The Spatial Impact of Local infrastructural Investment in New Zealand[1]

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Abstract

In this paper we estimate the impact of local authority infrastructure spending in New Zealand using spatial econometric modeling, with the infrastructure spending itself endogenously determined. Utilizing data from the New Zealand Census and Local Authorities Finance data (1991-2008), aggregated to functional labor market areas, we formulate a simultaneous equations growth model of real income, population, land rent and public infrastructure investment. Estimation is conducted using a spatial 3SLS procedure. We find that an increase in local infrastructure spending increases population growth, real income and land values, but is itself endogenous and spatially correlated.

JEL Codes: H54, J21, R12

Keyword(s): local infrastructure, economic growth, migration, land value, spatial spillover

1 Introduction

Public infrastructural investment has been widely used as a tool in regional economic development, motivated by the view that such infrastructure is an intermediate public good that plays an active role in the production process. It is expected that increasing the stock of public infrastructure in a region will improve the productivity of existing firms and induce new firms to locate in the region. Consequently, regional output and employment will grow (Lall, 2007). In an endogenous growth context, it is even possible that the region's long-run growth rate will increase. Meta-analyses of the empirical research does show that public expenditure on infrastructure benefits economic growth (Nijkamp and Poot, 2004; Bom and Lighthart, 2008). This is the case in at both the national and regional levels.

Given the magnitude of these investments and the policy emphasis on them as tools of regional development, the role of infrastructure in economic growth has been the subject of considerable research in the fields of public policy, economics, and planning, dating back to Nurske (1953) and Hirschman (1958). The past several decades have seen an intensification of this interest with numerous studies taking their lead from the work of Aschauer (1989) and Biehl (1986) in which infrastructure enters as an input in an aggregate production function.

The earlier studies in this tradition found a strong productive effect for public infrastructure. For example, Aschauer (1989), Reich (1991) and Deno (1988) all found that the return to private sector economic performance from public investment was greater than from private investment. However, more recent research has raised serious concerns around the robustness of these empirical results (see Sturm et al. (1998) for an overview of this literature). In terms of the specification of regression models that explain the contribution of public infrastructure to regional output, it has been found that, when regional and temporal fixed effects are introduced, the effects of public sector investment on private sector productivity and output are either markedly reduced or disappear completely (Holtz-Eakin,1994; Hulten & Schwab, 1991; Garcia-Mila & McGuire, 1992). Additionally, when the explicitly spatial context in which public infrastructural investment occurs is taken into account, the magnitude and significance of the estimated effect of that investment decreased as well (Kelejian & Robinson, 1997).

A number of possible avenues exist by which investment at one location may influence productivity and output at neighbouring locations. For instance;

- Public infrastructural investment in one region may induce mobile factors to move to that region to avail themselves of the improved infrastructural

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endowments. This mechanism suggests that the output of a region would depend positively on its stock of infrastructure and negatively on the stock of infrastructure in the surrounding regions.

- Conversely, public infrastructure – especially that related to transportation – may have a positive impact not only in the region where it is located but also on neighbouring regions due to the network characteristic of some infrastructure, in which any piece is subordinate to the entire network. For example, the building or expansion of a port or airport in one region may allow producers in neighbouring regions greater access to markets.
- In addition, the analysis of the effects of public infrastructural investment is usually carried out using data aggregated to administrative boundaries. These boundaries frequently reflect poorly functional economic areas or the networks that connect them. Linkages forward and backward are then not appropriately measured in the data and statistical spill-over effects result from this measurement problem.

One approach to measuring the spatially varying impacts of infrastructure is the spatial equilibrium approach suggested by Haughwout (2002), which has already been used to assess the impact of the Auckland northern motorway extension (see Grimes and Liang, 2010). This approach measures changes in land values at a highly disaggregated level, a mesh block.[1]

The approach that is adopted in the present paper complements this earlier research and considers the economic impact at a greater spatial level that is also of policy significance, namely that of the Labour Market Area (LMA) (defined below). This paper is therefore in the tradition of the macro-level impact studies cited above, but with the innovations of using spatial econometrics to measure interregional spill-over effects and the identification of the drivers of local public investment.

The paper is structured as follows: section 2 covers the theoretical framework, the specification of our model and the methodology used to perform the estimation. Section 3 discusses the data used in this paper along with outlining the rational for the use of LMA as the underlying spatial frame for the analysis. We also briefly outline how the boundaries of these areas were obtained. Section 4 reports first the results of the standard 3 stage least squares (3SLS) procedure to estimate the parameters of our model and then compares these results with those of a spatial 3SLS procedure. Section 5 discusses some extensions to our approach while Section 6 sums up.

[1] A mesh block is the smallest geographic unit for which statistical data is collected and processed by Statistics New Zealand. In urban areas it is about the size of a city block.

2 Model Specification and Methodology

The approach adopted here is to embed the impact of local infrastructure investment in a model of spatial equilibrium such as developed by, e.g., Roback (1982) and Haughwout (2002). Spatial variation in unemployment rates and labor force participation remain in the background. A simple extension of the Roback (1982) model suffices to motivate the empirical relationships that we anticipate.[2] In the Roback model, capital and workers are perfectly mobile. However, land availability and amenities are location specific. Following an exogenous shock, workers will migrate between regions until their utility is the same everywhere. Similarly, capital is moved across regions until the rate of return is the same everywhere. In the absence of differences in amenities across regions, wages and rents would be equal everywhere but, as Roback (1982) shows, different levels of amenities across regions will lead to spatial differences in wages and rents. Amenities may be fixed and natural, such as related to the climate, or varying such as positive or negative externalities associated with population density, or the amenities provided by local government.

In this paper we interpret local government-provided infrastructure as productive amenities. However, we will assume that the level of local infrastructure is endogenous. It is easy to show with the Roback model that an exogenous increase in productive amenities leads to higher rents, but an ambiguous effect on wages. What would drive such endogenous infrastructure investment? The simplest explanation is that most publicly provided services and infrastructure are congestible. Consequently, an increase in population would lead to a lower quality of public services and greater congestion, and possibly outward migration of residents, unless some infrastructure investment is undertaken. With endogenous infrastructure and local authorities being the third set of behavioural agents in the model, a third equilibrium condition (besides equal utility and equal unit production costs across space) must be imposed. A plausible condition would be a balanced budget for local government spending, with local infrastructural and other outlays funded by local taxes, usually in the form of a property tax.

If local infrastructure investment is endogenous and productive, wages are expected to increase as well. This is illustrated in Figure 1. A formal mathematical description is beyond the scope of this paper, but the impact of endogenous local authority spending illustrated in Figure 1. Consider a particular region in which the equilibrium land rent is r_1 and the wage is w_1. Following a positive productivity shock, the curve $C(w,r;s_1)$ that represents the wage/rent combinations that equalize unit costs across space will shift to the right, to $C'(w,r;s_1)$. Consequently, firms in the region will offer higher wages and rents will increase.

[2] See Moretti (2010) for a recent model of spatial equilibrium with heterogeneous labor and agglomeration.

However, with endogenous public infrastructure spending this is not the new equilibrium. The positive productivity shock leads to greater employment, which requires inward migration. To avoid a decline in the quality of public services, the local government responds with increasing public amenities from s_1 to s_2. This shifts the cost equalization curve from $C'(w,r;s_1)$ to $C'(w,r;s_2)$. At the same time, there are two influences on the curve $V(w,r;s_1)$ that represents wage/rent combinations with spatially equalized utility. The first is that the additional public spending is likely to have spill-over benefits for consumers (e.g., road infrastructure lowers travel times). This leads to a shift of V upwards. On the other hand, the local tax that needs to be raised lowers real disposable income, which shifts V to the right. The combined effect will be that the shift in V will be rather small, say between V^u and V^r, certainly smaller than the shift in C. The new equilibrium is somewhere along the bold segment in Figure 1.

The outcome as displayed in Figure 1 leads to the conclusion that a positive productivity shock unambiguously raises land rent in spatial equilibrium, further increases the population of the region through net inward migration, increases the level of public infrastructure investment, and finally increases wages as well. If the greater population subsequently enhances productivity growth further through agglomeration advantages (with the congestion externalities being partly offset by additional local government spending) a positive feedback loop has been created of self-reinforcing growth associated with inward migration.[3]

The simple endogenous processes described above suggest a growth model of four equations: one each for growth in public infrastructure capital, change in real income, population change, and lastly change in the real value of land.

In addition to accounting for a national period effect represented by a dummy variable (Period_dummy), the equation for growth in public infrastructure capital (Δ_Infrastructure) includes variables for the percentage change in real median income (Δ_Income), the percentage change in the usually resident population (Δ_Population), homeownership (%_Homeownership_1996), the interaction of the period dummy with homeownership (Period*Homeown) and the percentage change in estimated real land value (Δ_Landvalue). The last of these (Δ_Landvalue) is possibly of particular significance in the New Zealand context as nearly 60 percent of local services are funded from property taxes (McLuskey et al, 2006). On the other hand, local revaluations occur only three-yearly and property values are predominantly the means of determining the distribution of local property taxes across households rather than the absolute level.

The equation for change in real income per capita explains economic growth in terms of the growth in public infrastructure capital (Δ_Infrastructure), the percentage change in usually resident population (Δ_Population), the natural logarithm of median income at the beginning of the period (log_Income_1996), the interaction of the period dummy and the income variable (Period*Income), the local unemployment rate (%_Unemployed_1996), the interaction of the local unemployment rate and the period dummy (Period*Unemployed) and again a period effect (Period_dummy). In the presence of beta convergence in real income (e.g., Barro & Sala-i-Martin, 1992) we would expect a negative sign on the parameter estimate of the log of real income at the beginning of the period (log_Income_1996).

The variables growth in public infrastructure capital (Δ_Infrastructure), change in overseas born population (Δ_Overseas_Born),[4] industry mix (Industry_Mix), the natural logarithm of the median real income (log_Income_1996) the interaction of the period dummy and the income variables (Period*Income), the percentage unemployed (%_Unemployed_1996) the interaction of the local unemployment rate and the period dummy (Period*Unemployed) and the period dummy (Period_dummy) enter into the equation for population growth (Δ_Population). Our expectation would be that areas with high levels of migration, a favorable industry mix and high real incomes would experience high levels of population growth.

The equation for the percentage change in real land value consists of the variables for growth in public infrastructure capital (Δ_Infrastructure), the natural log of the estimated real land value at the beginning of the period (log_landvalue_1996), the interaction of the land value and the period dummy (period*landvalue) percentage change in usually resident population (Δ_Population) and the period dummy (period_dummy). While spatial differences in amenities will lead to persistent spatial differences in the value of land, on the long-run growth path there may be neoclassical convergence, in which case we expect a negative sign on the parameter estimate for the natural log of estimated real land value (log_landvalue_1996).

In a recent article Wu and Gopinath (2008) examine the causes of spatial disparities in economic development in the United States using a two-step procedure based on the general approach of Kelejian and Prucha (2004). Firstly a system of simultaneous equations, being structural equations of demand and supply in the labour and housing markets, is estimated using a 3SLS estimator, thus correcting for endogeneity and contemporaneous correlation. In the second step of the procedure the residuals from the

[3] A recent meta-analysis suggests that an increase in the rate of net internal migration by one percentage point, raises the rate of real income growth by 0.1 percentage points. This is consistent with the suggested self-reinforcing growth (Ozgen et al. 2009).

[4] International migration is proxied here by the five-yearly change in the percentage of overseas born persons in an LMA.

3SLS estimation were tested for spatial auto-correlation. If spatial auto-correlation is identified in an equation, the 3SLS residuals are used to estimate the spatial correlation parameter (ρ) by means of the generalised moment estimator suggested by Kelejian and Prucha (1999). The data are then transformed using the matrix $(I - \rho W)$ where I is a $N \times N$ identity matrix, N being the number of observations, and W a spatial weights matrix. Using the transformed data, each equation is then re-estimated using the ordinary least squares estimator (OLS).

In this paper we face a similar problem; the estimation of a system of equations representing the growth path of regional economies in the presence of spatial auto-correlation. We adopt a different approach from Wu and Gopinath (2008). Initially the four-equation growth model (one equation each for growth in public infrastructure capital, change in real income, population change and change in the real value of land) is estimated using standard 3SLS.[5] Obviously in performing this estimation we are confronted with significant problems arising from the endogenous determination of variables, such as homeownership, which must be addressed. One avenue for doing this might be to use beginning of period values (i.e. 1996 values for the 1996-2001 period and 2001 values for the 2001-2006 period). However, while this might be satisfactory for the first period (1996-2001) it is clearly not for the second as the values for 2001 would be endogenously determined with the 1996-2001 change variables. Instead for both time periods endogenous variables[6] are entered as their 1996 values and as their 1996 value interacted with the time period dummy.

The residuals of each of the estimated equations were then inspected for the presence of spatial autocorrelation. Where the residuals of a particular equation show a significant level of spatial autocorrelation, the spatial lag of the dependent variable was created. Next, the 3SLS was re-estimated with the inclusion of the spatially lagged variables in the relevant equations. The inclusion of the spatially lagged dependent variables in the 3SLS system can be seen as analogous to the use of the Spatial Autoregressive Regressive (SAR) model in the single equation context (see Lesage and Pace, 2009, pg 32-33).

All models were weighted by the LMA's usually resident population for the beginning of the period in question.[7]

3 Data and descriptives

The data used in this paper are drawn from a number of sources covering the two periods 1996-2001 and 2001-2006;

- The quinquennial New Zealand Census of Population and Dwellings,
- Motu's[8] Quotable Value New Zealand (QVNZ)[9] sales and valuation database,
- Motu's Regional and Local Authorities Finance databases,
- Statistical profiles of individual councils available from the Department of Internal Affairs at http://www.localcouncils.govt.nz/lgip.nsf.

These data were aggregated to Labor Market Areas (LMA) which were been built up from census area unit[10] (CAU) level and made available for this research by Motu Economic and Public Policy Research. It has long been recognized that functional economic areas are the most appropriate unit of analysis for examining regional economic activity (Stabler and Olfert, 1996, p. 206) as administrative areas such as Regional Council regions or territorial authorities tend to be rather arbitrary in terms of their boundaries in so far as they are reflective of economic relations. Administrative areas have largely served as the basis for most regional analysis in the past as most official statistics have been gathered or aggregated to administrative boundaries. These days, however, it is possible to build up regional data with any defined boundaries from very small geographical units of measurement, using GIS and related systems.

Consequently, there has been growth in the use of functional economic areas, notably in the analysis of various labor market phenomena (see, for instance, Casado-Diaz, 2000; Newell and Papps, 2001; ONS and Coombes, 1998). Newell and Papps (2001) used travel to work data from the 1991 and 2001 censuses to define LMAs in New Zealand. This research yielded 140 LMAs for 1991 and 106 for 2001. This level of breakdown is too refined for linking to regional characteristics that come from sources other than the census. A level of disaggregation that permits the building up of a regional analysis with a wide range of regional indicators is that of 58 LMAs. The boundaries and names of these LMAs are shown in Figure 2.

Turning to the derivation of the main dependent variables: Total additions to fixed capital in the LMA were estimated on the basis of reported Territorial

[5] All estimations were carried out in Stata 11 using either the reg3 command (3SLS), the spatreg command (invoking the spatial procedures provided by Maurizio Pisati) or the splagvar commands of P. Wilner Jeanty.

[6] Variables treated as endogenous include those for homeownership, population density, unemployment rate, median income level and land value.

[7] Analytical weights can be used with most Stata regression commands, but not with spatreg.

[8] Motu Economic and Public Policy Research is a non-profit New Zealand research institute engaged in economic and social research (see http://www.motu.org.nz/).

[9] QVNZ is New Zealand's largest valuation and property information company and focuses primarily on the provision of rating, taxation and valuation information (see http://www.qv.co.nz/aboutus/default.htm).

[10] Census area units are the second smallest geographic area used by Statistics New Zealand and are comprised of a number of mesh blocks. In urban areas they usually contain between 3000-5000 persons.

Authority (TA) and Regional Council (RC) additions to infrastructure capital, apportioned to their constituent CAU on the basis of population, then re-aggregated to the LMA level. It should be noted that estimates of fixed capital stocks of public infrastructure are unfortunately not available in New Zealand. Hence we only have information on additions to stocks of infrastructure capital rather than the stocks themselves.

Growth in infrastructural capital was assumed to be proportional to the investment ratio (I/Y*100). This ratio was calculated by dividing the sum of total additions to fixed capital in the LMA by Territorial Authorities (TA) and Regional Councils (RC) by LMA aggregate income. The latter was proxied by the mean personal income in the LMA multiplied by the usually resident population aged 15 years and over.

Figure 3 and figure 4 show the spatial distribution of growth in infrastructural capital for the 1996-2001 and 2001-2006 periods, respectively. The Moran's *I* statistic for both periods are positive and significant (I=0.156, p<.05), indicating the clustering of similar values of infrastructural growth. For the 1996-2001 period infrastructural capital growth rates range from about 1.5 percent (Hutt Valley) to 28 percent (Queenstown) while for the 2001-2006 period the range is similar, ranging from 1.7 percent (Hutt Valley) to 28 percent (Queenstown) with growth rates in the two periods being strongly correlated (r=.65, p <.01).

The percentage change in real median income (NZ$2006) was calculated from census data from the census mesh block data base aggregated to LMA boundaries for the 1996, 2001 and 2006 censuses. For the first period, 1996-2001, percentage change in real median income ranged from a decline of around 1 percent in Bulls to an increase of approximately 17 percent in Kaikohe while in the second period the percentage change in real median income ranged from just under 1 percent in Tokoroa to nearly 25 percent in Alexandra. The correlation in growth in median income between the two periods was insignificant. The Moran's *I* for the period was significant and positive (I=.168, p<.05) however for the second period *I* was not significant (I=.079, p>.1) indicating that in the latter period growth in real median income was geographically relatively uniformly distributed. Figures 5 and 6 show the spatial distribution of the percentage change in real median income for the two periods.

Percentage inter census change in usually resident population was again calculated on the basis of census counts aggregated to LMA boundaries. The spatial distribution of the percentage inter census change in usually resident population are shown in figures 7 and 8 for the 1996-2001 and 2001-2006 periods respectively. The Morans *I* for both periods were significant and positive (1996-2001, I=.212, p<.01; 2001-2006, I=.253, p<.001). For the first period population growth varied between a decline of nearly 14 percent in Taihape and an increase of 16 percent in Tauranga with over half (35) of the LMA experiencing population declines. In the second period population growth ranged between a decline of 5 percent in Eketahuna and an increase of nearly 30 percent in Queenstown with over a quarter of LMA experiencing population declines. Population growth between the two periods was highly correlated (r=.798, p<.05).

To obtain the percentage change in estimated real land value the land values were estimated by multiplying the CAU level mean sales price by the ratio of land valuation to capital valuation for each census year. The CAU estimates were then aggregated to LMA level, weighted by the number of dwellings in each CAU and converted to NZ$2006 dollars. The percentage change for the inter-census period was then calculated. In the first period percentage change in land values ranged from a decline of nearly 50 percent in Waipukurau to an increase of close to a 100 percent in Eketahuna. There was a moderate negative correlation between the percentage change in estimated real land value in the first and second periods (r=-.416, p<.05). In the second period the largest, and only, decline was that of Eketahuna (-14 percent) while in the MacKenzie LMA real land values increased by nearly 380 percent. Figures 9 and 10 shows the spatial distribution of percentage change in estimated real land value. The Morans *I* for both periods is significant and positive (1996-2001, I=.200, p<.01; 2001-2006, I=.129, p<.05) though *I* is considerably smaller in the second period.

Definitions for all variables used in this analysis can be seen in table 1 with their accompanying descriptive statistics shown in table 2.

The industry mix variable is the industry mix effect calculated by the classical shift share technique (Cochrane and Poot, 2008).

Finally before we turn to the results obtained in our estimation, we must consider the construction of the spatial weights matrix used to specify the spatial relation between LMAs. Although the selection of the spatial weights matrix is a crucial decision in a spatial econometric analysis, there exists unfortunately no clear cut means of deciding on which approach to use. It is mostly done in an ad hoc fashion governed primarily by convenience, convention and rules of thumb (Griffith, 1996, p 65).[11] The difficulties entailed in this decision are compounded also by the plethora of different specifications available. Getis and Aldstadt (2004) identified no fewer than eight commonly used methods and a wide range of lesser known ones, while Conley & Topa (2002) expand the number of possibilities to include non-spatial metrics.[12]

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11 Stetzer (1982) and Florax and Rey (1995) find that over-specification of the spatial weights matrix leads to a loss of statistical power while under-specification induces an increase in power in the presence of positive spatial auto correlation and a loss in power in the presence of negative spatial correlation. Both under- and over-specification produce an increase in the mean squared error for spatial econometric models (Griffith, 1996, p 66-67).

12 Getis and Aldstadt cite bandwidth distance decay, Gaussian distance decline and tri-cube distance decline

In this paper the weights matrix is constructed on the basis of the reciprocal of the squared travel time between the major urban centers of each LMA. The matrix takes a block diagonal form. Effectively, LMAs in one time period form an interacting block with no neighbors in another time period. Alternatively this can be interpreted as there being an infinite distance between any LMAs in a specific time period and all other LMAs at other points in time. Before carrying out the spatial regressions, the weights matrix has been row standardized.

4 Results

The results of the non-spatial 3SLS are presented in Table 3. Given that many of the variables used represent average outcomes for individuals and households within LMAs, such as the percentage of labour force that is unemployed, a control for heteroscedasticity was introduced by means of analytical weights that were equal to the population size of each LMA.

Two variables attain significance at the 5 percent level (with positive coefficients) in the growth in public infrastructure capital (Δ _Infrastructure) equation. The variable for percentage change in median income (Δ _Income) is significant, which suggests that that a growth in real income in a region leads to greater growth in public capital. Secondly, the percentage change in estimated real land value (Δ_Landvalue) is also significant, in line with the expected importance of land taxes (rates) in funding local infrastructural investment. The other variables are all statistically insignificant. It would seem that the spatial distribution of investment in public infrastructure is rather haphazard in New Zealand, possibly more determined by national and local political factors rather than conventional economic drivers.

In the change in real income (Δ _Income) equation the population change variable (Δ _Population) and the growth in public infrastructure capital (Δ _Infrastructure) variable are significant and positive. Infrastructure growth increases productivity and, consequently, real income as the work of Aschauer (1989) and other suggested. Moreover, population growth also provides a boost to real income growth, which is not consistent with the neoclassical growth model (in which population growth lowers growth in real income per head on the transition to the steady-state growth path), but which is consistent with a meta-analysis of findings in the recent international literature (Ozgen et al. 2009).

The equation which describes regional population growth in New Zealand performs well. Investment in public infrastructure (Δ _Infrastructure) positively affects population change as does, unsurprisingly, international migration (Δ _Overseas_Born), a favourable mix of industries (Industry_Mix), and the period income interaction term (Period*Income). In addition, the period unemployment interaction variable (Period*Unemployed) is also associated with high levels of population growth, perhaps due to the greater labour market churn in such areas. The period dummy is negative even though population growth in the latter period was more than in the earlier one (see Table 2). However, as the equation includes a term to capture the effects of international migration (Δ _Overseas_Born), this reflects the fact that natural increase in the population of New Zealand was relatively lower in the second period with overall population growth being driven by international migration.

Lastly the variable for investment in public infrastructure (Δ _Infrastructure) attains significance for the change in real value of land (Δ_Landvalue) equation, as does the interaction between the period dummy and the log of real land value in 1996 (Period*Landvalue) and the period dummy itself.

Table 4 shows the Moran's *I* statistics for the residuals from the non-spatial 3SLS. In all but the case of the equation for the inter census change in usually resident population Moran's *I* for the residuals of the non-spatial 3SLS estimation are positive and significant indicating[13] that spatial auto correlation is indeed a problem in this instance. Accordingly the 3SLS is re-estimated including spatial lags on the dependent variables in the growth in public infrastructure capital (Δ _Infrastructure), change in real income (Δ _Income) and change in real value of land (Δ_Landvalue) equations.

The results of the spatial 3SLS are shown in table 5 along with the along with the Moran's I statistics for the residuals (Table 6) while table 7 compares the results of the non-spatial and spatial 3SLS.

In the spatial growth in public infrastructure capital (Δ _Infrastructure) equation the percentage change in median income (Δ _Income) variable remains significant and positive though of a somewhat smaller magnitude. The estimated real land value (Δ_Landvalue) variable is, while still positive, no longer significant. In addition the spatial lag of the growth in public infrastructure capital (Δ _Infrastructure) is significant and positive indicating that growth in infrastructure spending in one region spending spills over into surrounding areas.

For the spatial change in real income (Δ _Income) equation the population change variable (Δ _Population) and the growth in public infrastructure capital (Δ _Infrastructure) variable remain significant and positive although the estimated parameter value is between a third and a quarter lower in the spatial 3SLS.

Turning to the regional population growth equation from the spatial 3SLS we find that the parameter estimates for public infrastructure (Δ _Infrastructure), international migration (Δ _Overseas_Born), industry

functions as examples. To this list should be added their own AMOEBA methodology (Getis & Aldstadt, 2004)

[13] Cliff and Ord (1981, p. 200-206) and Schabenberger and Gotway (2005, p. 314-315) discuss the problem of accessing spatial auto correlation in regression residuals using Moran's *I*.

mix (Industry_Mix), and the period income interaction term (Period*Income) all remain significant, positive and of similar magnitude to those obtained in the non-spatial 3SLS. The period dummy (Period_dummy) also remains significant, of a similar magnitude and retains a negative sign.

In the final equation of the system, the change in real value of land (Δ_Landvalue) equation, the interaction between the period dummy and the log of real land value in 1996 (Period*Landvalue) and the period dummy remain significant and of similar magnitude to the estimates obtained in the non-spatial 3SLS while the variable for investment in public infrastructure (Δ _Infrastructure) ceases to be significant.

Table 6 reports Moran's *I* for the residuals of the spatial 3SLS estimation. This indicates that the inclusion of the spatial lags in the growth in public infrastructure capital (Δ _Infrastructure), change in real income (Δ _Income) and change in real value of land (Δ_Landvalue) equations has reduced the impact of spatial auto correlation with none of the Moran's *I* for the 3SLS being significant.

5 Further developments

The approach taken to modelling spatial effects in this paper is founded on the Spatial Autoregressive SAR model in which spatial effects are modelled through the inclusion of a spatial lag on the independent variable as an explanatory variable (see Lesage and Pace, 2009, pg 32-33). An obvious extension to this approach is the inclusion of spatial lags of the explanatory variables as well as the dependent variable, the so called spatial Durbin Model (SDM). The spatial Durbin Model enjoys a number of advantages over SAR, Spatial Error Models (SEM) and possibly the general spatial model (SAC) in that it is able to produce unbiased coefficient estimates under a wider range of data generating processes and is less susceptible to omitted variable bias (Lesage and Pace, 2009, p. 157-158). Software to estimate the SDM through SUR is not available to us at present though this will change in the immediate future with the release of splm (Millo & Piras, 2009).

6 Conclusion

In this paper we estimated the impact of local authority infrastructure spending in New Zealand using spatial econometric modelling techniques. Both the spatial and non-spatial 3 SLS estimators told a similar story; that is that the spatial distribution of investment in public infrastructure is rather haphazard in New Zealand, possibly more determined by national and local political factors rather than conventional economic drivers. However, a growth in income generates more infrastructure. There is also significant spatial dependence in infrastructure with clear evidence that growth in infrastructural spending in an area spills over into surrounding regions.

The results are also supportive of endogenous (i.e., self-reinforcing growth) with real income growth being positively affected by infrastructure growth and population growth. The equation for population growth is consistent with theories of migration .

Finally, infrastructure investment does yield a productivity effect that is also reflected in land values. All in all, the Roback model is confirmed by these results.

References

Aschauer, D. (1989). Is Public Expenditure Productive? *Journal of Monetary Economics* 23(2): 177–200.

Barro, R. J., & Sala-i-Martin, X. (1992). Convergence. *Journal of Political Economy, 100*(2), 223–251.

Biehl, D. (ed.) (1986). The Contribution of Infrastructure to Regional Development. Final Report of the Infrastructure Studies Group to the Commission of the European Communities. Luxembourg: Office for Official Publications of the European Communities.

Bom, P. R., & Ligthart, J. (2008). How productive is public capital? a meta-analysis. *Unpublished paper, Tilburg University*.

Cliff, A. D., & Ord, J. K. (1981). Spatial processes: models and applications (Pion, London).

Cochrane, W., & Poot, J. (2008). Forces of Change: A Dynamic Shift-Share and Spatial Analysis of Employment Change in New Zealand Labour Markets Areas. *Studies in Regional Science 38*(1), 51–78.

Conley, T. G., & Topa, G. (2002). Socio-Economic Distance and Spatial Patterns in Unemployment. *Journal of Applied Econometrics, 17*(4).

Casado-Diaz, J. M. (2000). Local Labour Market Areas in Spain. *Regional Studies, 34*(9), 843-856.

Deno, K.T. (1988). The Effect of Public Capital on U.S. Manufacturing Activity: 1970 to 1978. *Southern Economic Journal* 55(1): 400–411.

Florax, R., & Rey, S. (1995). The impacts of misspecified spatial interaction in linear regression models. *New directions in spatial econometrics*, 111–135.

Garcia-Mila, T., & McGuire T.J. (1992). The Contribution of Publicly Provided Inputs to States' Economies. *Regional Science and Urban Economics* 22(2): 229–242.

Getis, A., & Aldstadt, J. (2004). Constructing the Spatial Weights Matrix Using a Local Statistic. *Geographical Analysis, 36*(2), 90-104.

Griffith, D. (1996). Some Guidelines for Specifying the Geographic Weights Matrix Contained in Spatial Statistical Models. In S. Arlinghaus (Ed.), *Practical Hand Book of Spatial Statistics* (pp. 65-82). Boca Raton: CRC Press.

Griffith, D. A. (2003). *Spatial autocorrelation and spatial filtering*. Springer.

Grimes, A & Liang, Y. 2010. “Bridge to Somewhere: Valuing Auckland’s Northern Motorway Extensions”, *Journal of Transport Economics and Policy*, forthcoming

Haughwout, A. (2002) Public Infrastructure Investments, Productivity and Welfare in Fixed Geographic Areas. *Journal of Public Economics* 83(3): 405-428.

Hirschman, A. (1958). *The Strategy of Economic Development*. Westview Press Inc.

Holtz-Eakin, D. (1994). Public-Sector Capital and the Productivity Puzzle. *Review of Economics and Statistics* 76(1): 12-21.

Hulten, C. R., & Schwab, R. M. (1991). Public Capital Formation and the Growth of Regional Manufacturing Industries. *National Tax Journal* 44(4): 121–134.

Kelejian, H.H. & Robinson, D.P. (1997). Infrastructure Productivity Estimation and its Underlying Econometric Specifications: a Sensitivity Analysis. *Papers in Regional Science* 76: 115–131

Kelejian, H.H., and I.R. Prucha. 1999. “A Generalized Moments Estimator for the Autoregressive Parameter in a Spatial Model.” *International Economic Review* 40:509–33.

Kelejian, H. H., & Prucha, I. R. (2004). Estimation of Simultaneous Systems of Spatially Interrelated Cross Sectional Equations. *Journal of Econometrics, 118*, 27–50.

Lall, S. (2007). Infrastructure and Regional Growth, Growth Dynamics and Policy Relevance for India. *Annals of Regional Science* 41(3): 581-599.

LeSage, J. P., & Pace, R. K. (2009). *Introduction to spatial econometrics*. Chapman & Hall/CRC.

McLuskey, W., Aitken, A,. Grimes, A,. Kerr , S,. & Timmins, J,. 2006. "Rating Systems in New Zealand: An Empirical Investigation into Local Choice," *Journal of Real Estate Literature,* 14:3, pp. 381-397.

Millo, G., & Piras, G. (2009). splm: econometric analysis of spatial panel data. Presented at the useR!, Rennes.

Moretti, E. (2010) Local Labor Markets. IZA DP 4905. Bonn: IZA Institute for the Study of Labor.

Newell, J.O., & Papps, K.L. (2001). *Identifying Functional Labour Market Areas in New Zealand: A Reconnaissance Study using Travel-to-Work Data* (New Zealand Department of Labour Occasional Paper Series No. 2001/6). Wellington: Department of Labour.

Nijkamp, P. and Poot, J. (2004). Meta-Analysis of the Impact of Fiscal Policies on Long-Run Growth. *European Journal of Political Economy* 20(1): 91-124.

Nurske, R. (1953). *Problems of Capital Formation in Underdeveloped Countries*. Basil Blackwell.

ONS, & Coombes, M. G. (1998). *1991- Travel to Work Areas*. London: Office for National Statistics.

Ozgen, C., Nijkamp, P. and Poot, J. (2009) The Effect of Migration on Income Growth and Convergence: Meta-Analytic Evidence. IZA DP No. 4522, IZA Institute for the Study of Labor, Bonn.

Roback, J. 1982. “Wages, Rents, and the Quality of Life.” *Journal of Political Economy* 90:1257–78.

Reich, R. (1991). The Real Economy. *The Atlantic Monthly* 267(2): 35–52.

Schabenberger, O., & Gotway, C. A. (2005). *Statistical methods for spatial data analysis*. CRC Press.

Stetzer, F. (1982) "Specifying Weights in Spatial forecasting Models: The Results of Some Experiments", *Environment and Planning A* 14, 571-584.

Stabler, J. C., & Olfert, M. R. (1996). Spatial Labor Markets and the Rural Labor Force. *Growth & Change, 27*(2), 206-230.

Sturm, J.-E., Kuper, G.H., & J. De Haan (1998) Modelling Government Investment and Economic Growth on a Macro Level: A Review. In: S. Brakman, H. Vanes, and S.K. Kuipers (Eds.), *Market Behaviour and Macroeconomic Modelling*. London: MacMillan, pp. 359–406.

Wu, J. J., & Gopinath, M. (2008). What Causes Spatial Variations in Economic Development in the United States? *American Journal of Agricultural Economics*, *90*(2), 392–408

Table 1 Variable Definitions

Variable Name	Definition
%_Degree_Plus	Percentage with Bachelors degree or better
%_Homeownership _1996	Percent Home ownership
%_Maori	Percentage Maori
%_Professionals	Percentage in professional occupations
%_Smokers_1996	Percentage smokers 1996
%_Unemployed_1996	Percentage of labour force that is unemployed in 1996
Dependency_Ratio	Demographic dependency ratio ((0-14 plus 65+) / (15-64))
Industry_Mix	Industry mix effect
Km_to_Auckland	Distance to Auckland (Km)
log_Income_1996	Natural logarithm of real median income $2006
log_Landvalue_1996	Natural log of estimated real land value $2006 (see following slide)
Period*Homeown	Interaction of %_Homeownership and the period dummy
Period*Income	Interaction of log_Income_1996 and the period dummy
Period*Landvalue	Interaction of log_Landvalue_1996 and the period dummy
Period*Population_Density	Interaction of Population_density and the period dummy
Period*Unemployed	Interaction of %_Unemployed_1996 and the period dummy
Period_dummy	0=1996-2001, 1=2001-2006
Population_density	LMA population density (population per km2)
Rainfall	Rainfall (ml) largest urban area in LMA (20 yr average)
Δ _Income	Change in real median income (percent)
Δ _Infrastructure	Estimated growth in infrastructure capital (see following slide)
Δ _Overseas_Born	Change in overseas born population (percent)
Δ _Population	Percentage change in usually resident population over the inter census period
Δ_Landvalue	Change in estimated real land value (percent)

Table 2 Descriptive statistics by period*

	Period beginning 1996				Period beginning 2001			
	mean	**sd**	**min**	**max**	**mean**	**sd**	**min**	**max**
%_Degree_Plus	9.44	4.79	3.21	21.46	11.59	5.3	3.83	23.8
%_Maori	13.64	7.99	4.51	52.59	13.41	8.13	4.39	55.42
%_Professionals	22.44	5.34	9.77	33.87	24.74	5.96	10.49	36.65
%_Smokers_1996	23.83	3.12	20.5	37.05	23.75	3.08	20.5	37.05
%_Unemployed_1996	7.81	1.89	2.37	18.87	7.8	1.86	2.37	18.87
Dependency_Ratio	53.35	6.29	34.21	69.84	53.52	6.76	35.48	71.12
Homeownership	70.54	3.33	51.97	79.24	70.51	3.28	51.97	79.24
Industry_Mix	-0.06	1.84	-5.71	3.42	-0.07	2.52	-7.82	3.62
Km_to_Auckland	474.13	482.5	1	1638	461.05	479.06	1	1638
log_Income_1996	9.94	0.11	9.47	10.15	9.94	0.11	9.47	10.15
log_Landvalue_1996	11.03	0.68	8.89	12	11.06	0.67	8.89	12
Period dummy	0.000	0.000	0.000	0.000	1	0	1	1
Period*Homeown	0.000	0.000	0.000	0.000	70.51	3.28	51.97	79.24
Period*Income	0.000	0.000	0.000	0.000	9.94	0.11	9.47	10.15
Period*Landvalue	0.000	0.000	0.000	0.000	11.06	0.67	8.89	12
Period*Population_Density	0.000	0.000	0.000	0.000	64.33	85.49	0.45	321.25
Period*Unemployed	0.000	0.000	0.000	0.000	7.8	1.86	2.37	18.87
Population_density	63.09	85.23	0.45	321.25	64.33	85.49	0.45	321.25
Rainfall	1123.02	293.89	360	2430	1124.78	289.7	360	2430
Δ _Income	5.85	2.29	-0.71	16.94	11.59	3.02	0.75	24.52
Δ _Infrastructure	8.21	2.59	1.45	28.05	9.69	3.01	1.7	27.54
Δ_Landvalue	15.64	18.51	-47.61	96.32	95.91	43.11	-13.97	376.07
Δ_Overseas_Born	12.39	9.46	-10.9	38.73	24.53	9.39	-2.37	69.34
Δ _Population	3.29	5.43	-13.52	16.44	7.78	5.21	-5.2	28.99

*Weighted by LMA usually resident population at commencement of period

Table 3 Non-Spatial 3SLS

Equation	Obs	Parms	RMSE	R-sq	chi2	P
Estimated growth in infrastructure capital	116	6	2.81	0.051	52.44	.000
Change in real median income	116	7	2.75	0.506	214.17	.000
Inter census change in usually resident population	116	8	2.14	0.861	800.87	.000
Change in estimated real land value	116	5	26.839	0.734	317.51	.000

	Coef.	Std. Err.	z	P>z	[95% Conf. Interval]	
Estimated growth in infrastructure capital						
Δ_Income	0.628	0.125	5.010	0.000	0.383	0.874
Δ_Population	0.037	0.057	0.640	0.519	-0.075	0.149
%_Homeownership_1996	0.078	0.091	0.850	0.394	-0.101	0.256
Period*Homeown	-0.050	0.127	-0.400	0.692	-0.300	0.199
Δ_Landvalue	0.026	0.011	2.290	0.022	0.004	0.048
Period_dummy	-0.807	8.914	-0.090	0.928	-18.278	16.664
Constant	-1.469	6.585	-0.220	0.823	-14.375	11.437
Change in real median income						
Δ_Infrastructure	0.610	0.162	3.760	0.000	0.292	0.928
Δ_Population	0.137	0.064	2.130	0.033	0.011	0.263
log_Income_1996	2.031	3.593	0.570	0.572	-5.012	9.074
Period*Income	-5.531	4.354	-1.270	0.204	-14.064	3.003
%_Unemployed_1996	0.004	0.176	0.020	0.981	-0.340	0.348
Period*Unemployed	-0.200	0.243	-0.820	0.412	-0.677	0.277
Period_dummy	60.755	44.197	1.370	0.169	-25.868	147.379
Constant	-19.830	36.955	-0.540	0.592	-92.261	52.602
Inter census change in usually resident population						
Δ_Infrastructure	0.519	0.139	3.730	0.000	0.246	0.792
Δ_Overseas_Born	0.414	0.027	15.560	0.000	0.362	0.466
Industry_Mix	0.474	0.130	3.660	0.000	0.220	0.729
log_Income_1996	5.284	3.421	1.540	0.122	-1.420	11.988
Period*income	13.119	3.978	3.300	0.001	5.323	20.915
%_Unemployed_1996	0.224	0.164	1.370	0.170	-0.096	0.545
Period*Unemployed	0.628	0.227	2.770	0.006	0.183	1.072
Period_dummy	-136.599	40.415	-3.380	0.001	-215.811	-57.388
Constant	-60.335	34.971	-1.730	0.084	-128.876	8.206
Change in estimated real land value						
Δ_Infrastructure	4.140	1.386	2.990	0.003	1.423	6.858
Log_Landvalue_1996	1.024	8.161	0.130	0.900	-14.971	17.020
Period*Landvalue	-35.812	7.340	-4.880	0.000	-50.197	-21.427
Δ_Population	-0.020	1.001	-0.020	0.984	-1.982	1.942
Period_dummy	470.428	81.592	5.770	0.000	310.510	630.346
Constant	-29.593	90.221	-0.330	0.743	-206.423	147.237

Endogenous variables: Δ _Infrastructure, Δ _Income, Δ _Population, Δ_Landvalue
Exogenous variables: %_Homeownership _1996, Period*Homeown, Period_dummy, lag_log_Income_1996, log_Income_1996, Period*Income, %_Unemployed_1996 , Period*Unemployed, Industry mix effect, lag_log_Landvalue_1996, log_Landvalue_1996, Period*Landvalue, %_Maori Rainfall, %_Professionals, %_Degree_Plus, %_Smokers_1996, Km_to_Auckland, Population_density, Period*Population_Density, Dependency_Ratio, Δ_Overseas_Born

Table 4
Moran's I

Variables	I	E(I)	sd(I)	z	p-value*
Estimated growth in infrastructure capital	0.107	-0.009	0.060	1.921	0.027
Change in real median income	0.093	-0.009	0.061	1.663	0.048
Inter census change in usually resident population	0.061	-0.009	0.061	1.140	0.127
Change in estimated real land value	0.107	-0.009	0.060	1.908	0.028

Table 5 Spatial 3SLS

Equation	Obs	Parm	RMS	R-sq	chi2	P
Estimated growth in infrastructure capital	116	7	2.570	0.205	54.42	.000
Change in real median income	116	8	2.547	0.577	210.24	.000
Inter census change in usually resident population	116	8	2.131	0.862	807.85	.000
Change in estimated real land value	116	6	26.772	0.735	312.51	.000

	Coef.	Std. Err.	z	P>z	[95% Conf. Interval]	
Estimated growth in infrastructure capital						
Lag_Δ_Infrastructure	0.415	0.128	3.250	0.001	0.165	0.666
Δ_Income	0.490	0.125	3.920	0.000	0.245	0.736
Δ_Population	0.016	0.057	0.280	0.781	-0.095	0.127
%_Homeownership_1996	0.024	0.094	0.250	0.800	-0.160	0.208
Period*Homeown	-0.029	0.131	-0.220	0.826	-0.285	0.228
Δ_Landvalue	0.016	0.011	1.420	0.154	-0.006	0.038
Period_dummy	-1.540	9.125	-0.170	0.866	-19.425	16.345
Constant	0.065	6.703	0.010	0.992	-13.072	13.202
Change in real median income						
Lag_Δ_Income	0.076	0.141	0.540	0.590	-0.200	0.351
Δ_Infrastructure	0.430	0.163	2.630	0.009	0.109	0.750
Δ_Population	**0.157**	**0.064**	**2.440**	**0.015**	**0.031**	**0.284**
log_Income_1996	2.504	3.697	0.680	0.498	-4.743	9.751
Period*Income	-7.371	4.456	-1.650	0.098	-16.105	1.364
%_Unemployed_1996	-0.019	0.182	-0.110	0.915	-0.376	0.337
Period*Unemployed	-0.205	0.254	-0.810	0.420	-0.702	0.293
Period_dummy	78.865	45.205	1.740	0.081	-9.736	167.466
Constant	-23.388	37.995	-0.620	0.538	-97.857	51.080
Inter censusal change in usually resident population						
Δ_Infrastructure	0.515	0.134	3.850	0.000	0.253	0.776
Δ_Overseas_Born	0.412	0.026	15.700	0.000	0.361	0.464
Industry_Mix	0.490	0.129	3.790	0.000	0.237	0.744
log_Income_1996	5.440	3.390	1.600	0.109	-1.205	12.084
Period*Income	12.971	3.963	3.270	0.001	5.204	20.739
%_Unemployed_1996	0.217	0.163	1.330	0.183	-0.102	0.536
Period*Unemployed	0.629	0.226	2.780	0.005	0.186	1.072
Period_dummy	-135.114	40.273	-3.350	0.001	-214.048	-56.179
Constant	-61.764	34.639	-1.780	0.075	-129.655	6.127
Change in estimated real land value						
Lag_Δ_Landvalue	0.064	0.115	0.550	0.579	-0.161	0.289
Δ_Infrastructure	2.179	1.418	1.540	0.125	-0.602	4.959
log_Landvalue_1996	-0.498	8.502	-0.060	0.953	-17.162	16.165
Period*Landvalue	-36.918	8.456	-4.370	0.000	-53.491	-20.345
Δ_Population	0.426	1.020	0.420	0.677	-1.574	2.425
Period_dummy	477.405	99.404	4.800	0.000	282.576	672.234
Constant	0.539	93.937	0.010	0.995	-183.574	184.653

Endogenous variables: Δ _Infrastructure, Δ _Income, Δ _Population, Δ_Landvalue
Exogenous variables: lag_infrastructure, %_Homeownership _1996, Period*Homeown, Period_dummy, lag_log_Income_1996, log_Income_1996, Period*Income , %_Unemployed_1996 Period*Unemployed, Industry mix effect, lag_log_Landvalue_1996, log_Landvalue_1996, Period*Landvalue , %_Maori, Rainfall, %_Professionals, %_Degree_Plus, %_Smokers_1996, Km_to_Auckland, Population_density, Period*Population_Density, Dependency_Ratio, Δ_Overseas_Born

Table 6
Moran's I

Variables	**I**	**E(I)**	**sd(I)**	**z**	**p-value***
Estimated growth in infrastructure capital	0.012	-0.009	0.06	0.337	0.368
Change in real median income	0.070	-0.009	0.061	1.288	0.099
Inter census change in usually resident population	0.061	-0.009	0.061	1.136	0.128
Change in estimated real land value	0.083	-0.009	0.06	1.519	0.064

Table 7 Comparison of Non-Spatial and Spatial 3SLS

	Non Spatial 3SLS		Spatial 3SLS	
Equation	**R-sq**	**P**	**R-sq**	**P**
Estimated growth in infrastructure capital	0.051	0.000	0.205	0.000
Change in real median income	0.506	0.000	0.577	0.000
Inter census change in usually resident population	0.861	0.000	0.862	0.000
Change in estimated real land value	0.734	0.000	0.735	0.000
Estimated growth in infrastructure capital				
	Coef.	**P>z**	**Coef.**	**P>z**
Lag_ Δ_Infrastructure			0.415	0.001
Δ_Income	0.628	0.000	0.490	0.000
Δ_Population	0.037	0.519	0.016	0.781
%_Homeownership_1996	0.078	0.394	0.024	0.800
Period*Homeown	-0.050	0.692	-0.029	0.826
Δ_Landvalue	0.026	0.022	0.016	0.154
Period_dummy	-0.807	0.928	-1.540	0.866
Constant	-1.469	0.823	0.065	0.992
Change in real median income				
			0.076	0.590
Δ_Infrastructure	0.610	0.000	0.430	0.009
Δ_Population	0.137	0.033	0.157	0.015
log_Income_1996	2.031	0.572	2.504	0.498
Period*Income	-5.531	0.204	-7.371	0.098
%_Unemployed_1996	0.004	0.981	-0.019	0.915
Period*Unemployed	-0.200	0.412	-0.205	0.420
Period_dummy	60.755	0.169	78.865	0.081
Constant	-19.830	0.592	-23.388	0.538
Inter census change in usually resident population				
Δ_Infrastructure	0.519	0.000	0.515	0.000
Δ_Overseas_Born	0.414	0.000	0.412	0.000
Industry_Mix	0.474	0.000	0.490	0.000
log_Income_1996	5.284	0.122	5.440	0.109
Period*income	13.119	0.001	12.971	0.001
%_Unemployed_1996	0.224	0.170	0.217	0.183
Period*Unemployed	0.628	0.006	0.629	0.005
Period_dummy	-136.599	0.001	-135.114	0.001
Constant		0.084	-61.764	0.075
Change in estimated real land value				
Lag_Δ_Landvalue			0.064	0.579
Δ_Infrastructure	4.140	0.003	2.179	0.125
Log_Landvalue_1996	1.024	0.900	-0.498	0.953
Period*Landvalue	-35.812	0.000	-36.918	0.000
Δ_Population	-0.020	0.984	0.426	0.677
Period_dummy	470.428	0.000	477.405	0.000
Constant	-29.593	0.743	0.539	0.995

Figure 1 The Roback model with endogenous local authority spending

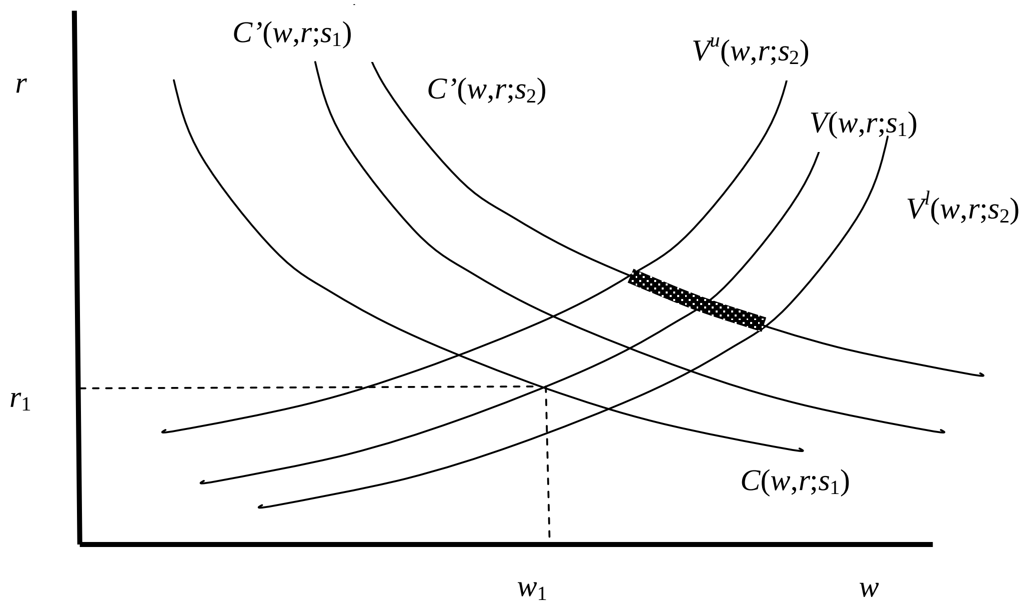


Figure 2 New Zealand Labour Market Areas

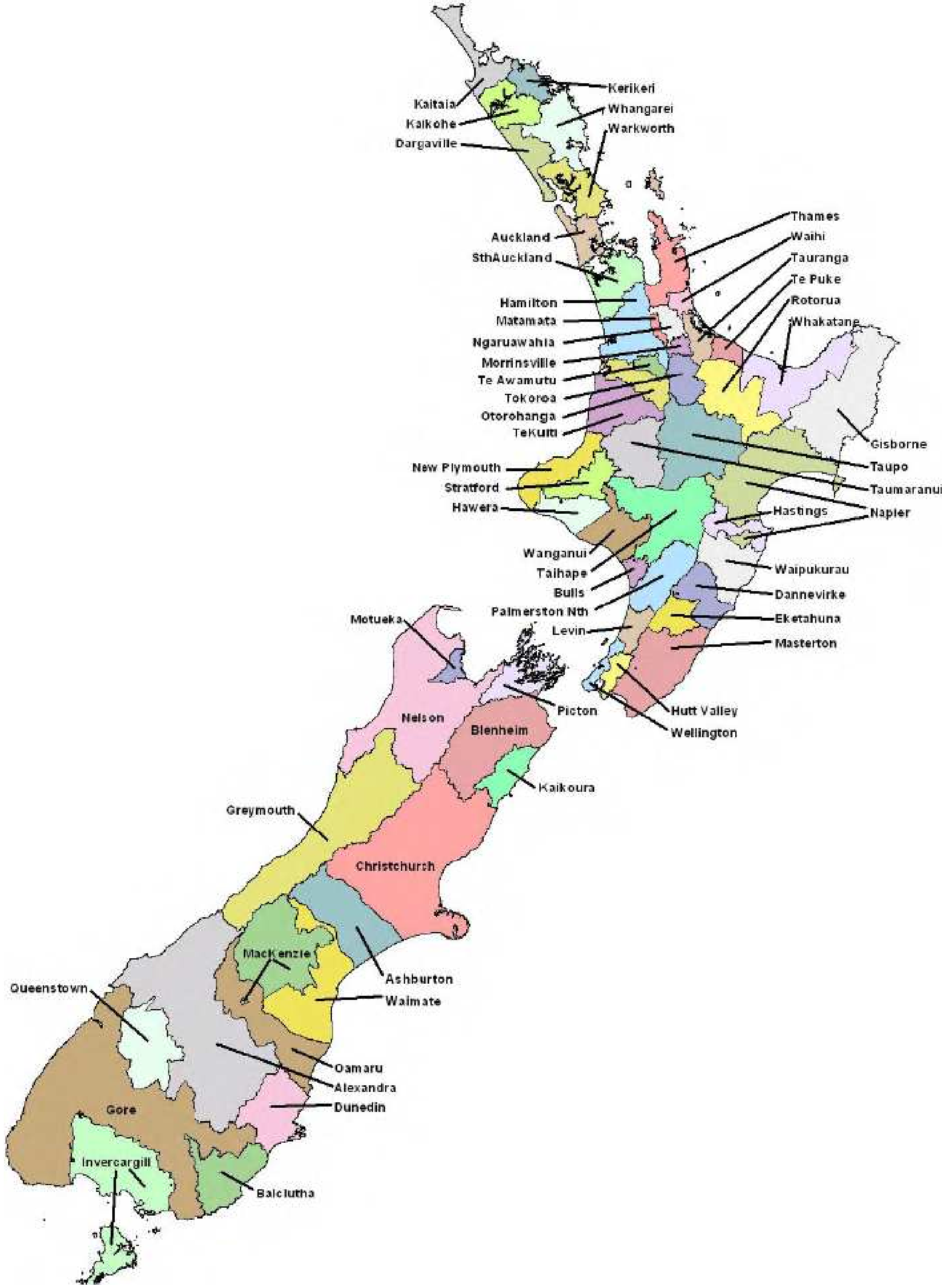
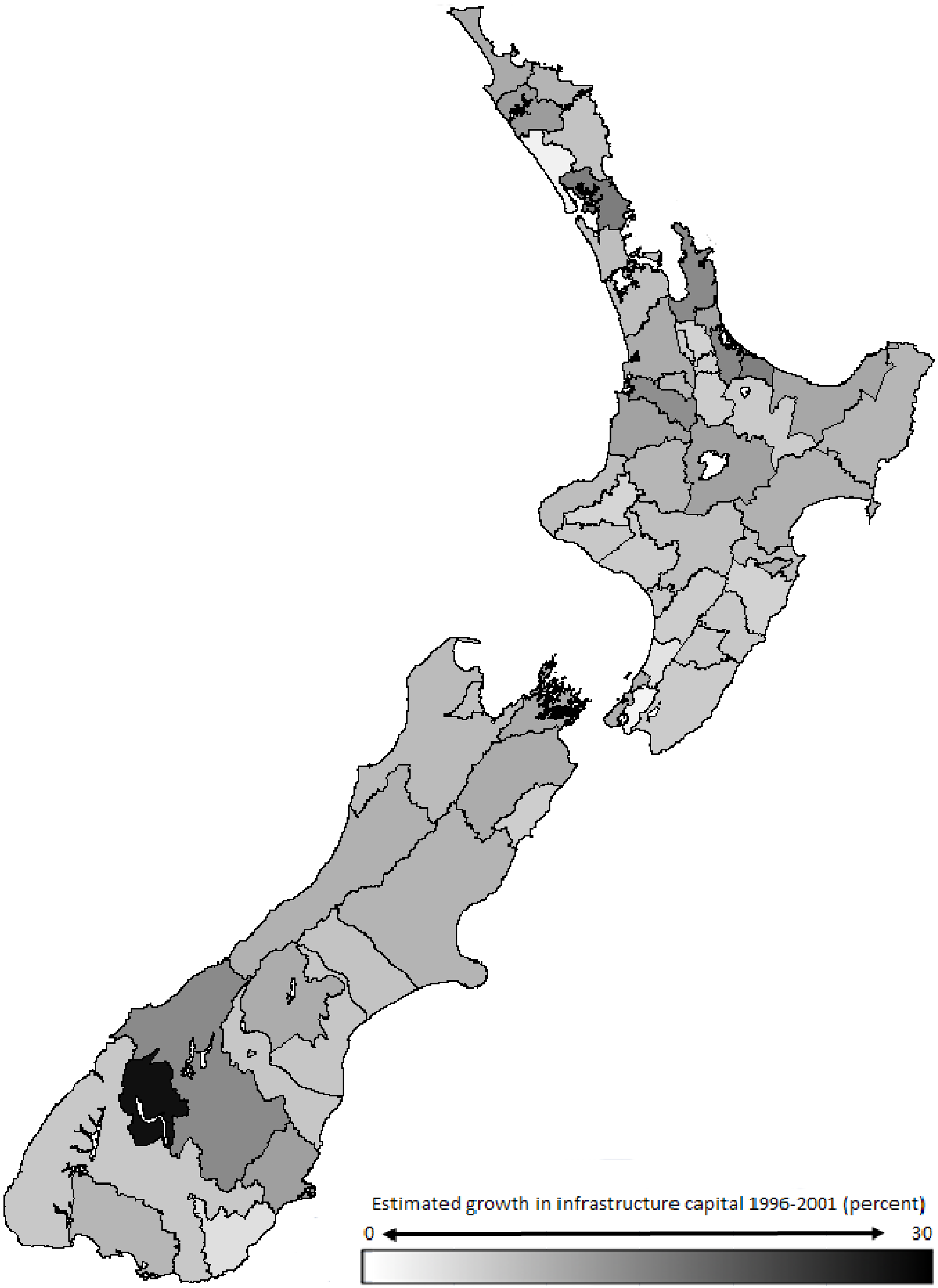


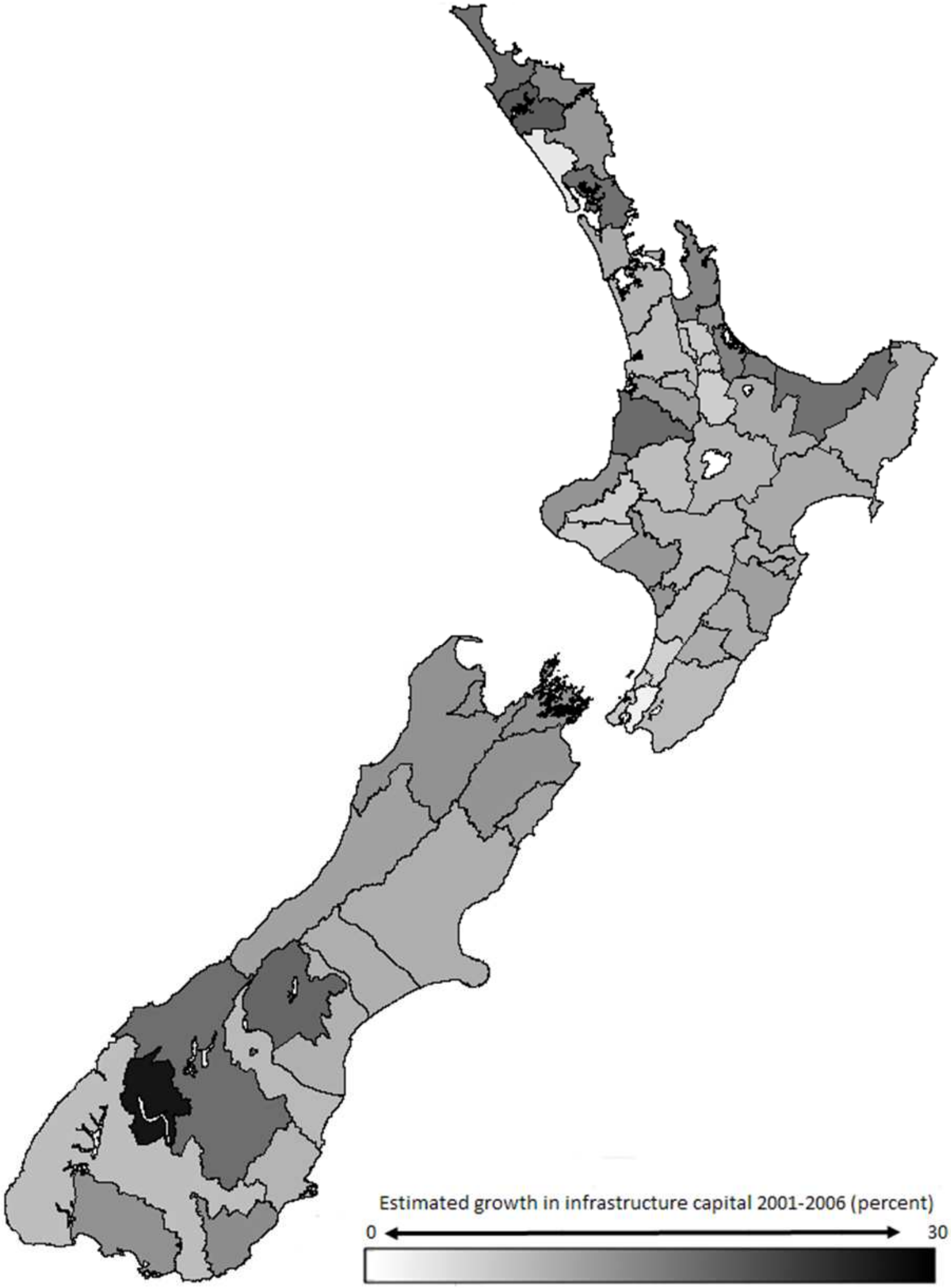
Figure 3 Estimated growth in infrastructure capital 1996-2001



Morans I

I	E(I)	sd(I)	z	p-value*
0.156	-0.018	0.078	2.239	0.013

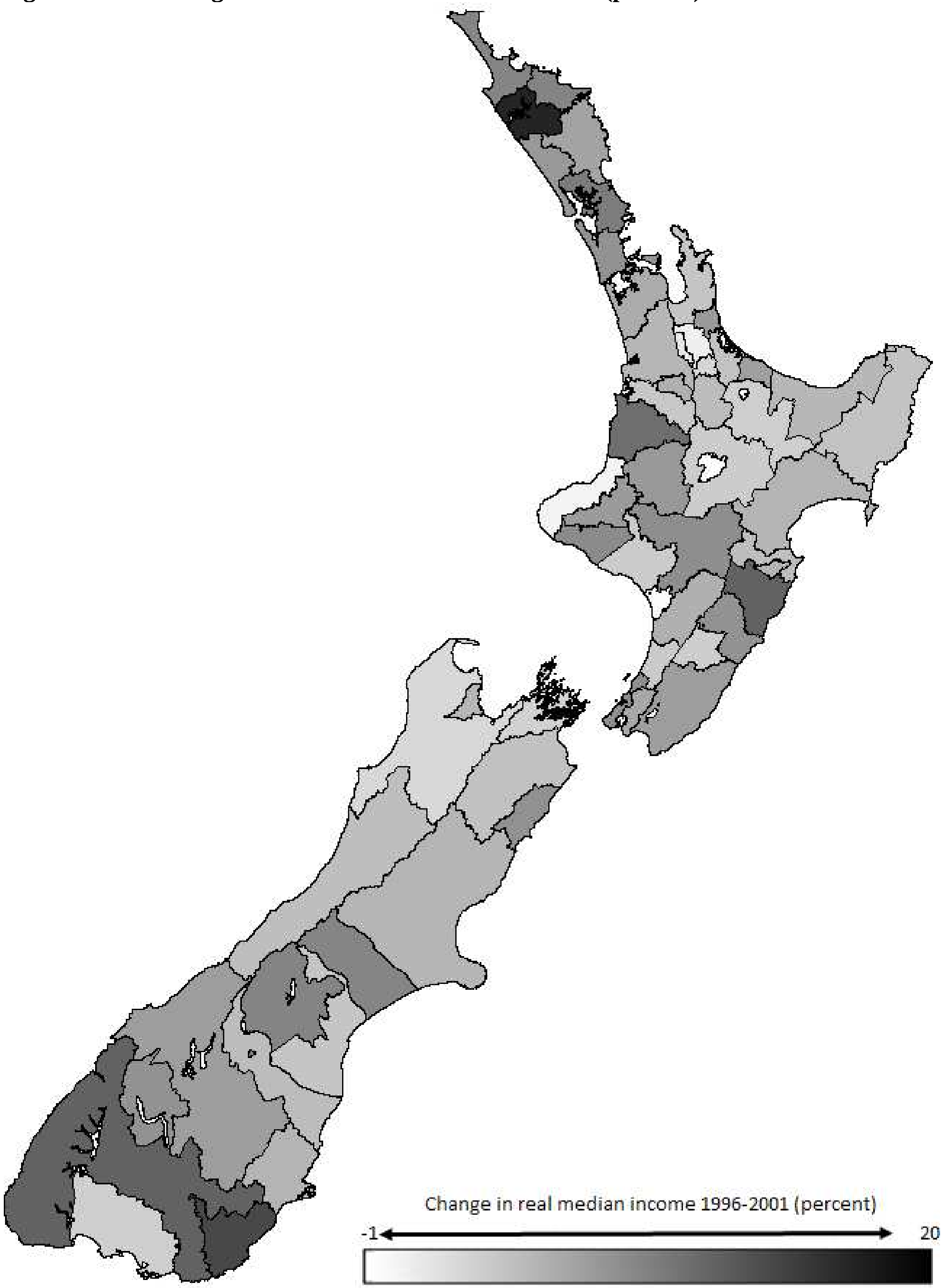
Figure 4 Estimated growth in infrastructure capital 2001-2006



Morans I

I	E(I)	sd(I)	z	p-value*
0.227	-0.018	0.083	2.955	0.002

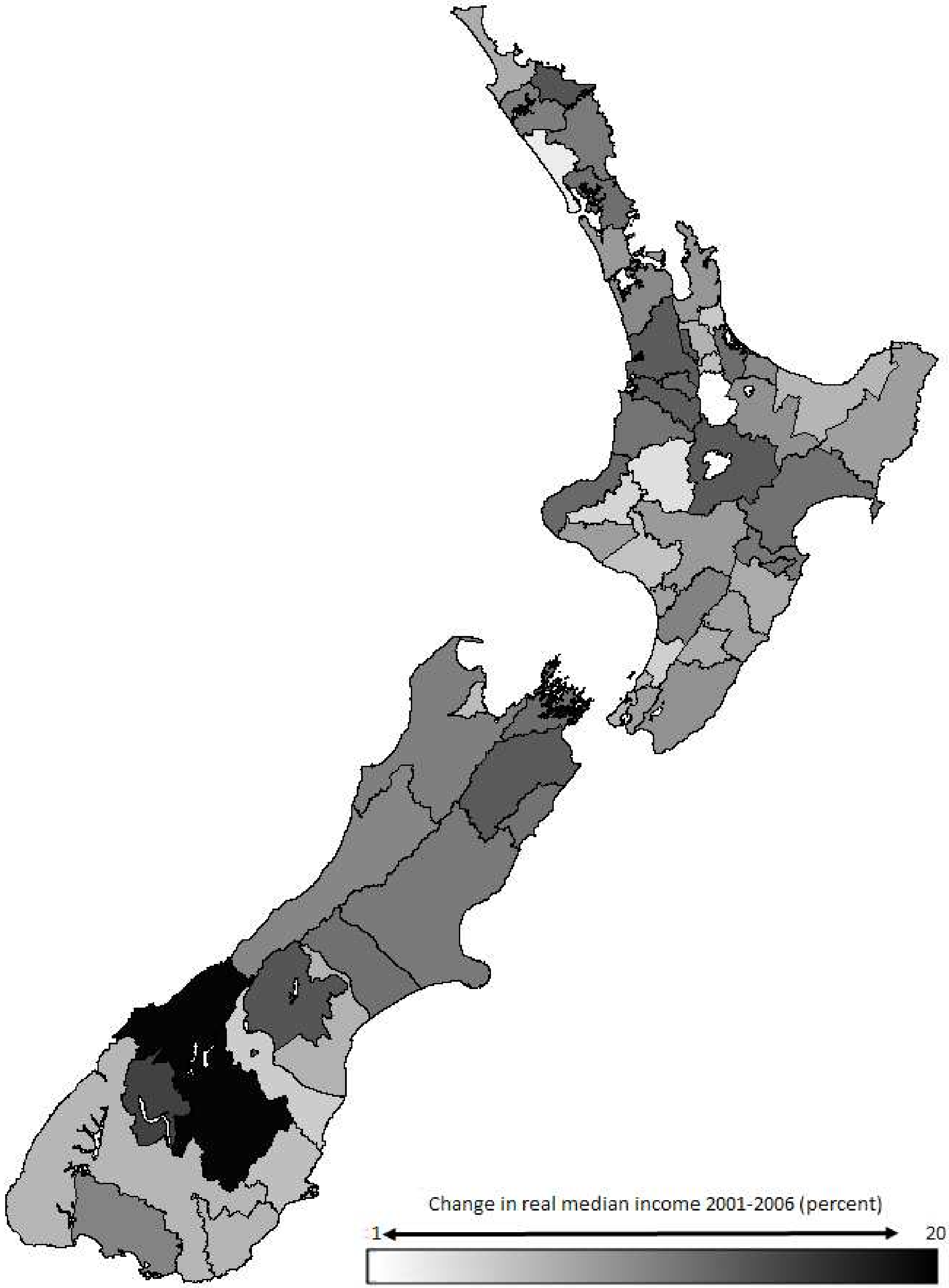
Figure 5 Change in real median income 1996-2001 (percent)



Morans I

I	E(I)	sd(I)	z	p-value*
0.168	-0.018	0.084	2.206	0.014

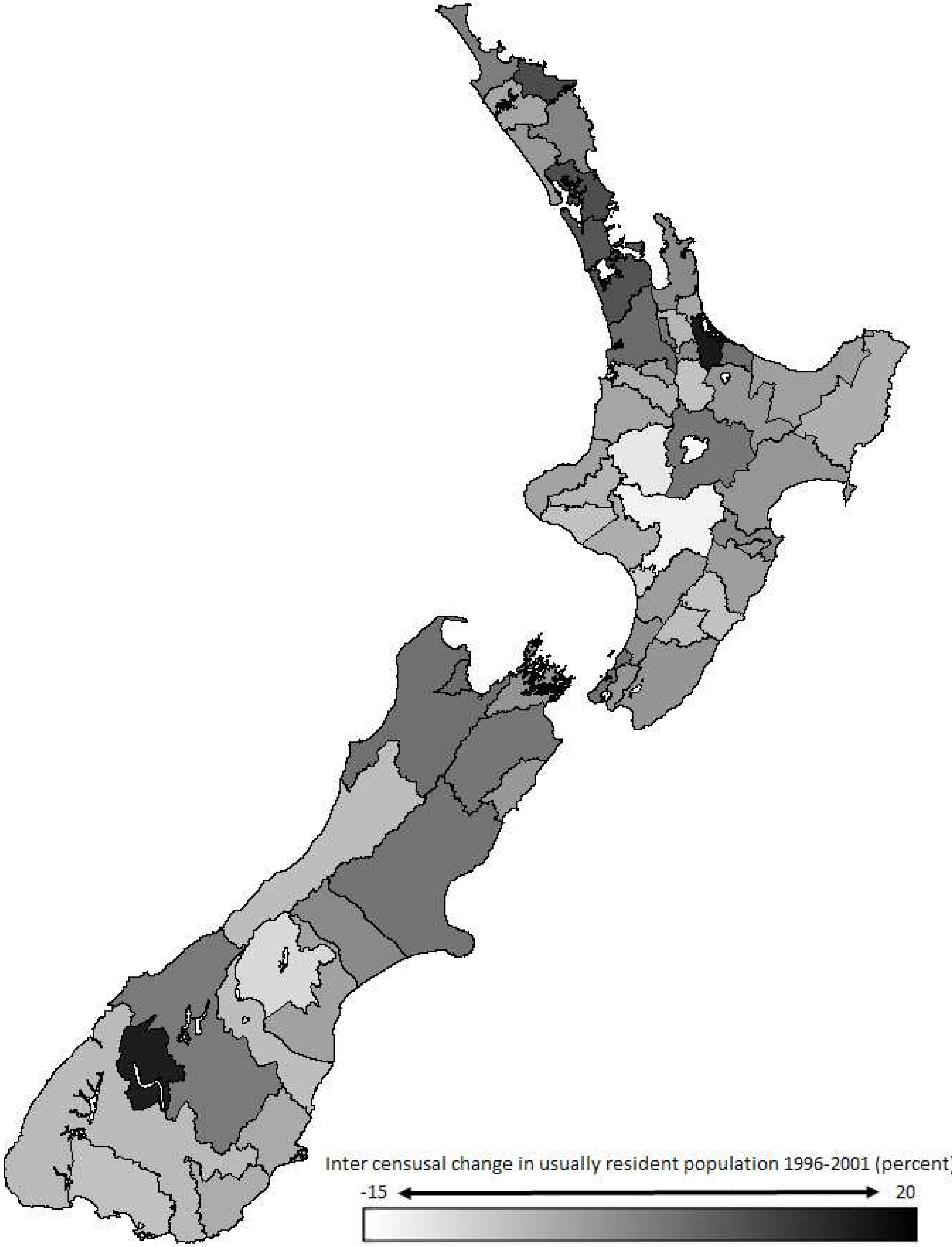
Figure 6 Change in real median income 2001-2006 (percent)



Morans I

I	E(I)	sd(I)	z	p-value*
0.079	-0.018	0.084	1.144	0.126

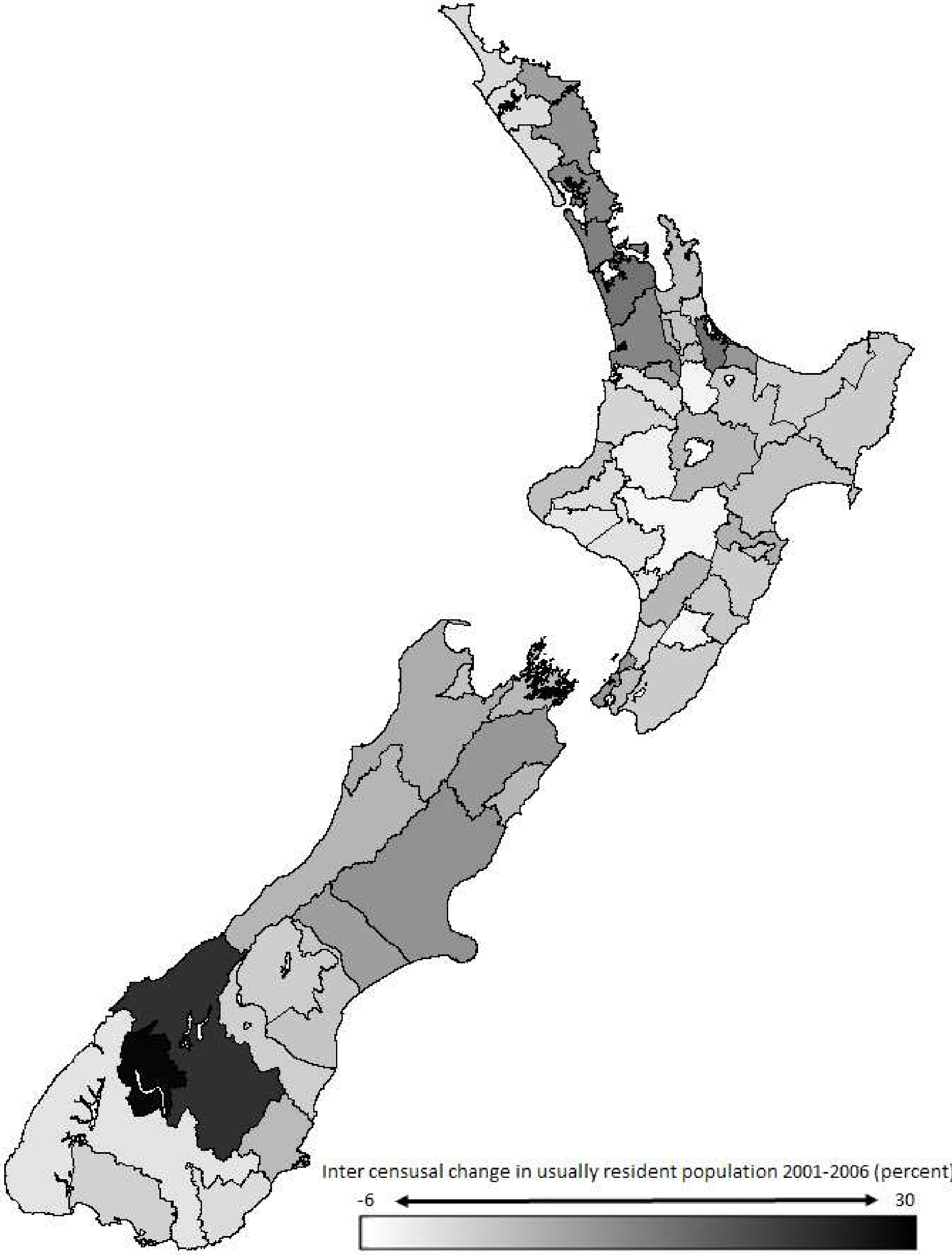
Figure 7 Inter censusal change in usually resident population 1996-2001 (percent)



Morans I

I	E(I)	sd(I)	z	p-value*
0.212	-0.018	0.084	2.732	0.003

Figure 8 Inter censusal change in usually resident population 2001-2006 (percent)



Morans I

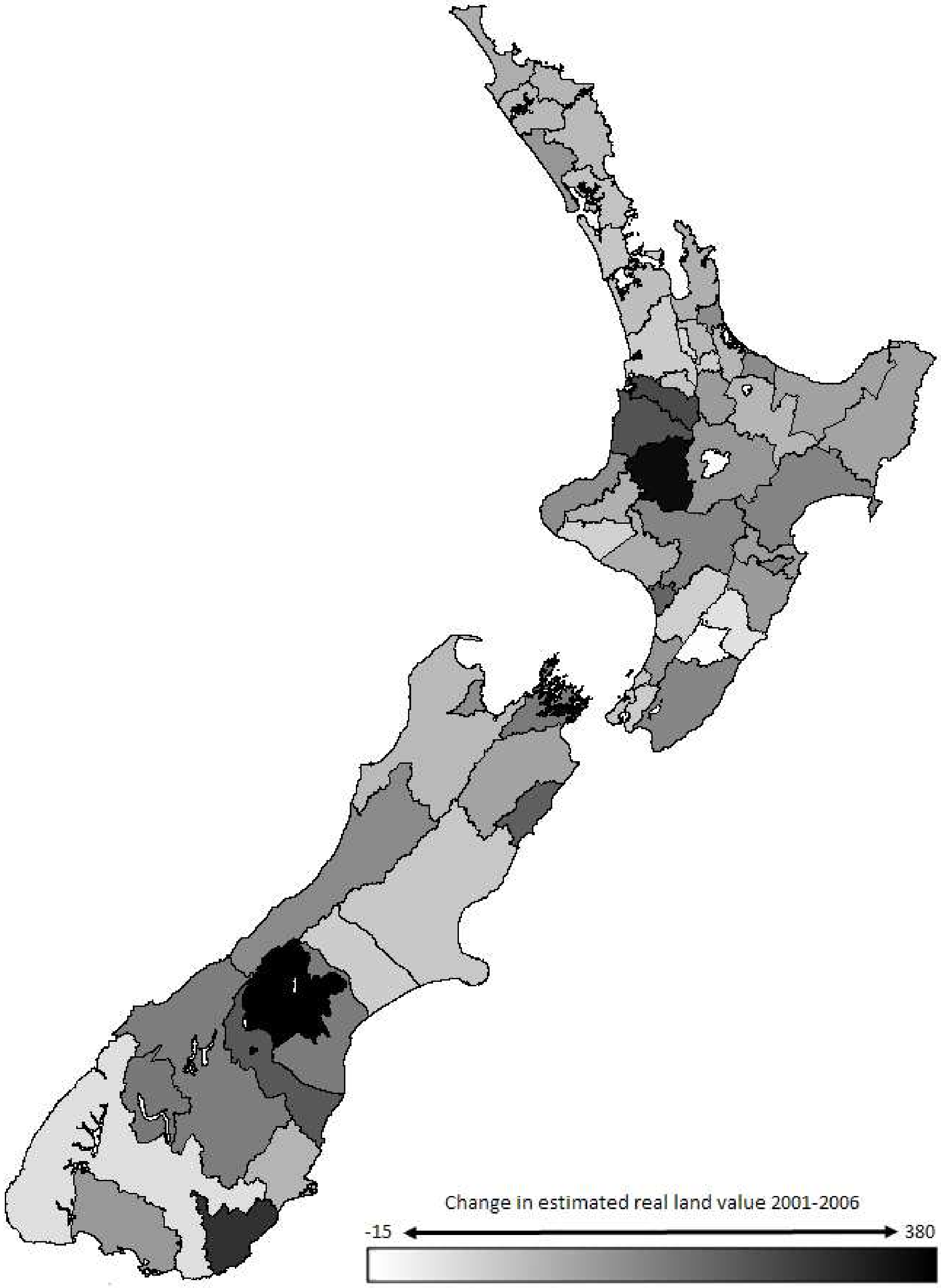
I	E(I)	sd(I)	z	p-value*
0.253	-0.018	0.081	3.316	0.000

Figure 9 Change in estimated real land value 1996-2001

Morans I

I	E(I)	sd(I)	z	p-value*
0.200	-0.018	0.084	2.583	0.005

Figure 10 Change in estimated real land value 2001-2006



Morans I

I	E(I)	sd(I)	z	p-value*
0.129	-0.018	0.084	1.750	0.040