Ann Reg Sci
DOI 10.1007/s00168-010-0397-1

SPECIAL ISSUE PAPER

Capital deepening and regional inequality: an empirical analysis

Michael Beenstock · Daniel Felsenstein · Nadav Ben Zeev

Received: 7 July 2009 / Accepted: 1 April 2010

Abstract We present a simple reproducible methodology for constructing regional capital stock data, which we apply to Israel. We find that capital deepening has been sigma-convergent since 1985. This process is "inverted" since capital stocks and capital–labor ratios in the richer center have been catching-up with their counterparts in the poorer periphery. We explain this phenomenon in terms of fundamental changes in regional policy. Despite this, regional wages have not been sigma-convergent because other wage determinants have been sigma-divergent.

JEL Classification O18 · R11 · R53

1 Introduction

Economic theory predicts that productivity and real wages will be greater in regions where the capital–labor ratio is larger.[1] Since governments do not publish data on regional capital stocks, lack of reliable data has impeded empirical research on the role of capital in regional economic inequality. To fill this vacuum researchers have tried to construct their own data. We distinguish between two main methodologies,[2]

[1] See, e.g., Weber and Domazlicky (2006). Bradfield and Dunn (1998) argue that capital might lower rather than increase wages, if it substitutes for labor as a whole. If technical change is skill-biased and embodied in capital, capital accumulation may increase wages of the skilled but lower the wages of the unskilled. In this paper we do not address the issue of skill-biased technical change in its regional context.
[2] There are, of course, other methodologies, e.g., Rickman et al. (1993) who generate simulated data from a CGE model. Such methodologies are yet more remote from the direct method that we prefer.

M. Beenstock · N. Ben Zeev
Department of Economics, Hebrew University of Jerusalem, Jerusalem, Israel

D. Felsenstein (✉)
Department of Geography, Hebrew University of Jerusalem, Jerusalem, Israel
e-mail: msdfels@mscc.huji.ac.il

Published online: 22 June 2010

which we refer to as "apportionist" and "direct", and which suffer from various shortcomings, some of which are major. Most studies apportion the national capital stock to the regions by using various regional indicators such as wages, employment, economic activity or even investment. For example, Munnell (1990) and Garofalo and Yamarik (2002) apportion in terms of regional economic activity, so that regions that have a greater share in gross regional product are assumed to have a greater share of the national capital stock. Gleed and Rees (1979) apportion by regional employment, Wells (1998) by regional wages, and Levtchenkova and Petchey (2000) by capital consumption. This methodology makes it impossible to test hypotheses about the role of capital deepening on regional inequality because the data have been constructed under the very hypothesis which is to be tested.

The direct method attempts to measure regional capital stocks directly and applies the perpetual inventory method typically used in constructing national capital stocks (Gleed and Rees 1979; Holtz-Eakin 1994; Rigby 1995; Christopoulos and Tsionas 2004). Data are collected on regional investment, which are anchored to estimates of regional capital stocks in a base year after allowing for depreciation. While the direct method is in principle preferable to the apportionist method, typically enormous data problems arise in its implementation. A particularly acute problem is the absence of data on price deflators for regional investment. Both time series and cross section deflators are required. Time series deflators are needed to express in constant prices investment in a given region over time. Cross section deflators are required to compare physical investment in different regions at the same point in time. The only attempt to come close to this is by Hulten and Schwab (1984), who constructed a regional plant deflator based on an index of commercial building costs (the Boeckh index) for 20 cities combined with the BLS/BEA national plant deflator. An appropriate deflator is particularly important in the case of plant where the price of land plays a key role. If the value of plant in two regions is the same, but industrial land is more expensive in one of the regions, its physical plant must be smaller. It is less serious in the case of machinery since machinery is a traded good and most probably the price of machinery is similar across regions.

Another problem is the absence of data on regional capital stocks in some base year. Or, if such data exist, there are no deflators to convert them into regionally comparable physical quantities (Holtz-Eakin 1993). For example, Giese and Schnorbus (1989) use regional investment data but there are no data on regional deflators to calculate gross regional fixed investment at constant prices. Nor are there data on regional capital stocks for some base year. A final problem concerns the absence of data on regional rates of capital depreciation. Varaiya and Wiseman (1981) and Melachroinos and Spence (2000) use a putty-clay approach to model the rate of depreciation. This approach assumes that the initial investment in capital stock fixes the other technical attributes (such as capital labor ratios) throughout its service lifetime. Anderson and Rigby (1989) further refine the putty-clay approach making it more regionally sensitive. In their estimation procedure, heterogeneity in regional capital stocks is not just the result of differences in regional investment but may also result from business cycle effects or from changes in the size of capital stock.

In this paper we propose a direct methodology for estimating regional capital stocks for plant, which we illustrate using data for Israel. The Central Bureau of Statistics

(CBS) publishes regional data on completions in square meters for non-residential buildings. Since these data are measured by quantity rather than price the problem of regional deflators does not arise. We use estimates from the Israel Land Survey to pin down regional capital stocks for plant in a base year, which are measured in square meters too. Therefore, here too the deflation problem does not arise. We apply the perpetual inventory method to construct time series for regional capital stocks measured in square meters for plant.

To determine the regional capital stocks for machinery we assume that the ratio of machinery to plant for each region is equal to the national average, which we obtain from data published by the Bank of Israel. We apportion the national capital stock for machinery according to each region's share in the capital stock for plant. This assumes uncomfortably that although the ratio of machinery to plant varies over time it does not vary by region at a given point in time. It also assumes uncomfortably strict complementarity between plant and machinery by region. Whereas the assumption of complementarity between say labor, capital, and raw materials would be too strong, in the case of plant and machinery it is defensible since increasing plant for a given amount of machinery cannot affect production. On the other hand, as we discuss in the following, there is an incentive to economize on plant if rents are high.

In short, we use the direct method for plant and the apportionist method for machinery. However, we think our approach should be distinguished from the crude apportionist methodologies that we criticize because there is an a priori case for assuming that plant and machinery are correlated across regions, and in any case, we use national data to allow the plant–machinery ratio to vary over time. Of course, it would be better to construct truly regional capital stock data for machinery, but this is not feasible.

We use our methodology to construct annual capital stocks in nine regions in Israel during 1986–2006. Subsequently, we calculate capital–labor ratios for these regions. We show that substantial "inverted" sigma-convergence has taken place. The better-off regions in the central parts of the country surprisingly had lower capital–labor ratios in 1986 than their counterparts in the periphery. By 2006 the central regions had largely closed the capital–labor gap with respect to the periphery. We explain that this inverted convergence occurred as a result of major changes in regional policy. We also show that regional wages vary directly with regional capital–labor ratios as well as other variables such as the regional human capital.[3] We draw comfort from the fact that our data constructions for regional capital stocks explain regional wage differentials. We interpret this is a form of validation of our method. Finally, we show that despite sigma-convergence in capital there has been no sigma-convergence in regional wages because other factors such as human capital have sigma-diverged.

[3] We do not enter here into issues that have preoccupied labor economists nationally and internationally such as skill-biased technical progress. We therefore investigate the effect of capital on regional wages without investigating whether the skilled have benefited differentially to the unskilled.

2 Methodology for constructing regional capital stocks

2.1 A direct method for plant

In Israel, as in most countries, physical data are published on non-residential construction by region, which typically distinguish between starts and completions. In what follows we use regional data for non-residential building completions in Israel, which we denote by C_{jt} where j refers to region j and t refers to year t. These data are measured in square meters, and measure the gross annual change in floor-space for plant. We denote by P_{jt} the floor-space for plant in region j at the start of year t. Whereas C is flow data, P is stock data. We use the perpetual inventory method, which links stocks and flows, to measure the physical stock of plant:

$$P_{jt} = P_{jt-1} + C_{jt-1} - D_{jt-1} \tag{1}$$

where D denotes net demolitions. Unfortunately there are no direct measures of demolitions. No doubt some completions are greenfield while others replace existing buildings that have been demolished. Also, residential buildings might have been redesignated into commercial property,[4] so net demolitions are equal to gross demolitions minus redesignations.

To apply Eq. (1) also requires data on plant stocks in at least one base year which we denote by P_{j0}. The Central Bureau of Statistics (CBS) has constructed GIS data on non-residential floor-space for 2005, which we use to represent P_{j0}. Since these data are measured in square meters, issues of deflators do not arise. These data are obtained from the Israel Land Survey, based on aerial photography and orthophoto-generated data relating to roof surfaces of industrial and commercial buildings. Building height data were created using the GIS point-to-raster procedure to create a 250×250 m grid in which each cell contained average non-residential building heights.

This leaves absence of data on net demolitions as the main data problem. We assume that D is a proportion of the existing stock of plant, i.e., $D_{jt} = \delta_j P_{jt-1}$. Although this is quite standard (e.g., Melachroinos and Spence 2000) we would have preferred to make assumptions about the life expectation of buildings (k) in which case $D_t = C_{t-k}$. This requires data on completions in the remote past, which unfortunately we do not have.

Had GIS data been available for a second base year, we would have experimented with different demolition rates so that Eq. (1) would have fitted the data for P_{jt} in the two base years. In the absence of such data, we nevertheless experiment with different demolition rates. In doing so, we obviously rule out demolition rates that generate negative values for P. Our main criterion for selecting the demolition rate is that the rate of growth of plant across the regions as a whole should equal the rate of growth of the capital stock invested in plant as published by the Bank of Israel for the country as a whole. Specifically, we use the following criterion:

$$\Delta \ln P_t = \Delta \ln K_{\mathrm{pt}} + e_t \tag{2}$$

[4] It rarely happens the opposite way round, i.e., when commercial property becomes residential.

where $P_t = \sum_{j=1}^{N} P_{jt}$, K_p denotes the national capital stock invested in plant measured at constant prices, and e denotes measurement error. We experiment with demolition rates that minimize measurement error.

2.2 A semi direct method for machinery and equipment

In Israel, as in most countries, there are no regional data at all on machinery and equipment (henceforth machinery). We suggest the following solution to this problem. In each year t we apportion the national capital stock for machinery (K_m) between the regions according to each region's share in year t in the capital stock for plant. This assumes that in each year the ratio of machinery to plant is the same for each region because it is equal the national ratio of machinery to plant. Although the ratio of machinery to plan is assumed to be the same for all regions at a given point in time, it varies over time.

The Bank of Israel publishes national capital stocks for plant (K_p) and machinery (K_m) measured in shekels at constant prices.[5] The physical counterparts for K_p and K_m are denoted by P and M, respectively. Since P is measured in square meters and K_p is measured in real shekels we may obtain the implicit price per square meter of plant as $\pi_t = K_{\mathrm{p}t}/P_t$. We denote the ratio of machinery (K_m) to plant (K_p) by ρ, which measures the space-intensity of a unit of machinery.

We apportion the national capital stock in machinery to the regions using the following formula:

$$K_{\mathrm{m}jt} = P_{jt}\pi_\mathrm{t}\,\rho_\mathrm{t} \tag{3}$$

which ensures that when $K_{\mathrm{m}j}$ is summed across the regions it is equal to the national total K_m. We show empirically below that ρ varies inversely with π, so that when the price per square meter of plant increases the machinery–plant ratio decreases nationally. It pays to cram more machinery into less space. This suggests that the machinery–plant ratio is most probably larger in regions where the rental price of plant is relatively cheap. If this is true, then Eq. (3) will underestimate K_m in regions were the rental cost of plant is relatively low.

Since Eq. (3) apportions the national capital stock invested in machinery at constant prices between the regions according to each region's share in the physical capital stock for plant, it is, strictly speaking, an apportionist method. However, we prefer to refer to it as a "semi-direct" method to distinguish it from methods which apportion using third variables such as gross regional product. We think that this difference is not just semantic because regional capital stocks for machinery are likely to be more closely related to their counterparts for plant than to various third variables.

[5] These data are published for gross and net measures of the capital stock, where the former deducts scrapping and the latter deducts depreciation. Here we use the former.

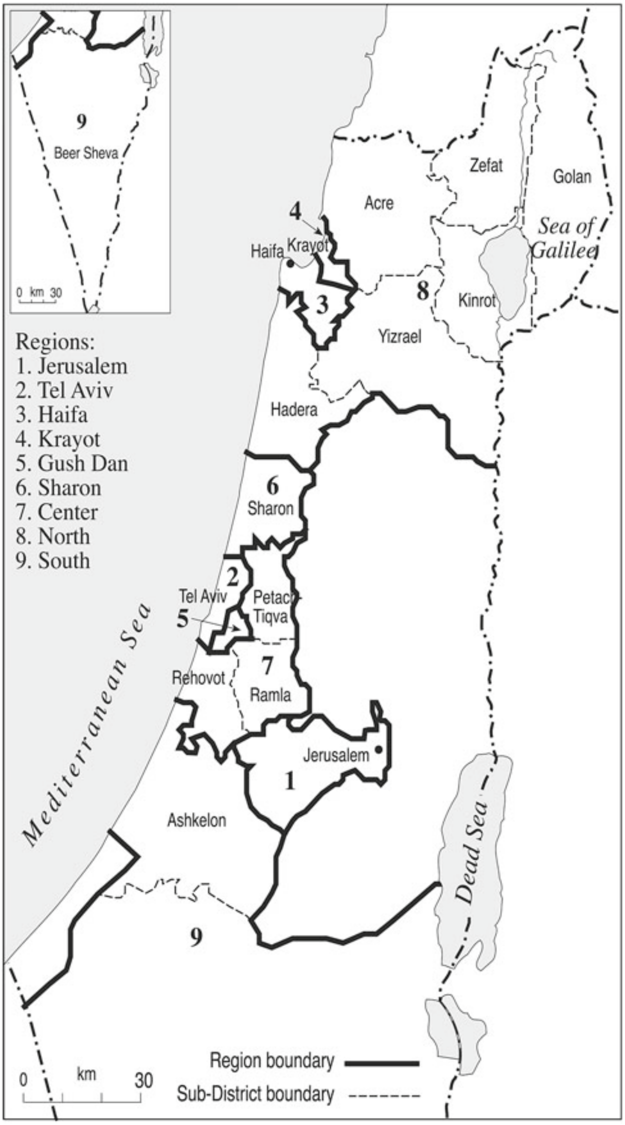

Fig. 1 Regional divisions as used in this study

3 Results

We have applied the methodology described in Sect. 2 to nine regions in Israel during 1986–2006. These nine regions have been used in previous work (Beenstock and Felsenstein 2007a,b, 2008, 2010) and are mapped in Fig. 1. The data on regional wages and various socio-demographic measures, such as age, gender, schooling, ethnicity, etc., are constructed by us from annual micro-data collected by the Central Bureau of

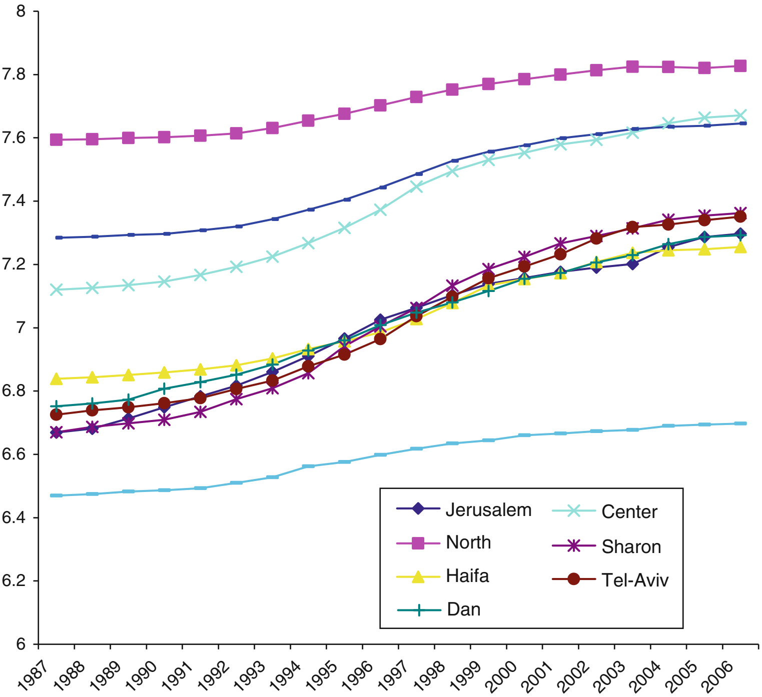

Fig. 2 Regional capital stocks for plant (logs, thousand sq meters)

Statistics in Israel in its Household Income Survey and its Labor Force Survey. We now describe our efforts to construct data for regional capital stocks.

3.1 Regional capital stocks for plant

We begin by reporting the results for plant, which are plotted in Fig. 2. Evidently, 'inverted' convergence is taking place with the more prosperous central regions of the country (Center, Tel Aviv, Jerusalem, Sharon) leveling-up with respect to the traditionally capital intensive plant stocks existing in the periphery (North and South). This process is particularly pronounced over the 1990s and would seem to herald a break with the traditional focus of regional policy.

3.2 Regional capital stocks for machinery

Our starting point is the data published by the Bank of Israel for gross capital stocks disaggregated by plant and machinery for the country as a whole measured at constant price shekels. These data show (Fig. 3) that the ratio of machinery to plant (ρ) has risen throughout the period by about 20 percent, but has stabilized since 2001. This means that floor-space is being used more intensively and that machinery is being crammed into less space. Figure 3 also plots the imputed real price of floor-space (π),

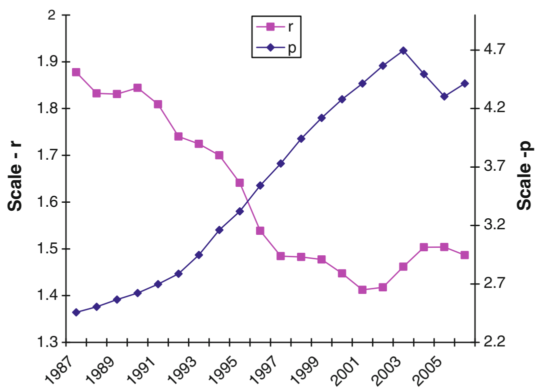

Fig. 3 Machinery–plant ratio (ρ) and the real price of plant (π) in Israel

which decreases by 26 percent during the period, but has stabilized since 2003. This suggests that the increase in the price of floor-space has created an incentive to cram machinery. Regressing ln ρ on ln π yields an estimate of β of -0.1973 ($R^2 = 0.9208$), suggesting that the elasticity of cramming with respect to the real price of floor-space is almost -0.2.

We use Eq. 3 to calculate the regional capital stocks for machinery measured at constant price shekels. Finally, we calculate the regional capital stocks at constant prices by converting the regional capital stocks for plant into constant price shekels and adding the result to the regional capital stocks for machinery measured in constant price shekels:

$$K_{jt} = P_{jt}\pi_t + K_{mjt} \tag{4}$$

Throughout the period the North had the most capital and the Krayot towns the least. The natural way to normalize these data is by employment, which we have calculated from micro-data in the Labor Force Surveys published by CBS. These capital–labor ratios are plotted in Fig. 4. What emerges is a picture of "inverted" sigma-convergence in capital–labor ratios. The variance in 2006 is visibly smaller than what it was in 1987. In 1987 the capital–labor ratio was smallest in the center of the country (Dan and Tel Aviv) and largest in the periphery (North and South), and the difference between them was 100 percent. Subsequently the capital–labor ratio in the periphery remained stable. Elsewhere capital–labor ratios increased, especially in the Sharon region. Indeed, by 2000 Sharon had the largest capital–labor ratio. The smallest capital–labor ratio in 2006 was in Haifa, having dropped for third place in 1987. The most accelerated growth in capital deepening took place over the 1990s corresponding to the national high-tech boom which saw the rapid expansion of demand for high-tech and business parks in the metropolitan area of Tel Aviv (Rehovot, Herzlia, Raanana).

As noted earlier, this type of sigma-convergence is "inverted" because the relatively affluent center of the country leveled-up with respect to the relatively poor periphery. This begs the question, why was the periphery relatively poor when it had the highest capital–labor ratio? In other words, why was the productivity of capital relatively low in the periphery? Our answer lies in the conduct of regional policy in Israel, which

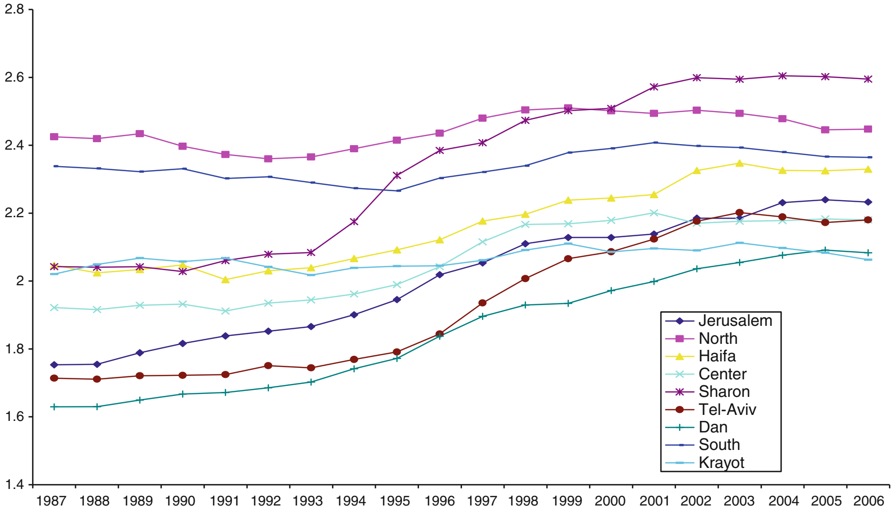

Fig. 4 Regional convergence in capital–labor ratios (logs), 1987–2006

prior to 1985, preferred capital investment in the periphery to investment in the center (Razin and Schwartz 1992; Bregman et al. 1998). During this period regional policy was designed to prevent depopulation in the periphery for strategic and not just economic reasons. However, investment in the periphery had a low return.

Following the Economic Stabilization Plan of 1985 regional policy, like other aspects of economic policy, underwent radical change. Greater emphasis was placed on market forces in trade policy, labor market policy, macroeconomic policy, and innovation policy. Wholesale support for investment in the periphery was abandoned in favor of more selective regional incentives such as R&D, high-tech and business incubator projects (Avnimelech et al. 2007; Trajtenberg 2001). Therefore, it is not surprising that periphery began to lose its head-start over the center.

3.3 Regional differences in the price of floor-space

We have already mentioned that there is evidence of capital cramming when the real price of floor-space increases. We also mentioned that Eq. (3) implicitly assumes that there are no regional differences in the real price of floor-space. Insofar as floor-space is relatively expensive we might have apportioned less machinery to the region. Unfortunately, there are no systematic data on industrial and commercial rents both nationally and regionally. It was for this reason that we ignored the issue. Anecdotal data on non-residential property prices supports the distinction between the extensive and intensive regional use of capital stock. For example, asking prices for industrial property lots in the Southern region (Kiryat Gat) and the Northern region (Haifa Bay) are between \$100–150,000 per lot. This represents only 20–25 percent of the asking price for similar lots in the Tel Aviv region (Holon) and Central Regions (Petach Tikva) where asking prices are \$500–550,000 (NATAM 2009).

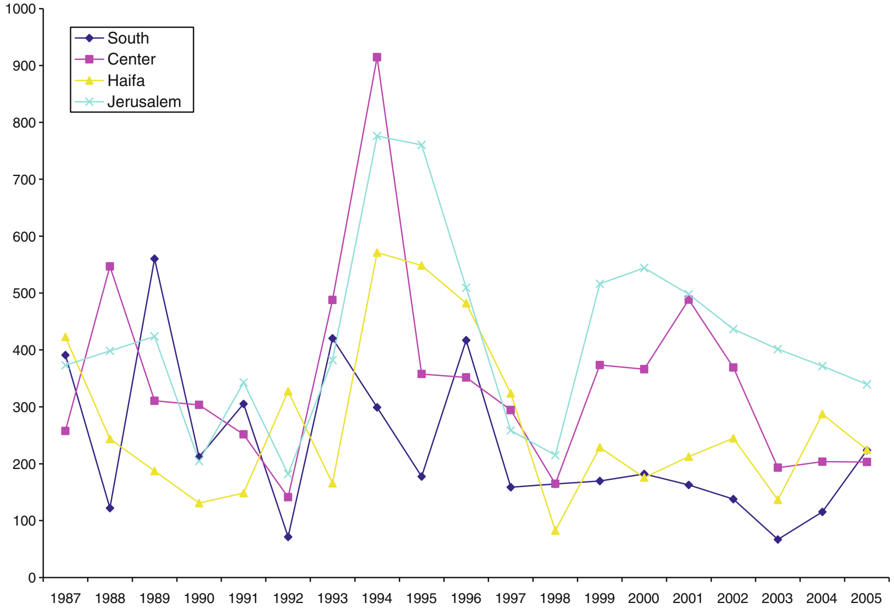

Fig. 5 Regional non-residential land prices (industrial, office and commercial); Israel land authority tenders 1987–2005 (m^2 in 1991 Shekel prices)

We have also obtained unpublished data on tender prices for industrial and commercial land auctioned by the Israel Land Authority, which we plot for four supra regions[6] in Fig. 5 during 1987–2005. We stress that these prices are not representative of prices in general because land auctioned by ILA was not necessarily representative of land as a whole in the regions concerned. Figure 5 shows that average annual non-residential land prices are consistently higher in the more central regions such as Jerusalem and Center than in the North and South. The average price per square meters (1991 prices) over the whole period was highest in Jerusalem (417 shekels) and lowest in the North (270 shekels) and the South (229 shekels). In the Central region prices (346 shekels) were intermediate. Figure 5 also shows that land prices are procyclical, peaking at the cyclical peaks of 1989, 1994, and 2000 and bottoming out at the troughs of 1992, 1998, and 2003.

4 Capital deepening and regional wage inequality

This section has a twofold purpose. Since we have constructed regional capital stocks independently of third variables, such as regional products and regional wages, we

6 These are the Northern region (covering Haifa, Krayot and the North), the Central region (incorporating the Center and Sharon regions), Jerusalem, and the Southern region. The ILA data cover nearly 1000 transactions over this period and represent only those tenders relating to publicly owned land held by the Israel Land Authority. Much of the land market activity in the central part of the country (Tel Aviv and Dan regions in particular) is privately owned and therefore these areas are not covered.

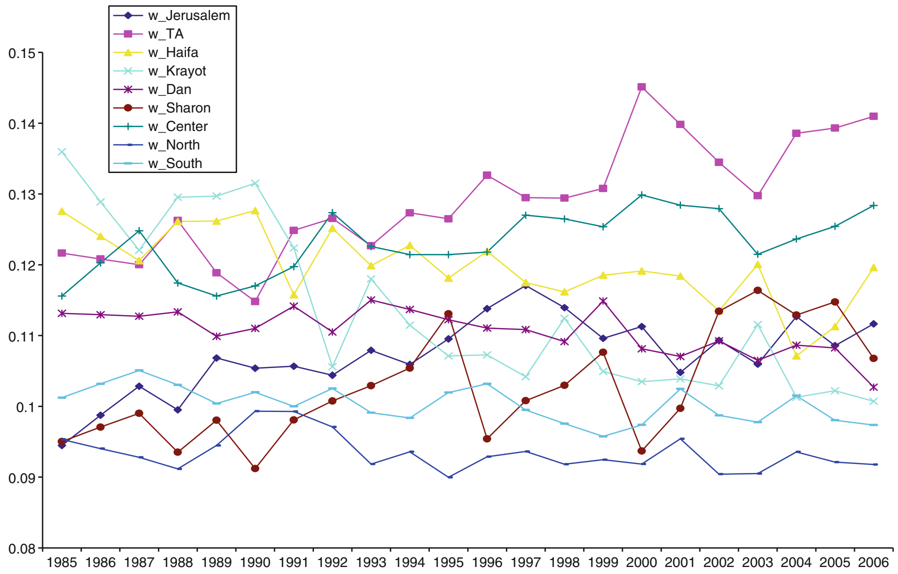

Fig. 6 Relative regional wages

check whether our capital stock estimates are in fact correlated with such variables. We regard this is a sort of validation test since it would be surprising, not to say disappointing, if it turned out that our capital stock estimates were independent of variables such as regional wages and product. Second, if our estimates are validated, what do they tell us about the affect of capital on regional inequality?

In Israel there are unfortunately no data on regional products, wages, employment, etc. Elsewhere (Beenstock and Felsenstein 2007b, 2008) we have explained how we constructed regional data for wages using the CBS's Household Income Surveys for the nine regions in our study. In Fig. 6 we plot wages in each region relative to the national average. This "spaghetti" graph shows, for example, that relative wages have increased in Tel Aviv and decreased in Krayot and Haifa. It also shows that relative wages have been stable and low in the North and South. Elsewhere (Beenstock and Felsenstein 2007b) we have commented that regional wages in Israel are characterized by "sigma-sclerosis". Indeed, this impression is conveyed visually by Fig. 6. However, the continued increase in relative wages in Tel Aviv may be beginning to break this mold.

We apply the same methodology to construct data for regional employment using the CBS's Labor Force Surveys. We have already used these data in Fig. 5 to construct regional capital–labor ratios. We use these data to investigate the statistical association between regional wages and capital–labor ratios. Unfortunately, we have been unable to construct regional products for Israel. Regional product is equal to regional wage income plus regional income from capital. We can construct the former using our constructed data for regional employment and regional wages. We can almost construct the latter using our newly constructed data on regional capital. To construct income from capital we also require data on regional profits, which we do not have at

Table 1 Panel Unit Root Tests

	IPS		CIPS	
	$d=0$	$d=1$	$d=0$	$d=1$
ln w	−1.392	−4.834	−1.257	−4.077
ln k	−0.644	−2.789	−1.205	−2.708
Schooling	−1.518	−6.067	−1.410	−4.702
Age	−3.015	−6.030	−2.755	−5.124
Males	−4.049	−7.106	−3.525	−6.088
Non_Jews	−3.151	−6.505	−2.952	−6.064
Immigrants	−2.049	−4.904	−2.384	−5.227

IPS, heterogeneous unit root test due to Im et al. (2003); *CIPS*, common factor counterpart due to Pesaran (2006); *schooling*, average years of education; *age*, average age. *males*, percent males in population; *non-Jews*, percent non-Jews in population; *immigrants*, percent of immigrants (less than 10 years in Israel) in population

this stage. Therefore, we are currently unable to investigate the relationship between regional capital and regional product.

4.1 Estimating the effect of capital deepening on regional wages

The main relationship that we investigate is

$$\ln w_{jt} = \alpha_j + \delta_t + \gamma \ln k_{jt} + \sum_{k=1}^{K} \theta_k x_{kjt} + u_{jt} \tag{5}$$

where w denotes regional wages deflated by national consumer prices, k denotes the capital–labor ratio, and the xs are a set of regional demographic or "Mincer" controls (regional averages for schooling, age, gender, etc.) that are hypothesized to determine wages apart from k. Since Eq. (5) is estimated using panel data econometrics, the α and δ coefficients are two-way fixed effects for the nine regions and 20 years of data. Finally, u denotes the residual error.

Table 1 shows that the panel data for wages, capital–labor ratios and schooling are clearly nonstationary, but are stationary in first differences. By contrast the demographic variables (age, males, etc. expressed as proportions of the population) are clearly stationary. Since w, k and schooling are nonstationary they might be spuriously correlated. Therefore, Eq. (5) has to be estimated using panel cointegration methods. If the estimated residuals are stationary, Eq. (5) is panel-cointegrated and the relationship between w, k and the xs is not spurious. Elsewhere (Beenstock and Felsenstein 2010) we discuss panel cointegration tests with nonstationary spatial panel data such as the present data.

If Eq. (5) is panel-cointegrated the parameter estimates are super-consistent, which means if k and the xs happened to be jointly determined with w, these variables

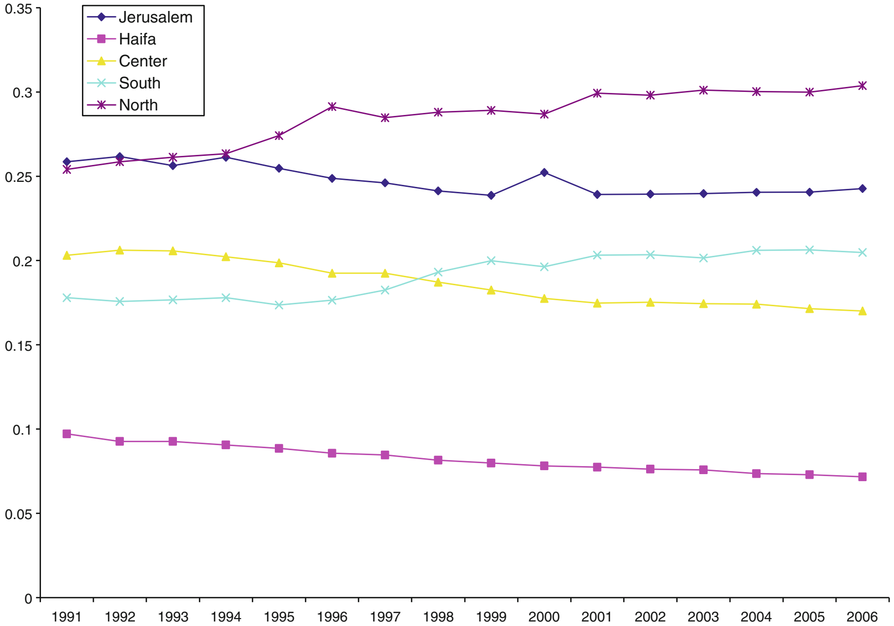

Fig. 7 Regional shares of human capital

are asymptotically independent of u.[7] Had the data been stationary this would have induced inconsistency in the parameter estimates and instrumental variables would have been necessary to identify the parameters. In our data, however, IVs are not required for consistency.

Before reporting our panel cointegration tests of Eq. (5) we mention that we have constructed regional data for the demographic controls (the xs in Eq. 5) using the same methodology for constructing regional data for employment and wages. In previous work (Beenstock and Felsenstein 2008) we used these controls with microdata on wages. Here, we use regional averages for these controls since w is defined as average earnings in the region. We have used the Labor Force Surveys to construct these regional averages. For example, Fig. 7 plots regional shares of human capital as measured by years of schooling.[8] For these purposes we have consolidated Haifa and the Krayot towns ("Haifa") and Tel Aviv, Center, Dan and Sharon ("Center"). Figure 7 shows that Jerusalem and the North have the largest shares of human capital, as measured by schooling, and Haifa the least. The main purpose of Fig. 7 is to show that just as regional shares of physical capital have behaved differentially, so have regional shares of human capital. The gainers have been the North and South while the losers have been the center and Haifa.

[7] For example, if $\ln k \sim I(1)$ and $u \sim I(0)\, p\lim(\ln ku) = 0$.

[8] The ratio of average years of schooling in the region to the national average weighted by regional population shares.

According to Eq. (5) regional wages should vary directly with the capital–labor ratio, which is confirmed by Fig. 8 without exception for all regions. Finally, we estimate Eq. (5) under different specifications, which differ in terms of the degree of heterogeneity. In the most heterogeneous case parameters such as γ and θ are assumed to vary by region in addition to regional fixed effects. At the other extreme, all the parameters are homogeneous and there are no fixed effects.

Results are reported in Table 2. Note that although we report standard errors in parentheses they cannot be used for t-tests because in nonstationary panel data the parameter estimates have non-standard distributions. Hypothesis testing of individual parameters is by cointegration testing. For example, to test the hypothesis that $\gamma = 0$ involves estimating the model with $\ln k$ included in the cointegrating vector. If omitting $\ln k$ from the cointegrating vector causes the model to cease to be cointegrated the hypothesis that $\gamma = 0$ may be rejected.

Model 1 in Table 2 is the most homogeneous case since it is estimated without fixed effects and there is no heterogeneity in the parameters. The panel cointegration test statistics indicate that the model is clearly cointegrated in which event the parameter estimates are not spurious. The coefficient on $\ln k$ is positive, as expected, but is rather low. It implies that the elasticity of real wages with respect to the capital–labor ratio is 0.107. Apart from this the demographic variables carry the usual signs. For example, the return to a year's schooling is 13 percent, which is perhaps on the high side. The coefficients on age and its square imply that wages peak at 40.7 years, which is quite usual. If the share of males increases by a percent, real wages increase by 0.2 percent. The opposite happens if the percentage of non-Jews increases by a percent. Finally, if the share of immigrants increases by a percent, regional wages decrease by 0.15 percent.

Since the demographic controls specified in Model 1 are stationary, the stationarity of the residuals must be due to the fact that the nonstationary variables in the models ($\ln w$, $\ln k$ and schooling) are cointegrated. Although this is an asymptotic claim, it turns out that these nonstationary variables are indeed cointegrated. If $\ln k$ is dropped from Model 1 the panel cointegration test statistics cease to be significant, which establishes that γ is significantly different from zero.

In Model 2 γ is assumed to be heterogeneous. The estimates of γ range between 0.25 in the North and 0.45 in Tel Aviv. However, the coefficients on males and non-Jews change signs. The test statistics for panel cointegration deteriorate sharply, but are statistically significant at conventional levels of significance. In Model 3 γ is assumed to be homogeneous, but regional fixed effects are specified. In this case, the elasticity of wages with respect to the capital labor ratio increases to 0.38, and the estimated return to schooling decreases to 9.8 percent. The coefficients on males and non-Jews remain contrary to expectations as in Model 2. The panel cointegration test statistics of Model 3 are the weakest of the three models, and are marginally insignificant.

4.2 Decomposing regional wage inequality

We use Model 1 in Table 2 to decompose regional wage inequality, where the latter is measured by the cross-section variance. The decomposition due to Eq. (5) is

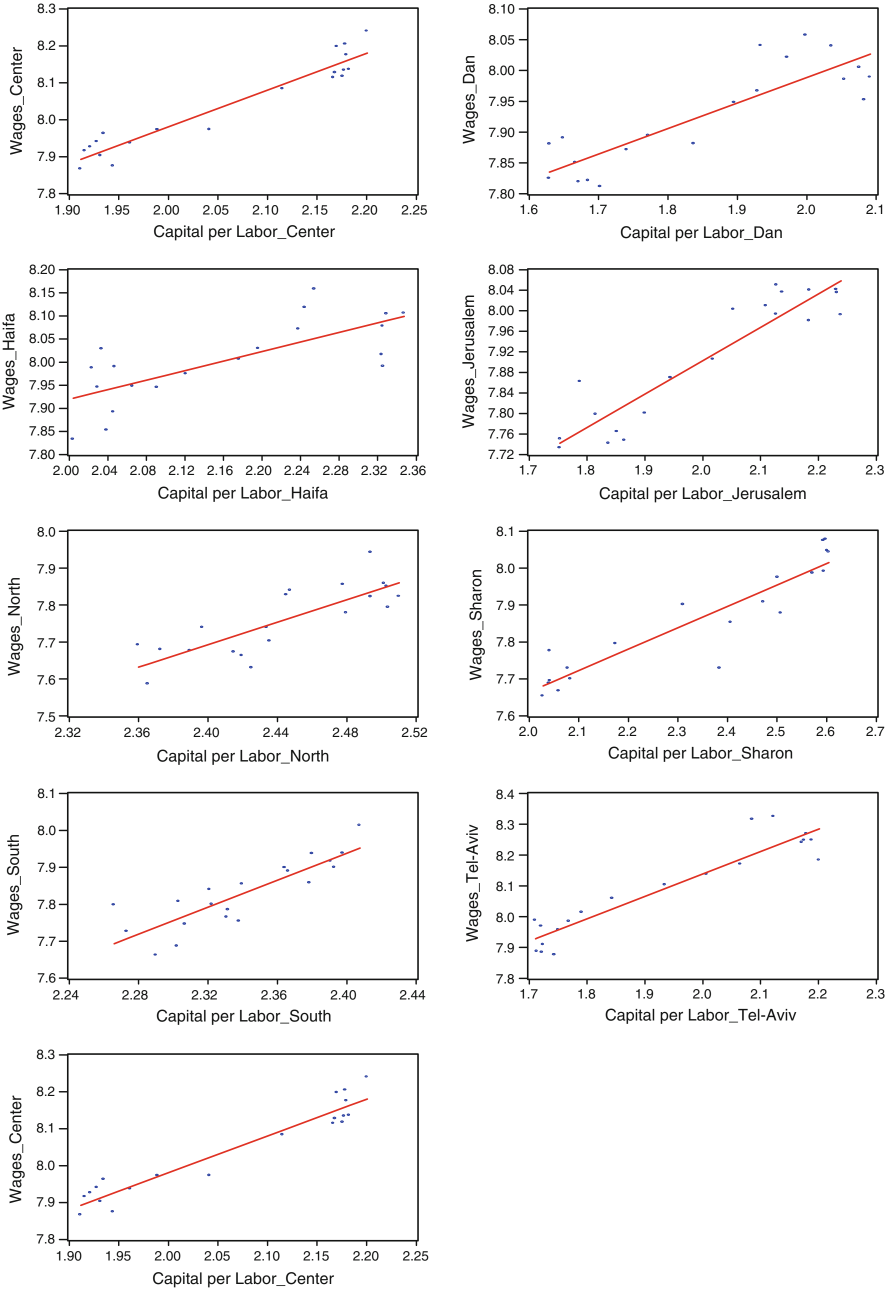

Fig. 8 Wages and capital–labor ratios by region

Table 2 Panel cointegration tests for Eq. (5)

Model	1	2	3
ln k	0.107 (0.021)	0.25−0.45	0.3769
Schooling	0.13 (0.005)	0.103 (0.0097)	0.0983 (0.00996)
Age	0.35 (0.155)	0.408 (0.173)	0.36327 (0.1756)
Age^2	−0.0043 (0.0019)	−0.0049 (0.0021)	−0.004 (0.0021)
Males	0.0022 (0.0013)	−0.0031 (0.0013)	−0.002 (0.0013)
Non-Jews	−0.0023 (0.00028)	0.00264 (0.0043)	0.0021 (0.0004)
Immigrants	−0.0015 (0.00048)	−0.00045 (0.00023)	−0.0004 (0.0004)
Fixed effects	No	No	Yes
Standard Error	0.064	0.05	0.049
R^2	0.998	0.999	0.969
t-bar	−0.9	−1.67	−1.8
Pedroni	−0.95	−1.48	−1.61

Dependent variable is ln w. Estimated by EGLS with SUR cross-section dependence. Standard errors of parameters in parentheses. Estimation period 1991–2006. t-bar is the average ADF statistic of the residuals. Pedroni is the Phillips-Perron cointegration test statistic suggested by Pedroni (2004) for spatial panel data

$$\mathrm{var}(\ln\ w)_t = \gamma^2\,\mathrm{var}(\ln\ k)_t + \sum_{k=1}^{K}\theta_k^2\,\mathrm{var}(x_k)_t + c_t + \mathrm{var}(\hat{u})_t \tag{6}$$

$$c = 2\sum_{k=1}^{K}\gamma\theta_k\,\mathrm{cov}(\ln\ k x_k) + \sum_{j}^{K}\sum_{h}^{K}\theta_k\theta_h\,\mathrm{cov}(x_k x_h) \tag{7}$$

Results are presented in Table 3 where regional wage inequality in 2006 is compared to what it was in 1991. The variance of regional wages more than doubled over the period from 0.0091 in 1991 to 0.0192, so that regional wages have been sigma-divergent. By contrast regional capital–labor ratios have been sigma-convergent. The variance of ln k in 2006 was half of what it was in 1991. So was schooling sigma-convergent. Furthermore, the residual variance was sigma convergent too; the residual variance in 2006 was half of what it was in 1991. If the residual measures regional total factor productivity, this would imply that regional TFPs sigma-converged during 1991–2006.

If all the drivers of regional wages were sigma-convergent, how could regional wages have been sigma-divergent? The answer lies in the covariance contribution defined in Eq. (7), which was sigma-divergent, and which increased from −0.196 to −0.182. Also, some of the demographic controls were slightly sigma-divergent.

5 Conclusions

This paper presents a hybrid methodology for estimating regional capital stocks. We use a direct method for estimating capital stocks for plant and a plant-derived

Table 3 Decomposing regional inequality

Variance	1991	2006
ln *k*	0.00065621	0.000352
Schooling	0.012436751	0.0074308
Age	0.091168376	0.091360
Age-squared	0.087859542	0.095657
Males	6.82691E−06	3.63226E−06
Non-Jews	0.000848695	0.00072
Immigrants	2.61073E−05	3.70551E−05
Residual	0.0112	0.0054
Covariance	−0.196	−0.182
Regional wage	0.0091	0.0192

'apportionist' approach for determining capital stocks for machinery. On this basis we construct regional capital stocks for Israel over the period 1986–2006. As a plausibility test for our regional estimates we calculate regional capital–labor ratios and relate these to regional wages. Charting capital–labor ratios over time reveals a pattern of 'inverted' convergence with the richer central regions of the country leveling-up with respect to the initially high capital–labor ratios of the poorer peripheral regions. We find that these capital–labor ratios are associated with regional wages in a plausible way.

We use panel cointegration methods to estimate regional wage functions in terms of capital–labor ratios as a measure of capital deepening, and schooling as a measure of deepening in human capital. Demographic controls are also taken into consideration. We find that despite sigma-convergence in the drivers of regional wage inequality, regional wages sigma-diverged and regional wage inequality doubled between 1991 and 2006. This apparent paradox is simply explained by the covariance component in wage inequality, which sigma-diverged over the period.

What is the significance of the observed regional redistribution of capital stock for regional policy in Israel? Traditionally, government assistance to industrial activity was intended to generate a more even spatial distribution of economic activity. In practice, the primary vehicle for executing this policy was capital assistance to low-tech production facilities in assisted areas. The upshot was high turnover rates of plants, unstable employment, and a revolving-door policy which generated large capital stocks in the periphery but failed to induce a growth dynamic (Schwartz and Keren 2006). Since the early 1990s the size of the capital assistance has slowly eroded and the map of assisted regions has constantly contracted. Hands-on government policy has been largely discredited and structural change in the Israeli economy has led to capital deepening in those sectors such as communications, business, and financial services, high tech, for which peripheral location is disadvantageous. To a certain extent, the capital-deepening observed in the central regions of the country and the inverted regional convergence in capital–labor ratios reflect the increasing redundancy of traditional regional policy.

References

Anderson WP, Rigby D (1989) Estimating capital stocks and capital ages in Canada's regions, 1961–1981. Reg Stud 23:117–126

Avnimelech G, Schwartz D, Bar-El R (2007) Entrepreneurial high-tech cluster: Israel's experience with venture capital and technological incubators. Eur Plan Stud 15(9):1181–1198

Beenstock M, Felsenstein D (2007a) Mobility and mean reversion in the dynamics of regional inequality. Int Reg Sci Rev 30(4):335–361

Beenstock M, Felsenstein D (2007b) Spatial vector autoregressions. Spatial Econ Anal 2(2):167–196

Beenstock M, Felsenstein D (2008) Regional heterogeneity, conditional convergence and regional inequality. Reg Stud 42(4):475–488

Beenstock M, Felsenstein D (2010) Spatial error correction and cointegration in nonstationary panel data: regional house prices in Israel. J Geogr Syst 12:189–206

Bradfield M, Dunn K (1998) Technical change and regional wage rates. Can J Reg Sci 5:243–284

Bregman A, Fuss M, Regev H (1998) The effects of capital subsidization on Israeli industry. NBER Working Paper # 6788

Chang SE (1997) Regional economic structure and capital investment in the built physical environment. Pap Reg Sci 76(4):385–407

Christopoulos D, Tsionas E (2004) Convergence and regional productivity differences: evidence from greek prefectures. Ann Reg Sci 38(3):387–396

Cummins J, Violante GL (2002) Investment-specific technical change in the United States (1947–2000): measurement and macroeconomic consequences. Rev Econ Dyn 5:243–284

Garofalo GA, Yamarik S (2002) Regional convergence: evidence from a new state by state capital stock series. Rev Econ Stat 84(2):316–323

Giese AS, Schnorbus R (1989) A new approach to regional capital sock estimation: measurement and performance. Working Paper Series, Federal Reserve Bank of Chicago

Gleed RH, Rees RD (1979) The derivation of regional capital stock estimates for UK manufacturing industries. 1951–1973. J R Stat Soc Ser A 142(3):330–346

Holtz-Eakin D (1993) State-specific estimates of state and local government capital. Reg Sci Urban Econ 23:185–209

Holtz-Eakin D (1994) Public-sector capital and the productivity puzzle. Rev Econ Stat 76(1):12–21

Hulten CR, Schwab RM (1984) Regional productivity growth in US manufacturing, 1951–1978. Am Econ Rev 74(1):152–162

Im K, Pesaran MH, Shin Y (2003) Testing for unit roots in heterogeneous panels. J Econ 115:53–74

Levtchenkova S, Petchey J (2000) Regional capital stock data for Australia. Aust Econ Rev 33(2):193–197

Melachroinos K, Spence N (2000) Constructing a manufacturing fixed capital stock series for the regions of Greece. Eur Plan Stud 8(1):43–67

Munnell AH (1990) How does public infrastructure affect regional economic performance? In: Munnell A (ed) Is there a shortfall in public capital investment? Federal Reserve Bank of Boston, Boston, pp 69–104

NATAM (2009) Industrial buildings report, No 24, NATAM- Colliers International, Tel Aviv

Pedroni P (2004) Panel cointegration: asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis. Econ Theory 20:597–625

Pesaran MH (2006) Estimation and inference in large heterogeneous panels with a multifactor error structure. Econometrica 74:967–1012

Pischke JS (2005) Labor market institutions, wages and investment: review and implications. CESifo Econ Stud 51:47–75

Razin E, Schwartz D (1992) An evaluation of Israel's industrial dispersal policy in the context of changing realities. Econ Q 153:236–276 (Hebrew)

Rickman D, Shao G, Treyz G (1993) Multiregional stock adjustment equations of residential and non-residential investment in structure. J Reg Sci 33:207–222

Rigby D (1995) Investment, capital stocks and age of capital in US Regions. Growth Change 25:524–552

Schwartz D, Keren M (2006) Locational incentives and the unintentional generation of employment instab-uility: some evidence from Israel. Ann Reg Sci 40(2):449–460

Trajtenberg M (2001) R&D policy in Israel: an overview and reassessment. In: Feldman MP, Link AN (eds) Innovation policy in the knowledge-based economy. Kluwer, Boston, pp 409–454

Varaiya P, Wiseman M (1981) Investment and employment in manufacturing in US metropolitan areas 1960–1976. Reg Sci Urban Econ 11:431–469

Weber WL, Domazlicky BR (2006) Capital deepening and manufacturing's contribution to regional economic convergence. J Reg Anal Policy 36(1):31–44

Wells M (1998) Some thoughts on the feasibility of state capital stock estimates, presented at the 94th Annual Meeting of the Association of American Geographers, Boston