis of housing supply, internal migration and local employment growth in the Netherlands, *Journal of Housing Economics* 18, 294–310
- Westerlund J. (2007) Error correction based panel cointegration tests, *Oxford Bulletin of Economics and Statistics*
- Yu J.,R. de Jong and L. Lee (2012) Estimation of spatial dynamic models with fixed effects: the case of spatial cointegration. *Journal of Econometrics*, 167: 16-37.