Bridge to Somewhere:
The Value of Auckland's Northern Motorway Extensions

Arthur Grimes and Yun Liang

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Author contact details

Arthur Grimes
Motu Economic and Public Policy Research and University of Waikato
arthur.grimes@motu.org.nz

Yun Liang
Motu Economic and Public Policy Research
yun.liang@motu.org.nz

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Motu Economic and Public Policy Research
PO Box 24390
Wellington
New Zealand

Email	info@motu.org.nz
Telephone	+64-4-939-4250
Website	www.motu.org.nz

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Abstract

We estimate benefits that have resulted from extensions to Auckland's Northern Motorway since 1991. Population and employment rose substantially in locations near the new exits and to the north of the motorway extension, relative to developments elsewhere on the North Shore and in the broader Auckland Region. Land values also rose strongly near the new exits. Our approach to measuring net benefit uses changes in land values (after controlling for other factors) as a revealed preference indicator of value. We compare the estimated benefits with costs of the project to gain a measure of the project's benefit:cost ratio (B:C). Our results indicate that the gross benefit of the extensions from Tristram Avenue to Orewa is at least $2.3 billion (2004 NZ$s) compared with the estimated extension costs (discounted to 2004) of $366 million, giving a B:C ratio of at least 6.3, which exceeds the standard ratio of 4.0 used to approve roading projects in New Zealand. Our estimates take account of the possibility of diminution in value occurring elsewhere near the existing Northern Motorway network, but not in other areas of Auckland or elsewhere in the country. Conversely, they do not include any benefits that may be impounded in commercial property values in the CBD (and elsewhere) arising from increased accessibility to an enlarged labour pool.

JEL classification

H43, H54, R42

Keywords

infrastructure; transport investment; benefit:cost; Auckland motorway

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1 Introduction

In 1959, Auckland opened its first harbour bridge connecting the fledgling northern suburbs to the main part of the city south of the harbour. By 1970, a motorway[1] extended six kilometres north of the bridge (to Tristram Avenue) and the surrounding area had become an urban settlement with relatively high income households. In 1995, the Constellation Drive interchange was opened; and in 2000 an extensive section was opened that stretched from the Greville Road interchange (adjacent to the emerging suburb of Albany) to Silverdale (adjacent to Orewa, a beachside resort 32 kilometres north of the bridge).[2] The motorway extension raised the potential for new subdivisions contiguous with the existing northern limits of Auckland's North Shore suburbs. It also improved access to the inland towns and small coastal resorts to the north of Orewa.

Our purpose is to estimate the economic benefits that have resulted from these motorway extensions. We use changes in land values (after controlling for other influences) as a revealed preference indicator of value. We compare the estimated benefits with costs of the project to gain a measure of the project's net benefit and of its benefit:cost ratio (B:C). Further, we compare the estimated (*ex post*) benefit with the *ex ante* benefits formulated prior to the project that were used to judge whether the project should proceed. The latter comparison provides information on whether the standard methodology used to assess *ex ante* benefits is appropriately comprehensive in its assessment of infrastructure benefits.

Briefly, our results indicate that the value of the extension is at least $2.3 billion (all values are expressed in 2004 NZ$s) compared with an estimated extension cost (discounted to 2004) of $366 million, giving a B:C of at least 6.3. Our estimates take account of the possibility of diminution in value elsewhere near the existing Northern Motorway network, but not in other areas of Auckland or elsewhere in the country. Conversely, they do not include any benefits that may be impounded in commercial

[1] I.e. a "freeway" in North American terminology.
[2] Subsequently, a short section was opened from Silverdale (approximately three kilometres south of Orewa town-centre) to Grand Drive (a similar distance west of the town centre).

property values in the CBD (and elsewhere) arising from increased accessibility to an enlarged labour pool.[3]

The paper proceeds as follows. In section 2 we present our methodology for estimating net benefits for a generic new infrastructure investment, also identifying types of supporting evidence that could be used to check consistency of outcomes with the net benefit results derived from that methodology. Section 3 describes the Northern Motorway extensions in more detail, including its costs and *ex ante* estimated benefits. We present descriptive statistics on impacts associated with the extensions. These statistics utilise census data on population, employment and incomes, plus property value information. Section 4 presents econometric results using a panel of detailed spatial land values and using two different estimators. These results provide a range of estimates for the *ex post* gross benefits of the project that we use to derive our estimates of net benefit. Section 5 discusses our results and relates them to the *ex ante* project estimates of net benefit.

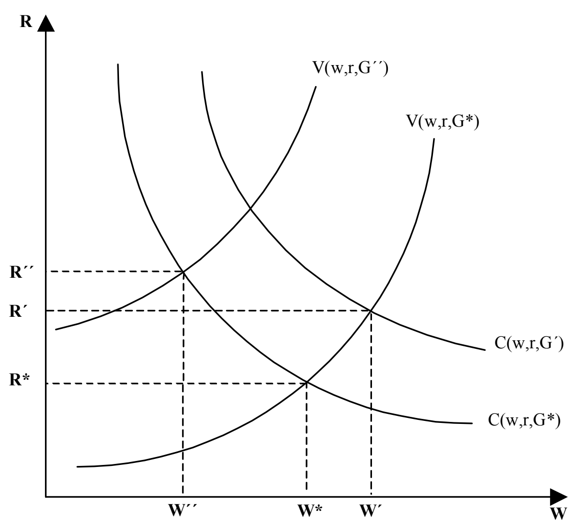
2 Methodology

Our approach to measuring benefits of a new infrastructure project builds on the spatial equilibrium models of Roback (1982) and Haughwout (2002).[4] Labour and capital are considered mobile factors of production, while land is a fixed factor. Equilibrium returns to labour and capital in a locality are therefore exogenous to that locality; any feature that impacts specifically on the productivity and/or desirability (amenity value) of the locality will be reflected in the price and rental value of local land. In particular, a new infrastructure investment will affect local land values where productivity, accessibility and/or social amenity values for the locality are affected by the investment.

[3] Grimes and Liang (2007b) find that the ratio of CBD to outlying land values increased throughout the period suggesting that the increased labour pool servicing the CBD may be an additional source of benefits that lie over and above our estimates.
[4] See McMillan and McDonald (2004) for use of related methodologies to measure the benefits of a Chicago rail expansion.

Graphically, building on Roback (1982), this approach is depicted in Figure 1 in rent (R) and wage (W) space. The downward sloping curves, C(.), are the firm's iso-cost curves; costs are an increasing function of wages and rents, and a decreasing function of public infrastructure (G). The iso-cost curve with the initial level of public infrastructure (G*) is C(w,r,G*); C(.) is exogenously determined by the minimum costs of production outside the locality. The upward sloping curves, V(.), are workers' indirect iso-utility curves; utility is increasing in wages, decreasing in rents and (in this example) increasing in infrastructure. The iso-utility curve with initial public infrastructure (G*) is V(w,r,G*). As with costs, V(.) is determined exogenously, in this case by the net benefits of residing in other localities.

Figure 1: Infrastructure, wages and rents equilibrium



Source: Timmins (2005), based on Roback (1982).

The initial equilibrium is given by rents R* and wages W*, at which firms and workers are indifferent about producing and residing in the locality relative to others. Consider a new infrastructure investment that contributes solely to increased firm productivity locally, but does not directly change worker satisfaction. The iso-utility curve remains V(w,r,G*); the new cost curve is C(w,r,G'). With free mobility of firms, C(.) is still set exogenously, so the costs of each firm are unchanged. The improved infrastructure induces firm to migrate to the region, raising rents for scarce land and raising wages; the latter effect is required to compensate workers for increased rents. The new equilibrium is at rents R' and wages W'.

Now consider an infrastructure investment that solely benefits workers, for example by improving access to local amenities. The cost curve is still C(w,r,G*); the new iso-utility curve is V(w,r,G"). V(.) is still set exogenously; the amenity benefit of the new infrastructure is reflected in higher rents as workers migrate to the locality. For firms' costs to remain unchanged, wages decline; thus workers' benefit from the infrastructure is offset by higher rents (R") and lower wages (W").

If new infrastructure both lowers firms' costs and improves workers' utility, the relevant curves are C(w,r,G') and V(w,r,G"). Firms and workers migrate to the region so rents unambiguously rise. Depending on relative benefits for workers versus firms, wages may either rise or fall relative to W*.

In all cases where costs and benefits of the infrastructure are fully internalized within the locality, movements in rents (i.e. returns to the fixed factor) summarise the overall net flow of benefits for the project. However, a number of cases may arise where costs and/or benefits are not fully internalised within the locality.

First, the cost of the new infrastructure may be partly or fully borne outside the locality (e.g. by central government). In this case, these external costs must be deducted from the gross benefits that accrue within the locality to determine overall net benefit. Second, the new infrastructure may reduce attractiveness of other localities (e.g. by changing their accessibility through changes in congestion, or reducing their access to rural amenities). These changes in attractiveness will reduce rental values in those localities; those reductions in value need to be deducted from the net benefits calculated for the locality being studied to determine overall net benefit. Third, the new infrastructure may increase the attractiveness of other localities. One avenue for this to occur is if the infrastructure is used as a conduit to more distant localities, as may occur with a motorway. In this case, the additional values in these more distant localities need to be accounted for. Another avenue for this effect is if the new infrastructure is used by residents in the locality to access work opportunities outside the locality (e.g. in the

CBD). If CBD productivity is subject to urbanisation and/or localisation agglomeration benefits (Duranton and Puga, 2004; Rosenthal and Strange, 2004, Mare and Timmins, 2006) the improved accessibility will be reflected in CBD ground rents and not just in rental values of the particular residential location. These potential benefits also need to be recognised in the analysis.

Our econometric specification applies the insights from this approach to estimate the net benefits of a new infrastructure project. Specifically, we estimate the determinants of local land values using spatial panel data that incorporate changes in infrastructure provision over time and over space. Land values equal the expected present discounted value (pdv) of rents and are used in place of rents for this analysis to gain an estimate of the pdv of the infrastructure project which can be compared against the project's capital cost.

We effectively adopt a difference-in-differences approach by deflating land values (per hectare) in locality i by average per hectare values elsewhere in the city. This enables us to abstract from any changes in value due to changing macroeconomic conditions (e.g. liquidity, discount rates, risk premia, etc) or to changes in population, preferences and/or productivity for the city as a whole. Thus we are only interested in the *relative* change in values of the affected localities as a result of the investment, not the absolute change in land values.

Let L_{it} represent the (regionally deflated) value of land per hectare in locality i at time t. L_{it} is hypothesized to be a (non-decreasing) function of relevant infrastructure, G_{it}, that influences the attractiveness of locating in i. L_{it} also incorporates other influences pertaining to the locality which we proxy by a vector of local fixed effects, F_i; and it incorporates shifts in broader sub-regional influences relative to other parts of the city-region, proxied by a vector of time fixed effects, F_t. Thus:

$$L_{it} = f(G_{it}, F_i, F_t, c, \varepsilon_{it}) \qquad (1)$$

where c is a constant term, ε_{it} is an iid error term. Our null and alternative hypotheses are respectively $f_1 = 0$ and $f_1 \geq 0$.

In the specific case of the motorway extension, we proxy G_{it} by distance of locality i from the nearest motorway ramp at time t; the impact of G_{it} on L_{it} is hypothesized to decline, possibly non-linearly, as distance from the nearest ramp increases. This effect can be incorporated through appropriate specification of f(.). Estimation of (1) can be used to establish the gross benefits of the infrastructure investment within locality i by estimating the difference in L_{it} that is due to changes in G_{it}. Externally borne direct costs of the investment are deducted from this estimate to gain an estimate of net benefit.

This approach is appropriate in cases where the new infrastructure has no positive or negative impacts on other localities. We test whether there is a spillover effect of the extension on other localities that may be negatively affected by the new addition. Specifically, we examine whether areas that are serviced by pre-existing Northern Motorway exits (i.e. areas that are close to exits at the start of the sample period) suffer any reduction in value following the extension. We do so by including dummy variables for those areas interacted with time dummies and examine whether values in these areas declined after construction of the new exits. If the relevant estimates are not significantly different from zero, we conclude that any negative impacts of the extension on 'competing' localities are minimal. If they are significant (and negative) the reductions in value must be incorporated into the analysis.

We also test whether there are spillover effects on localities that enjoy improved access even though those localities remain distant from the nearest motorway exit after completion of the extension. This may apply particularly to towns and resorts to the north of Orewa. Again, we do so by including dummy variables for those areas interacted with time and examine whether values in these areas rise after construction of the new exits. We do not estimate the impact of the extension on CBD and other Auckland land values since these values will be affected by many factors, not just by the motorway extension. However, we utilise other research to make a qualitative assessment of the direction of impact that the extension may have had on these values.

As well as estimating a form of (1), we infer some of the underlying processes influencing the impact of the investment by examining descriptive information pertaining to population, employment, incomes and land values. These outcomes do not need to be controlled for in estimation (since rents and/or land values summarise the local benefit derived from the investment) but do indicate whether any changes in land values are due primarily to benefits accruing to firms or workers. For instance, if average incomes (wages) fall following a new infrastructure investment (that itself has a positive impact on land values) the implication is that benefits of the project accrue predominantly as benefits to workers.

3 Northern Motorway Extension

Auckland's Northern Motorway extends from the city's harbour bridge to Silverdale (just south of) and Grand Drive (just west of) the resort town of Orewa and neighbouring resorts on Whangaparoa Peninsula. Prior to the 1990s, the motorway extended northwards to Tristram Avenue (six kilometres north of the harbour bridge). A motorway extending well to the north had been mooted in the 1960s but the idea was suspended indefinitely in the 1970s and was only reactivated in the 1990s (Sinclair Knight Merz, 2001). In 1995, the Constellation Drive interchange (two kilometres north of Tristram Avenue) was opened. The motorway was extended from Greville Road (just east of Albany) to Silverdale (24 kilometres north of the bridge) in 2000 (this extension being referred to as ALPURT A).[5] The extension to Silverdale effectively acted as a conduit to Orewa and to the Whangaparoa Peninsula (WP). Our focus is on the economic effects of the extensions from Tristram Avenue to Silverdale (although we will generally refer to the latter as Orewa-WP since Silverdale acts as a conduit to Orewa and the Whanagaparoa Peninsula).[6]

[5] ALPURT stands for "Albany-Puhoi Realignment".

[6] The ALPURT B1 project extended the motorway to Grand Drive, similarly distant from the Orewa town centre as is Silverdale; the Silverdale exit is used for access to the Whangaparoa Peninsula. The motorway is currently being extended further north to Puhoi, an extension referred to as ALPURT B2. In 2008, a dedicated buslane (Northern Busway) was opened parallel to the Northern Motorway from the harbour bridge to Constellation Drive (and thence on to Albany). These additional investments fall outside our study period and so are not included in the analysis of this paper.

Table 1 sets out the distance of each Northern Motorway exit (as travelled) from the harbour bridge, together with the dates when each interchange was officially opened. Figure 2 maps the broader Auckland-North Shore-Orewa-WP vicinity; the harbour bridge runs between Auckland (as marked) and the North Shore; the extended motorway runs to Silverdale and Orewa. Figure 3 shows more detail of the North Shore, indicating Tristram Avenue (the pre-existing motorway end) plus the initial extension to Constellation Drive and the subsequent exits at Greville Road and Oteha Valley Road (continuing thereafter to the Silverdale and Orewa exits).

Table 1: Northern Motorway exits (interchanges)

Exit	Km north of Harbour Bridge (as traveled)*	Year Interchange Opened**
Stafford Rd	0	Pre-1990
Onewa Rd	1	Pre-1990
Akoranga/Esmonde Rd	2	Pre-1990
Northcote Rd	4	Pre-1990
Tristram Avenue	6	Pre-1990
Constellation Drive	8	1995
Greville Rd	10	2000
Oteha Valley Rd	12	2000
Silverdale	24	2000

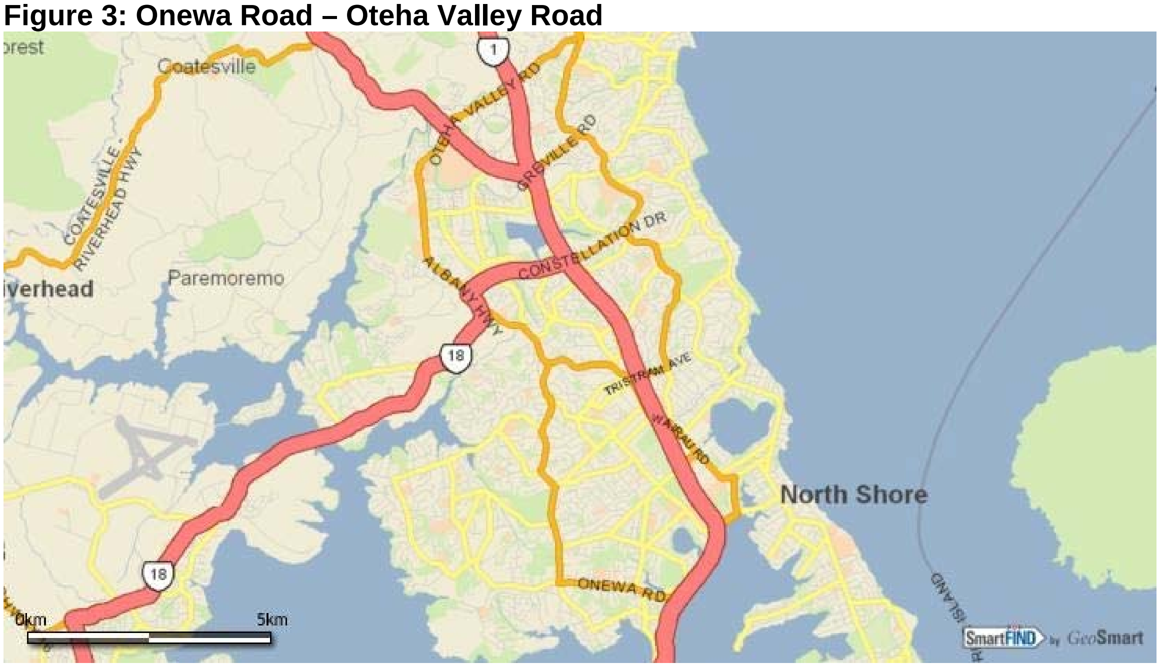
* Source: Author's measurements
** Source: Transit New Zealand

Figure 2 indicates a dense network of roads extending to just south of Redvale (i.e. just north of Oteha Valley Road), with significant density again around Orewa-Silverdale-Whangaparoa. This pattern of urban development is driven by: (a) proximity of areas south of Oteha Valley Road to the Auckland CBD and to the established built-up areas of North Shore; (b) desirability of the beach resorts of Orewa and Whangaparoa Peninsula, and (c) the impact of the Auckland Region's Metropolitan Urban Limits (MUL) which preclude development in the area between (just north of) Oteha Valley Road and Silverdale. The MUL is a piece of statutory legal infrastructure that represents a binding constraint on urban development in the intervening area (Grimes and Liang, 2007b); its existence is consistent with the long gap in motorway exits between Oteha Valley Road and Silverdale (12 kilometres).

Figure 2: Auckland – Puhoi

Source: Wises (www.wises.co.nz)

Figure 3: Onewa Road – Oteha Valley Road



Source: Wises (www.wises.co.nz)

The cost of ALPURT A (Albany – Silverdale) was estimated, *ex ante*, to be $63 million (nominal) spread over 1996-1999.[7] Costs however expanded as a result of a number of factors including scope changes, regulatory consent costs, economic conditions (especially an overheated local construction sector in the lead-up to the America's Cup yacht challenge, held just off the nearby coast), and unforeseen geotechnical and environmental protection difficulties. These factors led to total construction costs (inclusive of staff costs but exclusive of land costs) of $122 million (nominal) for the project. If real costs were spread evenly over the four years, the $122 million cost corresponds to approximately $34.5million p.a. in (undiscounted) 2004 dollars, a total of $138.2 million. This represents a cost (in 2004 dollars) of $9.88 million per kilometre. We do not have costings for the construction of Tristram Avenue – Greville Road (although the interchange of the latter is included in the ALPURT A costings), and so use the same real per kilometre cost for these four kilometres, and spread those costs evenly over the four years 1992 – 1995. The total estimated costs in undiscounted 2004 dollars of the extensions from Tristram Avenue – Silverdale are therefore calculated as $177.75 million.

These costs do not include discounting. The New Zealand government uses a real discount rate of 10 percent per annum for infrastructure projects. Using this discount rate, the 2004 dollar value of the full set of extensions increases to $366 million.[8] (The total discounted 2004 dollar value of the extensions would amount to only $256 million if a real discount rate of 5% were used, demonstrating the sensitivity of the calculation to the assumed discount rate.) Major roading projects have traditionally been undertaken in New Zealand if B:C>4.0 (using the 10% real discount rate). For the extensions to meet this hurdle, a gross benefit of at least $1,464 million (in discounted 2004 dollars) is therefore required.

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[7] We do not include the costs of ALPURT B1 (Silverdale – Grand Drive) in this analysis as they were incurred subsequent to our main analysis period.

[8] For instance, if the nominal construction cost in 1996 was $30 million, the real cost after applying a CPI adjustment, in (undiscounted) 2004 dollars, is $34.54 million; applying a 10% p.a. compounding real discount rate results in a $74 million cost when discounted forward to 2004 [=$34,540,000 x $(1.1)^8$].

Official *ex ante* estimates for ALPURT A gave a B:C ratio of 16 based on construction costs of $63 million (Sinclair Knight Merz, 2001).[9] This translates into a discounted 2004 benefit of $1,662 million for the ALPURT A extension alone. If one were to keep the same costs as attributed to the prior extensions (as above) and use a B:C of 16 for the entire set of extensions, the implied benefit in discounted 2004 dollars would be $3,390 million. However, the per kilometre cost of the earlier extensions (used above) were based on the *ex post* costs of constructing ALPURT A. If the pre-ALPURT per km costs were instead equal to the (lower) *ex ante* costings for ALPURT A (which may be a reasonable assumption since those costings may themselves have been based on prior extension costs), the implied benefit in discounted 2004 dollars for the entire set of extensions would be $2,450 million (using a B:C of 16 and a 10% real discount rate). We use this latter figure as the measure of *ex ante* anticipated gross benefits expressed in discounted 2004 dollars.

Our primary method of estimating the gross benefit of the project builds on (1); the detailed methodology is further described in section 4. The key data that we use are land values obtained at the meshblock level. A meshblock is the smallest area used to collect and present statistics by Statistics New Zealand. The size of a meshblock depends primarily on the number of people and type of area covered. Meshblocks in rural areas generally have a population of around 60 people, while in urban areas a meshblock is normally the size of a city block and contains approximately 110 people. Other agencies, notably Quotable Value New Zealand, the source of our land value data, can aggregate data to the same meshblock definitions to enable data compatibility.

Our land value data are described in Grimes and Liang (2007a). Quotable Value New Zealand, a state entity, estimates separate values for land and improvements for every property in the region; these values are used for

[9] The SKM study was prepared for the official bodies commissioning national roading infrastructure (Transfund and Transit New Zealand). The official B:C methodology includes, as benefits: vehicle operating cost savings, travel time savings, maintenance cost reductions and intangible benefits such as environmental benefits (e.g. fish preservation in streams). Costs include maintenance costs (in the analysis period), design and supervision fees, environmental/planning costs, and construction costs. Calculations are conducted with and without property acquisition

property tax (rating) purposes. Estimates for each property are based on recent sales information for like properties; the split between value of land and improvements is based on sale prices of vacant sections (lots) in the area and on construction costs for new structures of similar quality. The strengths of the data are that they are consistently and independently compiled by a professional body, and they provide explicit estimates of land values which are the data required for our study; the downside is that the data rely on valuers' estimates rather than being directly observed market prices. The latter could be of concern if market dynamics were the focus of the study. However our focus is longer term, using data at six yearly intervals. Given its method of construction (based on observed market prices), the valuation data is expected to provide a reliable guide for this type of application.[10]

We use data for meshblocks in each of the Rodney District and North Shore City territorial local authorities (TLAs). These are the two TLAs within the Auckland Region that lie to the north of the harbour bridge. We concentrate attention on meshblocks that lie within the MUL boundaries, given the Grimes and Liang (2007b) findings that property values outside the MUL are constrained by legal impediments to development, and so are set in a different manner from those within the urban boundary. Most North Shore City land lies within the MUL; in Rodney District, the area in and around Orewa and the Whangaparoa Peninsula lie within the MUL. We also include in our analysis a town further to the north (Warkworth) plus its associated beach resorts (Leigh, Snells Beach, Mahurangi), and a small town still further north (Wellsford), which are both within Rodney District.

Meshblock land values (expressed on a per hectare basis) are each deflated by the average per hectare land value for the relevant years in Waitakere and Manukau cities (two other non-CBD local authorities within the Auckland Region). Figure 4 depicts the log change in deflated meshblock land values

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costs. A 10% real discount rate is applied to both costs and benefits. Source: www.transit.govt.nz/about/faqs/History-of-Transit.pdf (accessed 5 May 2008).

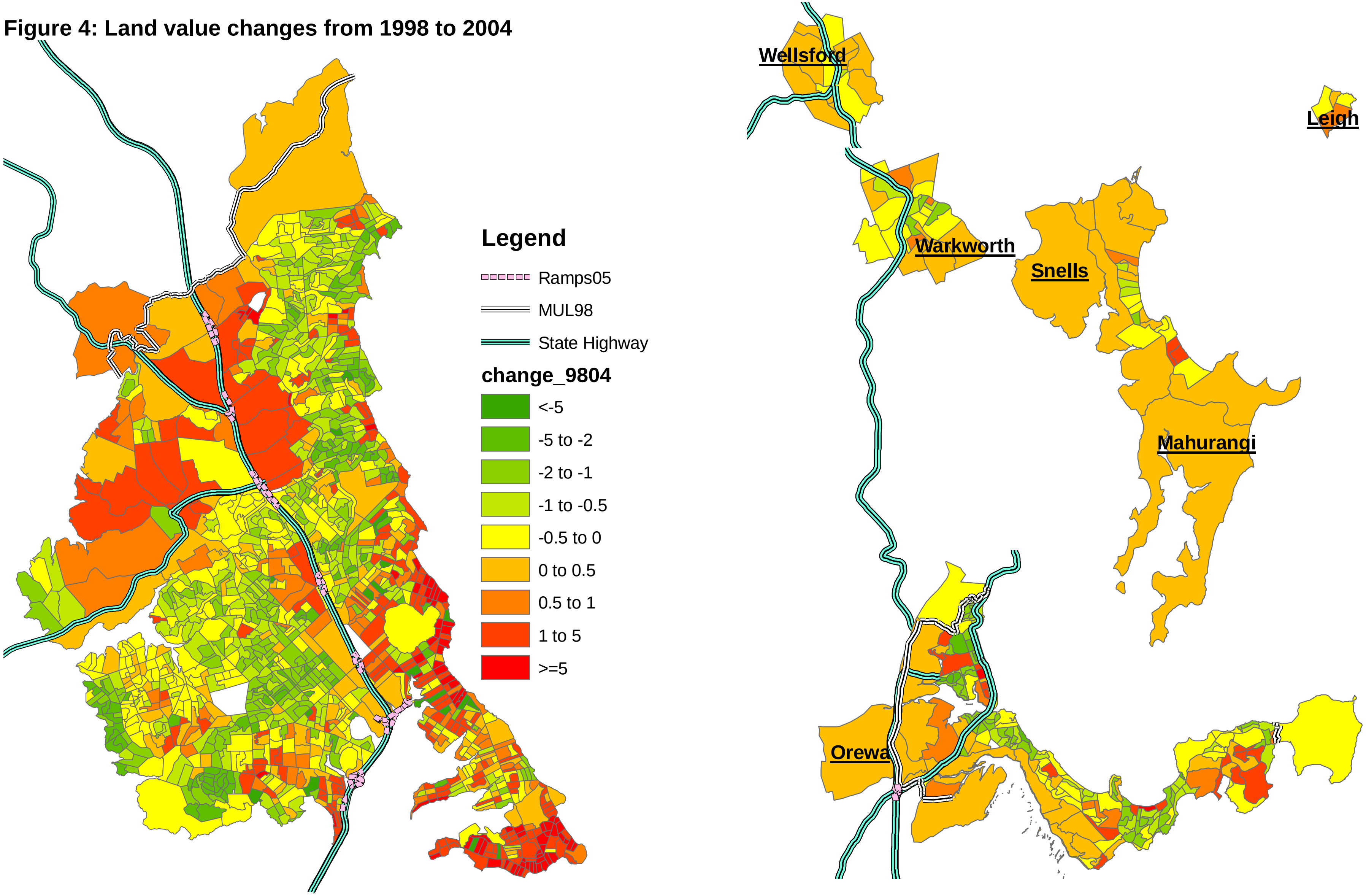
[10] Revaluations take place on a three-yearly rotational basis. Grimes and Liang (2007a) interpolate the land value data to annual frequency using vacant section sale price data for each territorial local authority to enable comparison of land values across local authorities for any given year.

throughout the relevant North Shore and Rodney meshblocks. Any value above (below) zero indicates that the land value in the relevant meshblock rose by a greater (lesser) proportion than did the average land value in Waitakere and Manukau cities. (On average, as shown in our subsequent empirical estimates, land values in North Shore and Rodney rose by slightly less than did those in Waitakere and Manukau over the period.) The map depicts changes in values between 1998 and 2004. A similar pattern exists for 1992 to 2004, but some meshblock land values are missing for 1992, so the map for the whole period is less complete.

In Figure 4, motorway exits are shown in pink; the northern three exits in North Shore correspond respectively to Constellation Drive, Greville Road and Oteha Valley Road. The Silverdale exit is marked in pink on the Orewa map. The map makes the rise in property values around the new exits visually apparent. These rising values contrast with many declining (relative) values elsewhere on the North Shore other than in areas closer to the Auckland CBD and in some coastal areas, consistent with earlier research findings. While indicative that the new motorway exits had an influence on land values over this period, the raw data do not control for any other effects on land values and do not differentiate the impact that distance from motorway exits has on land values. The econometric estimates in section 4 are designed to do so.

Prior to examining the econometric evidence, we examine supplementary descriptive data to provide insights into the nature of development in and around the new motorway exits. Table 2 presents data on population, employment, average real annual household income, and real land value per hectare (incomes and land values are deflated by the Consumers Price Index, CPI). The data are presented for eight areas. On the basis of the empirical results in the next section, we refer to meshblocks with a centroid that is within 7 kilometres of a new motorway exit as 'Treatment MBs'. These meshblocks are divided into those that are within North Shore TLA, those in Orewa/Whangaparoa that are within the MUL, those in Warkworth and nearby beaches, and those in Wellsford. The North Shore Treatment MBs are further divided into two groups: 'Inner' and 'Outer'. Inner Treatment North Shore MBs are those with a centroid

Figure 4: Land value changes from 1998 to 2004



within 3 kilometres of a new motorway exit; Outer Treatment North Shore MBs are those with a centroid between 3 and 7 kilometres of a new motorway exit. For comparison, we present data for Other North Shore MBs (i.e. those with a centroid that is at least 7 kilometres away from a new motorway exit), for Waitakere and Manukau cities (the areas used to deflate the land price data in our econometric analysis), and for the entire Auckland Region.

Census data for population, employment and average real household income are presented for each of the census years 1991, 1996, 2001 and 2006; 1991 precedes the motorway developments and 2006 post-dates all developments considered here. Land value data (from Quotable Value New Zealand) is consistent with the remainder of the study and is presented through to 2004 (the most recent available data). We concentrate on percentage changes observed over the full period in summarising developments.

Inner Treatment North Shore MBs had a population increase of 57% over 1991-2006, considerably in excess of the 38% increase in Auckland Region's population and the 42% increase in Waitakere and Manukau cities. North Shore population outside of the Treatment area increased by just 6%. These patterns are consistent with a sizeable population relocation to areas within North Shore close to the newly constructed motorway exits. The area with the largest percentage increase in population through the period was Orewa/Whangaparoa which experienced an 80% increase. Orewa/Whangaparoa is situated directly at the end of the new motorway and the magnitude of this increase is consistent with a significant improvement in accessibility for this area.

Employment increased markedly (120%) in Orewa/Whangaparoa and also in Warkworth and surrounding areas (80%). Inner Treatment MBs similarly experienced substantial employment growth (67%) that outstripped regional employment growth (55%). Together, the population and employment trends indicate that the new exits enabled considerable new development to occur along the path of the new motorway and in areas to the north.

Table 2: Descriptive data

Variable and Area (1)	1991	1996	2001	2006	% Δ 1991 to 2006
POPULATION (2)					
Inner Treatment North Shore MBs	57129	67221	77085	89814	57%
Outer Treatment North Shore MBs	75300	83022	86454	94050	25%
Other North Shore MBs	18156	19638	18885	19200	6%
Orewa/Whangaparoa	20799	26496	31164	37431	80%
Warkworth & Related Areas	5571	6237	7095	7827	40%
Wellsford	1719	1653	1740	1665	-3%
Waitakere and Manukau City	363003	409842	451947	515412	42%
Auckland Region	943776	1068645	1158891	1303068	38%
EMPLOYMENT (3)					
Inner Treatment North Shore MBs	28527	34749	39045	47622	67%
Outer Treatment North Shore MBs	36201	41505	42777	49473	37%
Other North Shore MBs	8601	9915	9501	10434	21%
Orewa/Whangaparoa	7998	11178	13257	17628	120%
Warkworth & Related Areas	1923	2412	2949	3465	80%
Wellsford	585	645	741	732	25%
Waitakere and Manukau City	148650	177540	194118	230190	55%
Auckland Region	404709	488334	533856	627834	55%
HOUSEHOLD INCOME (4)					
Inner Treatment North Shore MBs	61589	62705	66140	71253	16%
Outer Treatment North Shore MBs	59585	61965	65982	72249	21%
Other North Shore MBs	60469	65939	72787	82274.95	36%
Orewa/Whangaparoa	46194	49687	54171	60923.07	32%
Warkworth & Related Areas	40808	41244	43780	51561.58	26%
Wellsford	40346	42133	41355	45924.84	14%
Waitakere and Manukau City	52359	54338	54736	60573	16%
Auckland Region	55840	58023	61014	67333.2	21%
LAND VALUE (5)					
Inner Treatment North Shore MBs	731537	1464828	1606409	3228544	341%
Outer Treatment North Shore MBs	1030676	1817906	1988515	3872732	276%
Other North Shore MBs	1663113	2983089	3456712	7219305	334%
Orewa/Whangaparoa	316344	570014	716359	1250994	295%
Warkworth & Related Areas	84711	150260	236940	392085.8	363%
Wellsford	59767	94888	119375	225492.2	277%
Waitakere and Manukau City	114811	180353	266736	480892	319%
Auckland Region	116402	178785	302454	543232	367%

(1) The same meshblocks are included in every year for each variable.
(2) '000; source: census
(3) '000; source: census
(4) Mean; deflated by CPI; source: census
(5) Value per hectare; deflated by CPI; source: QVNZ. '2006' column for Land Value is for 2004.

Real household income increased faster than the Auckland Region average in Orewa/Whangaparoa and Warkworth. By contrast, Inner Treatment MBs had average household income growth that fell slightly below the regional average. The income data refers to income for households residing within the area, and does not measure incomes earned as employees within the area. It is therefore not a measure of local productivity. The slightly below-par income growth in Inner Treatment MBs implies that the population increase was skewed towards lower income households who may have located near the exits to take advantage either of new local employment opportunities or of the opportunity to commute to employment elsewhere in the region. Furthermore, there may be some dis-amenity value of residing very close to a motorway due to noise and pollution. A positive income elasticity on silence and clean air may have resulted in higher income households residing further from the motorway exits.

Grimes and Liang (2007b) found that since 1992, the ratio of Auckland CBD land values to values elsewhere in the Auckland Region had increased significantly.[11] Despite this trend, real land values in Inner Treatment MBs almost kept pace with those of the Auckland Region (341% versus 367%), and clearly outstripped those in Waitakere and Manukau cities (which are similarly distant from the CBD). Outer Treatment MBs suffered a significant decline relative to the Auckland Region (276% versus 367%). Land values in the more distant Treatment MBs of Orewa/Whangaparoa and Warkworth rose faster than those in Outer Treatment North Shore MBs consistent with the motorway extension raising the desirability of these areas.

For each of the four data sources, developments in the (most distant) town of Wellsford trailed those in other areas, with a slight decline in population and relatively slow growth in each of employment, household income and land value. These trends suggest that the town remained effectively 'distant' from Auckland even after the motorway's extension.

Overall, the descriptive statistics suggest that the extensions enabled a significant population and employment inflow into the areas near the new exits (i.e. Inner Treatment North Shore MBs and Orewa/Whangaparoa). The significant rise in employment indicates that production opportunities rose significantly in areas around the exits, inducing firms to locate nearby. This is consistent with an outward shift of the firm cost curve in Figure 1. However the income data indicates that firms did not have to pay higher relative wages (at least to local residents, to whom the income data applies). This may be a result of an ability to

[11] Ceteris paribus, the ratio of CBD per hectare land value to land values 25 kilometres distant from the CBD in 1992 and 2003 were estimated to be 1.7 and 5.3 respectively.

access a wider pool of labour throughout the region and/or because of the inward shift of population, effectively reflecting an overall amenity improvement. The latter is consistent with an upward shift of the iso-utility curve in Figure 1. Developments in land values reflect the increases in productive opportunities and amenity values, increasing relative to other local values, and increasing more strongly than could be expected of similarly distant land from the Auckland CBD. The descriptive data therefore imply that the motorway extensions resulted in enhanced productive opportunities and amenity values in areas serviced by the extensions. Estimates of the degree of these benefits are obtained in the following section.

4 Valuation of Gross Benefits

The econometric analysis begins with estimation of a variant of (1). Our sample comprises all meshblocks in the Rodney and North Shore (RNS) local authority areas that lie (fully or partially) within Auckland's Metropolitan Urban Limits (MUL) plus RNS meshblocks that lie in towns and resorts in the northern part of the region. Meshblocks within these towns are chosen according to the criterion that they lie within the Statistics New Zealand definition of 'Independent Urban Community'.[12] We restrict our attention to land within the MUL (and to the additional northern settlements) for reasons outlined above. To the extent that the motorway extension has positive impacts on land values in the excluded areas, our estimates will represent an under-estimate of the net benefits of the extension.

Specification of (1) recognises that a motorway exit may have non-linear effects on local land values, with the effect decreasing to zero beyond some distance. To account for these impacts we include a non-linear specification, as in Grimes and Liang (2007b), as follows. Let A^*_{it} represent the linear distance from the centroid of meshblock i to the nearest motorway exit at time t, and consider another variable A_{it} that we refer to as effective distance. We specify a minimum

[12] In addition, we include two areas (Leigh and Mahurangi) that are adjacent to Warkworth in our definition of the 'Warkworth' area. Leigh and Mahurangi are each defined by Statistics New Zealand as a 'Rural Area with High Urban Influence'. We exclude one 'Independent Urban Community', Helensville, that is not serviced directly by the extended motorway.

distance, $\underline{A}$ ($\underline{A} > 0$), and a maximum distance, $\bar{A}$, such that effective distance is given by:

$$\begin{aligned} A_{it} &= \underline{A} && \text{for } A^*_{it} < \underline{A}, \\ A_{it} &= A^*_{it} && \text{for } \underline{A} \le A^*_{it} \le \bar{A}, \\ A_{it} &= \bar{A} && \text{for } A^*_{it} > \bar{A}. \end{aligned} \qquad (2)$$

A_{it} is our measure of the effective proximity of the motorway to each meshblock. It reflects an assumption that there is little or no economic difference in values of properties that are less than $\underline{A}$ in distance from the exit. It also reflects an assumption that beyond some maximum distance, the motorway exit has zero economic effect and therefore the effect is constant beyond this distance. Non-linearity of impact is accounted for through the specification of (2) and through inclusion of both level (A_{it}) and log-level ($\ln A_{it}$) terms in the regression. This specification allows highly flexible modelling of non-linear spatial effects. We adopt a value for $\underline{A}$ of 0.25 km, being the same value as adopted in Grimes and Liang (2007b). We experimented with different values for $\bar{A}$ up to 10 kms. For any value of $\bar{A}$ that exceeded 7 kms, we found an almost flat effect beyond 7 kms. This is an intuitively plausible distance for the maximum distance over which an exit may have an impact in suburban contexts. Thus we set $\bar{A}$ at 7 kms in all our estimates.

The resulting initial panel equation takes the form:

$$\ln L_{it} = \beta_0 + \beta_1 A_{it} + \beta_2 \ln A_{it} + F_i + F_{1998} + F_{2004} + \varepsilon_{it} \qquad (3)$$

where L_{it} is per hectare land value in meshblock i at time t (deflated by Waitakere and Manukau city per hectare land values), A_{it} is effective distance as defined in (2), F_i is the vector of area fixed effects, F_{1998} and F_{2004} are fixed effects for 1998 and 2004 respectively, and ε_{it} is an iid error term.[13] The panel covers all eligible meshblocks (i=1, …., N) and three waves measured six years apart (t=1992, 1998, 2004). The initial wave (1992) is timed well before the opening of the first extension; the second wave (1998) follows the initial extension; the third wave (2004) occurs four years after the extension to Silverdale, and is four years prior to the opening of the Northern Busway. Thus the 2004 values are unlikely to be picking up the effects of this latter development.

Within RNS, there are two non-contiguous areas within the MUL. The first is the suburban North Shore area. The second is the resort area covered by Orewa and the Whangaparoa Peninsula (Orewa-WP). It is possible that other variables, in addition to the motorway extension, have caused values to vary in Orewa-WP relative to other parts of RNS; for instance higher incomes may have encouraged purchase of holiday houses over and above any effects caused by changing accessibility. For this reason, we supplement the variables in (3) with a dummy variable (D_{1i}) where D_{1i}=1 for meshblocks within Orewa-WP and 0 otherwise. We interact D_{1i} with each of the 1998 and 2004 time fixed effects and include the two interaction terms in the model.

The northern towns are 'distant' from the motorway extension (i.e. greater than 7 kms) but their access to Auckland has improved as a result of the motorway extension. The potential benefit from this effect is included by specifying a dummy variable, D_{2i}, where D_{2i}=1 for the included areas in and around Warkworth (and zero otherwise), and of another dummy variable, D_{3i}, where D_{3i}=1 for the areas within Wellsford (and zero otherwise). Again we interact these variables with F_{1998} and F_{2004} to test whether the motorway extension has impacted on land values in these two areas. We hypothesise that the effect, if present, will be more material for Warkworth and surrounding areas than for Wellsford, which is more distant.

The estimated parameters on these interaction terms may reflect a number of factors impacting on values, and will not necessarily solely reflect the

[13] Initially we estimate our equations using pooled-OLS. We test these residuals for spatial dependence and, if such dependence is found, we re-estimate the equations using a spatial lag model (see equations (6)-(10) in the text).

impact of the motorway extension. In calculating net benefits, we undertake two different assessments. The first is a "narrow" estimate that excludes any effects calculated for the interaction terms; the second is a "broad" estimate that includes the interaction effects. These estimates can be interpreted as providing reasonable bounds for the effects of the extension on the relevant areas.

The expanded equation incorporating the interaction terms is as follows:

$$\begin{aligned} \ln L_{it} = {} & \beta_0 + \beta_1 A_{it} + \beta_2 \ln A_{it} + F_i + F_{1998} + F_{2004} + \beta_3 D_{1i} F_{1998} + \beta_4 D_{1i} F_{2004} \\ & + \beta_5 D_{2i} F_{1998} + \beta_6 D_{2i} F_{2004} + \beta_7 D_{3i} F_{1998} + \beta_8 D_{3i} F_{2004} + \varepsilon_{it} \qquad (4) \end{aligned}$$

Equation (4), our baseline equation, is initially estimated using pooled OLS with fixed effects. We subsequently test the robustness of these estimates in a number of ways.

The first test is undertaken to ascertain whether the motorway extension had a negative effect on land values close to pre-existing motorway exits on the original Northern Motorway. We form a dummy variable, D_{0i}, where D_{0i}=1 for areas within 2 kms of the pre-existing exits (and zero otherwise).[14] We interact D_{0i} with each of F_{1998} and F_{2004} and test whether a negative effect is apparent in these two years. If there is a significant negative effect, the implication is that the opening of the new exits has resulted in a diminution of land value in areas that were previously valued highly because of their proximity to motorway exits. The resulting extended equation is shown as (5).

$$\begin{aligned} \ln L_{it} = {} & \beta_0 + \beta_1 A_{it} + \beta_2 \ln A_{it} + F_i + F_{1998} + F_{2004} + \beta_3 D_{1i} F_{1998} + \beta_4 D_{1i} F_{2004} \\ & + \beta_5 D_{2i} F_{1998} + \beta_6 D_{2i} F_{2004} + \beta_7 D_{3i} F_{1998} + \beta_8 D_{3i} F_{2004} \\ & + \beta_9 D_{0i} F_{1998} + \beta_{10} D_{0i} F_{2004} + \varepsilon_{it} \qquad (5) \end{aligned}$$

[14] We choose a 2 km range (rather than a wider range) since we wish to restrict attention to areas that are most likely to have had an accessibility premium built into their land values.

Second, we estimate a spatial lag variant of (5). Specifically, letting L_t be the (Nx1) vector of land values across all i for period t and W_i be a time-invariant weight (1xN) vector for meshblock i, we add $W_i lnL_t$ to the system, with parameter ρ, as in (6).

$$\begin{aligned} lnL_{it} = {} & \beta_0 + \beta_1 A_{it} + \beta_2 lnA_{it} + F_i + F_{1998} + F_{2004} + \beta_3 D_{1i}F_{1998} + \beta_4 D_{1i}F_{2004} \\ & + \beta_5 D_{2i}F_{1998} + \beta_6 D_{2i}F_{2004} + \beta_7 D_{3i}F_{1998} + \beta_8 D_{3i}F_{2004} \\ & + \beta_9 D_{0i}F_{1998} + \beta_{10} D_{0i}F_{2004} + \rho W_i lnL_t + \varepsilon_{it} \qquad (6) \end{aligned}$$

The elements of W_i are set = 0 where the distance of the centroid of meshblock i to the corresponding meshblock centroid exceeds Y kms (where Y is imposed in the construction of W_i) ; the remaining elements are equal and sum to unity. Thus we test whether spatial dependence exists between land values of meshblocks within Y kms of each other after controlling for all other effects that appear in (6). We estimate (6) using maximum likelihood. Our choice of Y is based on results from applying Moran's I test for spatial autocorrelation to the residuals of (5) over different distance bands.

If ρ is significantly different from zero, the β_1 and β_2 coefficients no longer represent the full effect of the motorway extension on land values since the new exits also impact on neighbouring meshblock values which impact on lnL_{it} through the $W_i lnL_t$ term. To estimate the full effect, rewrite (6) in matrix notation as:

$$\mathbf{lnL} = \rho \mathbf{WlnL} + \mathbf{X}\beta + \varepsilon \qquad (7)$$

where **lnL** is the vector of land prices, **W** is the spatial weight matrix, ρ is the spatial lag coefficient, **X** is the matrix of all other explanatory variables, β is a conformable coefficient vector, and $\boldsymbol{\varepsilon}$ is an iid error vector.[15] Hence (where $\mathbf{I}$ is the identity matrix):

$$\mathbf{lnL} = (\mathbf{I} - \rho\mathbf{W})^{-1}\mathbf{X}\boldsymbol{\beta} + (\mathbf{I} - \rho\mathbf{W})^{-1}\boldsymbol{\varepsilon} \tag{8}$$

If (8) is the true model (i.e. if $\rho>0$), it is appropriate to estimate the spatial lag model in (7) and to calculate the full effect on **lnL** of a change (Δ) in **X** as $(\mathbf{I} - \rho\mathbf{W})^{-1}\Delta\mathbf{X}\boldsymbol{\beta}$.[16]

The specification in (7) and (8) assumes that the nature of the spatial lag is consistent across all explanatory variables in **X**. This is an assumption that can be tested. Specifically, to check the appropriateness of (8), we can partition **X** into $\mathbf{X_1}$ and $\mathbf{X_2}$ (with coefficient vectors γ and δ respectively) and consider the alternative model in which the spatial lag applies to the explanatory variables in $\mathbf{X_1}$ but not to those in $\mathbf{X_2}$:[17]

$$\mathbf{lnL} = (\mathbf{I} - \rho\mathbf{W})^{-1}\mathbf{X_1}\gamma + \mathbf{X_2}\delta + (\mathbf{I} - \rho\mathbf{W})^{-1}\boldsymbol{\varepsilon} \tag{9}$$

If (9) were the true model, the full effect on **lnL** of a change in $\mathbf{X_1}$ is $(\mathbf{I} - \rho\mathbf{W})^{-1}\Delta\mathbf{X_1}\gamma$ whereas the full effect on **lnL** of a change in $\mathbf{X_2}$ is simply $\Delta\mathbf{X_2}\delta$. We can rearrange (9) as follows:

$$\mathbf{lnL} = \rho\mathbf{WlnL} + \mathbf{X_1}\gamma + \mathbf{X_2}\delta - \rho\mathbf{WX_2}\delta + \boldsymbol{\varepsilon} \tag{10}$$

If (9) were the true model and we were to estimate (7) instead, the residuals would display negative spatial autocorrelation (provided $\rho>0$) as a result of omitting $-\rho\mathbf{WX_2}\delta$ from the estimated equation (so incorporating this term into

[15] Equation (7) makes it clear why estimation of a non-spatial lag model ($\rho=0$) results in positive spatial autocorrelation in the residuals when $\rho>0$, since the term $\rho\mathbf{WlnL}$ is incorporated into the residual term.

[16] This approach is analogous to consideration of long-run effects in time series equations incorporating a Koyck lag.

[17] More generally, one could apply a different spatial lag parameter to the $\mathbf{X_2}$ variables relative to the $\mathbf{X_1}$ variables.

the residual term). When we estimate the spatial lag model, (7), we therefore test for residual spatial autocorrelation and, in particular, test for negative spatial autocorrelation. If the latter is present, and if the effect in which we are interested appears through $\mathbf{X_2}$ rather than $\mathbf{X_1}$, then the full effect calculation given by $(\mathbf{I} - \rho\mathbf{W})^{-1}\Delta\mathbf{X}\beta$ will lead to an over-estimation of the true full effect of the variables within $\mathbf{X_2}$.

As a third test of our results, we estimate the previous models (with and without spatial lags) using just the 1992 and 2004 observations (i.e. omitting 1998).[18] The reason for doing so is that 1998 property values may have impounded forward-looking expectations regarding completion of the motorway. Thus meshblocks north of Constellation Drive in areas serviced by the planned motorway may have shown increases in value in 1998 even though their distance to the nearest exit did not fall below 7 kilometres until 2000. If this behaviour occurred, inclusion of such meshblocks in 1998 will lead to biased results. By contrast, the extension was unlikely to have been a common expectation in 1992 and had been completed in 2004, so the motorway's status in each of these years will be more explicitly connected to observed property values.

Presentation of results begins with estimation of the panel given by (4). We estimate the equation using both a balanced and an unbalanced panel. The former covers 1,517 meshblocks, each for 3 years, yielding a total of 4,551 observations. The unbalanced panel has 4,665 observations. The additional observations mostly come from meshblocks that are missing 1992 data.

Table 3 presents the estimates for the coefficients (β_1 and β_2) on the level and log of distance (A_{it} and $\ln A_{it}$), the time fixed effects (F_{1998} and F_{2004}) and the six area-time interaction terms (β_3, β_4, β_5, β_6, β_7, β_8). In each case, we present the estimated coefficient, standard error and associated p-value; together with the equation's R^2, root mean square error (RMSE) and mean and standard deviation of the dependent variable. For clarity, we do not present the constant or cross-

[18] This approach gives identical results to an explicit difference-in-differences specification in which we estimate the models (respectively with and without spatial lags) in difference form (2004 less 1992) with no area fixed effects.

sectional fixed effects; in all cases, the cross-sectional fixed effects are jointly significant (p=0.0000).

Table 3: Estimates of baseline equation (RNS)

	Balanced Panel				Unbalanced Panel		
	Coeff	**s.e.**	**p-val**		**Coeff**	**s.e.**	**p-val**
β_1	0.0009	0.0130	0.946		0.0043	0.0128	0.739
β_2	-0.2463	0.0401	0.000		-0.2568	0.0391	0.000
F_{1998}	-0.1548	0.0104	0.000		-0.1550	0.0103	0.000
F_{2004}	-0.1796	0.0111	0.000		-0.1794	0.0110	0.000
β_3	0.1692	0.0307	0.000		0.1733	0.0304	0.000
β_4	0.1203	0.0314	0.000		0.1181	0.0312	0.000
β_5	0.2044	0.0511	0.000		0.2046	0.0508	0.000
β_6	0.2470	0.0513	0.000		0.2468	0.0510	0.000
β_7	-0.0109	0.0908	0.905		-0.0107	0.0903	0.906
β_8	0.0728	0.0909	0.423		0.0726	0.0904	0.422
Total Obs	4,551				4,665		
R^2	0.956				0.957		
RMSE	0.255				0.254		
Dep var							
Mean	2.093				2.084		
Std Dev	0.996				0.993		

Equation estimated by pooled OLS for meshblocks in RNS over 1992, 1998 and 2004.
Equation estimated is:

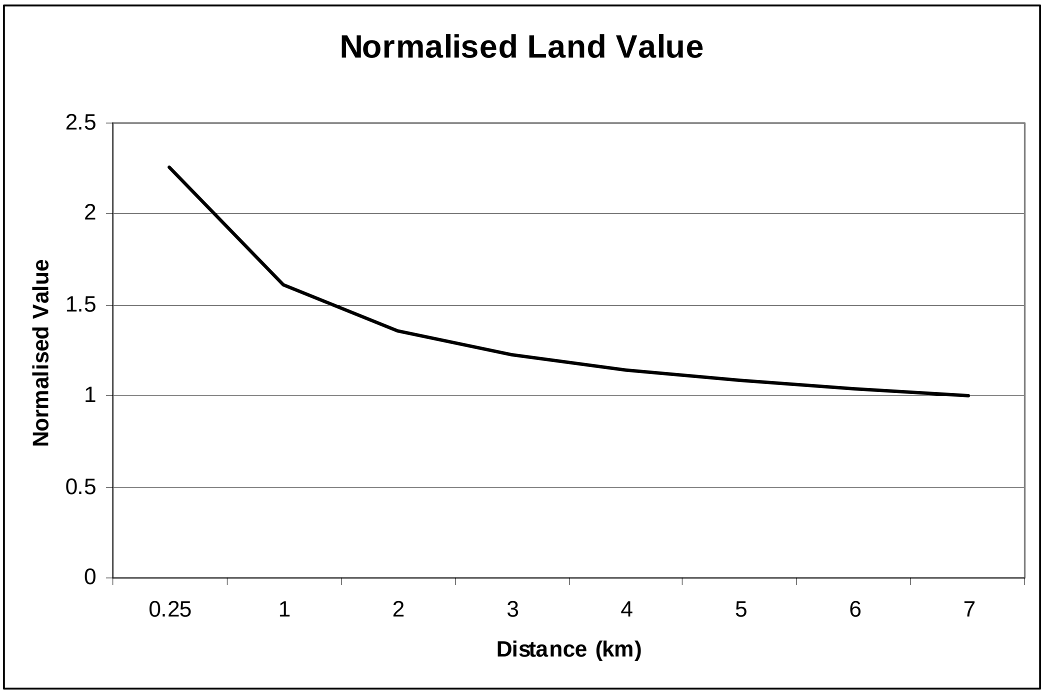
$$\ln L_{it} = \beta_0 + \beta_1 A_{it} + \beta_2 \ln A_{it} + F_i + F_{1998} + F_{2004} + \beta_3 D_{1i}F_{1998} + \beta_4 D_{1i}F_{2004} + \beta_5 D_{2i}F_{1998} + \beta_6 D_{2i}F_{2004} + \beta_7 D_{3i}F_{1998} + \beta_8 D_{3i}F_{2004} + \varepsilon_{it} \quad (4)$$

where L_{it} is (deflated) per hectare land value in meshblock i at time t, A_{it} is effective distance as defined in (2), F_i is a vector of area fixed effects (F_i and the constant are not reported for clarity), F_{1998} and F_{2004} are fixed effects for 1998 and 2004 respectively, D_{1i} is a dummy variable indicating whether the meshblock is in Orewa-WP, D_{2i} is a dummy variable indicating whether the meshblock is in Warkworth, D_{3i} is a dummy variable indicating whether the meshblock is in Wellsford, and ε_{it} is the residual.

The two sets of estimates (balanced and unbalanced panel) are very similar; henceforth we restrict our attention to the balanced panel results. The time fixed effects indicate that per hectare values in the RNS area declined (by 14% and 16% respectively in 1998 and 2004)[19] relative to other parts of Auckland following 1992.

The motorway effects are significant and non-linear. Taking both the estimated linear and log effects into account, land within ¼ km of an exit is worth 2.26 times land that is at least 7 kms from an exit after controlling for all other influences. The value gradient is shown in Figure 5, in which per hectare land value beyond 7 kilometres from an exit is normalised to one.

Figure 5: Baseline land value gradient (distance from nearest motorway exit)



In addition to this effect, land values in Orewa-WP increased materially in 1998 and 2004 relative to 1992, by 18% and 13% respectively. We cannot ascertain from these estimates whether this increase is due to the motorway impact or to other factors. The motorway exit by Orewa came on-stream in 2000 and strong forward-looking behaviour may have resulted in the rise in values in 1998; however this cannot be substantiated by the available evidence.

Compared with 1992, relative land values in Warkworth increased by 23% in 1998 with a further increase to 28% in 2004. Warkworth town itself grew during this period as did the popularity of nearby beach resorts. While it is entirely plausible that this growth was at least in part due to the anticipated, and then actual, improvement in accessibility, we again cannot substantiate whether this was the sole or contributing cause for the effect.

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[19] Note that the percentage changes equal [exp(x)-1] where x is the estimated time fixed effect.

By contrast, there was no significant change in land values for Wellsford following 1992. After controlling for other factors, Wellsford's 1998 values were within 1% of their 1992 values; its 2004 values were estimated to be 8% higher than in 2004. This latter figure may indicate some positive reaction to the motorway extension; however the effect is not statistically significant. The relative impacts of the extension on Warkworth compared with Wellsford are consistent with the hypothesized reaction of land values for these towns in response to the motorway opening. These relative reactions are indicative that some of the Warkworth impact, at least, was due to improved motorway access.

The estimates presented in Table 3 do not include any potential negative impact of the motorway extension on property values elsewhere. As discussed, it is possible that negative impacts were experienced in areas previously privileged by prior advantageous motorway access. To investigate whether negative impacts occurred in such areas, we estimate (5) which supplements (4) with two additional interaction terms. These terms (with coefficients β_9 and β_{10}) indicate whether land values within two kilometres of the pre-existing Northern Motorway exits altered following completion of the new motorway exits.[20] Results for the balanced sample are presented in the left-hand portion of Table 4.

Comparison of the coefficients in Tables 3 and 4 indicates that addition of the variables pertaining to pre-existing exits has very little effect on other coefficients, and has no discernible effect on overall model fit. The two additional interaction terms are negative, as expected if the new exits reduced the premium enjoyed by land near pre-existing exits, but neither is significantly different from zero. Further, neither point estimate is material in an economic sense; the 2004 term indicates that land near the former exits is valued within 1% of 1992 values after controlling for other influences. Thus there is no evidence of a material displacement effect of the new exits within the RNS area. Auckland land values generally rose relative to values in RNS after 1992, so there is also no evidence of

[20] We do not include any terms to account for potential diminution in value elsewhere in Auckland or the rest of the country, with the implied assumption that value loss will be most apparent in areas already served by the Northern Motorway. However we cannot rule out that other displacement effects could have occurred.

a displacement effect elsewhere in Auckland (although we do not subject this to explicit test).

Table 4: Estimates of extended equation (RNS) with Moran's I

	Balanced Panel			Moran's I-Statistic		
	Coeff	**s.e.**	**p-val**	**Distance Band (km)**	**I**	**p-val**
β_1	0.0040	0.0136	0.771	**1992**		
β_2	-0.2535	0.0406	0.000	**0 - 0.25**	0.171	0.000
F_{1998}	-0.1437	0.0136	0.000	**0 - 1.0**	0.291	0.000
F_{2004}	-0.1756	0.0151	0.000	**0 - 2.0**	0.177	0.000
β_3	0.1581	0.0319	0.000	**0 - 5.0**	0.021	0.000
β_4	0.1186	0.0321	0.000	**1998**		
β_5	0.1933	0.0519	0.000	**0 - 0.25**	0.298	0.000
β_6	0.2430	0.0523	0.000	**0 - 1.0**	0.229	0.000
β_7	-0.0220	0.0912	0.810	**0 - 2.0**	0.121	0.000
β_8	0.0688	0.0915	0.452	**0 - 5.0**	0.040	0.000
β_9	-0.0275	0.0212	0.194	**2004**		
β_{10}	-0.0088	0.0219	0.688	**0 - 0.25**	0.227	0.000
Total Obs	4,551			**0 - 1.0**	0.336	0.000
R^2	0.957			**0 - 2.0**	0.209	0.000
RMSE	0.255			**0 - 5.0**	0.055	0.000

Equation estimated by pooled OLS for meshblocks in RNS over 1992, 1998 and 2004.
Equation estimated is:

$$\begin{aligned} \ln L_{it} = \; & \beta_0 + \beta_1 A_{it} + \beta_2 \ln A_{it} + F_i + F_{1998} + F_{2004} + \beta_3 D_{1i} F_{1998} + \beta_4 D_{1i} F_{2004} \\ & + \beta_5 D_{2i} F_{1998} + \beta_6 D_{2i} F_{2004} + \beta_7 D_{3i} F_{1998} + \beta_8 D_{3i} F_{2004} \\ & + \beta_9 D_{0i} F_{1998} + \beta_{10} D_{0i} F_{2004} + \varepsilon_{it} \end{aligned} \qquad (5)$$

where L_{it} is (deflated) per hectare land value in meshblock i at time t, A_{it} is effective distance as defined in (2), F_i is a vector of area fixed effects (F_i and the constant are not reported for clarity), F_{1998} and F_{2004} are fixed effects for 1998 and 2004 respectively, D_{0i} is a dummy variable indicating whether the meshblock is within 2km of a pre-existing Northern Motorway exit, D_{1i} is a dummy variable indicating whether the meshblock is in Orewa-WP, D_{2i} is a dummy variable indicating whether the meshblock is in Warkworth, D_{3i} is a dummy variable indicating whether the meshblock is in Wellsford, and ε_{it} is the residual.

We can assess the gross value of the motorway extension both excluding and including the area-time interaction effects. Excluding the interaction effects, we calculate the gross benefit of the motorway as follows. First, we calculate the gross value of all meshblocks in 2004 as determined by the estimates in Table 4. We then recalculate the gross value using the 1992 motorway distances in place of the 2004 distances (i.e. as if the motorway had not been extended beyond its 1992 form). The difference between the two calculations is the narrow estimate of the new motorway's gross benefit on RNS land values in 2004 dollars (i.e. excluding any effects arising from the interaction terms for Orewa-WP, Warkworth, Wellsford and pre-existing exits).

To calculate our broad estimate of benefit, we proceed as before but also set the interaction dummy variable terms to zero in the second stage. This assumption implies that all the increment (or reduction) in value associated with these terms is attributable to the motorway extension, contrasting with the former method which assumes that none of this change in value is attributable to the extension. Accordingly, the two approaches present reasonable bounds for the estimated effect of the extension on RNS land values.

The gross benefit, excluding the interaction terms, is calculated at $2.35 billion. Including the interaction terms, the gross benefit is calculated at $3.28 billion. These figures correspond to a B:C of 6.4 and 9.0 respectively relative to the extension's cost (in discounted 2004 dollars) of $0.366 billion. The measure of *ex ante* anticipated gross benefits presented in section 3 ($2.45 billion) is very close to the estimated gross benefit excluding interaction terms, and is approximately three-quarters of the estimated gross benefit including interaction terms.

The right-hand portion of Table 4 tests the residuals of the extended equation for spatial autocorrelation using Moran's I statistic.[21] The null hypothesis is of no spatial correlation of residuals. We calculate Moran's I using the residuals for each of the three waves of the panel to check whether there are consistent patterns over time. In each year, there is evidence of positive spatial correlation of residuals, particularly over shorter distance bands. The 1 km distance band shows the highest correlation for 1992 and 2004 and the second highest correlation for 1998 (with the 0.25 km band showing the highest value in that year).

As a consequence of these tests, we estimate equation (6) using maximum likelihood (ML[22]) setting Y (the maximum distance used to choose meshblocks for the weight matrix) to 1.5 kms. We estimate the equation solely for

[21] Moran's I indicates the correlation of residuals across different spatial bands.
[22] Assuming that the errors are normally distributed.

meshblocks within North Shore (i.e. omitting all Rodney meshblocks). Choice of sample and of Y=1.5km is dictated by the requirement of the maximum likelihood estimator that all meshblocks in the sample have at least one eligible neighbour.[23] The smallest value of Y for which this requirement is met is 1.5km, provided we restrict the sample solely to North Shore. This value for Y is close to the maximum degree of spatial correlation as indicated by Moran's I. Extension of the sample to Rodney would require Y>3.5km which departs considerably from this value.[24]

Results for the North Shore sample, for both the pooled OLS and spatial lag models, are presented in Table 5 (interaction terms relating to Orewa-WP, Warkworth and Wellsford are omitted due to the omission of Rodney District meshblocks from the sample). The OLS results are very similar to those for the broader RNS sample so the restriction in sample coverage does not materially alter our estimate of the distance effects. The narrow estimate of gross benefit solely for North Shore using the OLS estimates in Table 5 is $1.71 billion, with a broad estimate of $1.43 billion.[25] These compare with gross benefit estimates for North Shore of $1.99 billion and $1.87 billion respectively using the coefficients from the complete RNS sample.[26]

The spatial lag results are qualitatively similar to the OLS estimates but are quantitatively different. Significant spatial autocorrelation is observed with ρ=0.89. Coefficients on the time fixed effects and for the pre-existing motorway exits are smaller than for the OLS estimates. The coefficient on A_{it} remains close to zero (and statistically insignificant); the coefficient on $\ln A_{it}$ is approximately halved and borders on significance at p=10%.

[23] All OLS and ML (spatial lag) estimates in the paper are estimated using Stata.
[24] In addition, extension to Rodney meshblocks would result in our having to use an 80% sample of meshblocks owing to computer memory constraints.
[25] The broad estimate is lower than the narrow estimate since the North Shore calculation includes the negative effect around existing North Shore exits while the positive interaction terms pertaining to the Rodney areas are excluded.
[26] The gross benefits accruing to Rodney in that case are $0.35 billion for the narrow estimate and $1.41 billion for the broad estimate.

Table 5: Estimates of OLS and spatial lag models (North Shore only)

	OLS Model				Spatial Lag Model: Y=1.5km		
	Coeff	**s.e.**	**p-val**		**Coeff**	**s.e.**	**p-val**
β_1	0.0158	0.0135	0.241		0.0086	0.0157	0.584
β_2	-0.2587	0.0385	0.000		-0.1056	0.0644	0.101
F_{1998}	-0.1369	0.0127	0.000		-0.0180	0.0108	0.097
F_{2004}	-0.1638	0.0143	0.000		-0.0244	0.0125	0.052
β_9	-0.0337	0.0196	0.085		-0.0046	0.0116	0.689
β_{10}	-0.0201	0.0205	0.327		0.0050	0.0141	0.725
ρ					0.8885	0.0537	0.000
Total Obs	3,879				3,879		
Adj-R^2	0.944				0.960		
RMSE	0.235						

Equation estimated by pooled OLS and ML respectively for meshblocks in North Shore over 1992, 1998 and 2004. Equation estimated is:

$$\ln L_{it} = \beta_0 + \beta_1 A_{it} + \beta_2 \ln A_{it} + F_i + F_{1998} + F_{2004} + + \beta_9 D_{0i} F_{1998} + \beta_{10} D_{0i} F_{2004} + \rho W_i L_t + \varepsilon_{it} \quad (6)$$

where L_{it} is (deflated) per hectare land value in meshblock i at time t, A_{it} is effective distance as defined in (2), F_i is a vector of area fixed effects (F_i and the constant are not reported for clarity), F_{1998} and F_{2004} are fixed effects for 1998 and 2004 respectively, D_{0i} is a dummy variable indicating whether the meshblock is within 2km of a pre-existing Northern Motorway exit, Y is the maximum distance (in kilometres) of the centroid of meshblock i to that of other meshblocks that have a positive weight in W_i (the spatial weight matrix), ρ=0 in the pooled OLS model; and ε_{it} is the residual. Note that coefficients β_3-β_8 and associated variables are excluded since they pertain to Rodney meshblocks.

Table 6 presents the Moran's I statistic for the residuals from the spatial lag model. There is still some evidence of positive spatial autocorrelation over very short distances (up to 0.25km) but this effect is much reduced compared with the OLS results. For distance bands of 1 km or more, there is very little spatial autocorrelation. In particular, there is no significant negative spatial autocorrelation in either 1998 or 2004; in 1992, the largest negative coefficient is -0.029; despite its low value, this statistic is however significant at the 0.1% level. Overall, we prefer the spatial lag model to the OLS model and conduct the "full effect" calculation based on (8).[27] However due to the slight negative spatial autocorrelation (for 1992) there is a possibility that this calculation over-states the gross benefits arising from the extensions.

[27] A Lagrange Multiplier test rejects the OLS model in favour of both a spatial lag model and a spatial error model (both with p=0.000). We have estimated a spatial error model in addition to the spatial lag model. We did so using demeaned data for all variables, dropping the area fixed effects. For the spatial lag model using this data, R^2=0.381 (with all coefficients identical to those in Table

Table 6: Spatial lag model

Moran's I-Statistic		
Distance Band (km)	**I**	**p-val**
1992		
0 - 0.25	0.131	0.000
0 - 1.0	-0.029	0.000
0 - 2.0	-0.012	0.001
0 - 5.0	0.000	0.518
1998		
0 - 0.25	0.188	0.000
0 - 1.0	-0.007	0.358
0 - 2.0	-0.004	0.375
0 - 5.0	-0.001	0.954
2004		
0 - 0.25	0.118	0.000
0 - 1.0	0.017	0.009
0 - 2.0	-0.006	0.102
0 - 5.0	0.002	0.042

Narrow and broad estimates of the gross benefit (for North Shore only) using the spatial lag estimates in Table 5 are calculated as \$5.96 billion and \$6.62 billion respectively.[28] These estimates are more than twice those calculated for North Shore under the OLS approach, implying that omission of spatial dependence in the model produces an under-estimate of the benefit.

Table 7 presents estimates using just 1992 and 2004 observations (i.e. omitting 1998). The first panel of the table presents OLS results for RNS (which can be compared with those in Table 4 noting that terms relating to 1998 are now omitted; the second panel presents ML spatial lag results for North Shore only (which can be compared with those in the second panel of Table 5). The OLS results are very similar to those that included the 1998 observations. The narrow and broad estimates of the gross benefit of the motorway extension for RNS in this case are \$2.30 billion and \$3.26 billion respectively, very similar to the prior OLS estimates. The spatial lag results are also similar to prior results, although the coefficient on $\ln A_{it}$ is now significant at p=8%. The narrow and broad estimates of

4.3) while the spatial error model has R^2=0.083. We adopt the spatial lag model in preference to the spatial error model given its greater explanatory power.

gross benefit for North Shore of the motorway extension in this case are calculated as $4.79 billion and $5.05 billion respectively, approximately four-fifths of the estimated benefit obtained when using all three periods in the estimation.

Table 7: Estimates of models using 1992 & 2004 data (omitting 1998)

	OLS: (Rodney-North Shore)				ML: North Shore only		
	Coeff	s.e.	p-val		Coeff	s.e.	p-val
β_1	0.0372	0.0196	0.058		0.0209	0.0204	0.307
β_2	-0.3755	0.0606	0.000		-0.1498	0.0855	0.080
F_{2004}	-0.1776	0.0196	0.000		-0.0287	0.0135	0.034
β_4	0.1325	0.0412	0.001				
β_6	0.2450	0.0670	0.000				
β_8	0.0708	0.1172	0.546				
β_{10}	-0.0143	0.0283	0.614		0.0024	0.0140	0.863
ρ					0.8631	0.0627	0.000
Total Obs	3,034				2,586		
R^2	0.948				0.952		
RMSE	0.3268						

OLS equation estimated for meshblocks in Rodney-North Shore; ML equation estimated for North Shore only. Estimated equation is:

$$\ln L_{it} = \beta_0 + \beta_1 A_{it} + \beta_2 \ln A_{it} + F_i + F_{2004} + \beta_4 D_{1i}F_{2004} + \beta_6 D_{2i}F_{2004} + \beta_8 D_{3i}F_{2004} + \beta_{10} D_{0i}F_{2004} + \rho W_i \ln L_t + \varepsilon_{it}$$

where L_{it} is (deflated) per hectare land value in meshblock i at time t, A_{it} is effective distance as defined in (2), F_i is a vector of area fixed effects (F_i and the constant are not reported for clarity), F_{2004} is a fixed effect for 2004, D_{0i} is a dummy variable indicating whether the meshblock is within 2km of a pre-existing Northern Motorway exit, D_{1i} is a dummy variable indicating whether the meshblock is in Orewa-WP, D_{2i} is a dummy variable indicating whether the meshblock is in Warkworth, D_{3i} is a dummy variable indicating whether the meshblock is in Wellsford, W_i is the spatial weight matrix, ε_{it} is the residual; $\rho=0$ in the pooled OLS model.

N.B. Estimates give identical coefficients and standard errors to a differences equation estimated using data for 2004 less 1998 with specification:

$$\Delta \ln L_{it} = \beta_0 + \beta_1 \Delta A_{it} + \beta_2 \Delta \ln A_{it} + \beta_4 D_{1i}F_{2004} + \beta_6 D_{2i}F_{2004} + \beta_8 D_{3i}F_{2004} + \beta_{10} D_{0i}F_{2004} + \rho W_i \Delta \ln L_t + \varepsilon_{it}$$

[28] The 2004 interaction term for pre-existing exits is slightly positive in the spatial lag model, so making the broad estimate of benefit larger than the narrow estimate.

5 Net Benefits and Conclusions

Auckland's Northern Motorway extensions over 1995-2000 resulted in substantial changes in areas near, and to the north of, the new exits. Population and employment increased substantially faster in these areas than occurred across the Auckland region. Relative land values rose for land close to the new exits. Average household incomes, on the other hand, rose by slightly less than average incomes elsewhere in the region. Together, these outcomes imply that productive opportunities rose as a result of the extensions and that residents' perceptions of amenity values also rose overall.

Estimates of gross benefit obtained from our econometric approaches are displayed in Table 8. They vary from a minimum of $1.43 billion for North Shore alone and $2.30 billion for Rodney and North Shore combined, to $6.62 billion for North Shore alone.

Table 8: Gross benefit and benefit:cost estimates (2004 NZ$s)

		Gross Benefit ($ billion)	Benefit: Cost Ratio[6]
Ex Post Benefit Calculations:			
Rodney & North Shore			
OLS[1]:	**- Narrow**	2.35	6.4
	- Broad	3.28	9.0
OLS[2]:	**- Narrow**	2.30	6.3
	- Broad	3.26	8.9
North Shore only			
OLS[3]:	**- Narrow**	1.71	5.6
	- Broad	1.43	7.8
ML[4]: Full Effect	**- Narrow**	5.96	17.2
	- Broad	6.62	21.9
ML[5]: Full Effect	**- Narrow**	4.79	14.0
	- Broad	5.05	17.7
Memo Item:			
Estimated Project Cost		0.366	

[1] Extended model, based on (5) using OLS estimates in Table 4 with 1992, 1998 and 2004 data.
[2] OLS estimates in Table 7 using 1992 and 2004 data only.
[3] OLS estimates in Table 5.
[4] Spatial lag model based on (6), maximum likelihood estimates presented in Table 5.
[5] Spatial lag model, ML estimates in Table 7 using 1992 and 2004 data only.
[6] All B:C calculations use a cost estimate of $0.366 billion. For the "North Shore only" estimates , the narrow (broad) estimates have $0.35 billion ($1.41 billion) added to them representing the benefits estimated for Rodney from the OLS estimates in Table 4.

A major source of variation in the estimates arises from the estimation method. The spatial lag model is the more complete model, since it incorporates the spatial dependence that is apparent in the data. For this reason, it is likely to provide a more accurate estimate of the gross benefits than do the OLS results which do not account for spatial dependence. Nevertheless, there is some risk that the "full effect" estimates obtained from the spatial lag model may over-state the benefits given the slight negative spatial autocorrelation observed when using the spatial lag model.

A second source of variation in the estimated benefit arises from our interpretation of area dummy variables interacted with year fixed effects. The nature of the results for the Rodney interaction terms (particularly the smaller effects attributed to Wellsford than for Warkworth and Orewa) indicates that it is reasonable to attribute at least some of the difference between the narrow and broad estimates of benefit (in the RNS sample) to the motorway extension.

Our lowest estimate of gross benefit for RNS (of $2.3 billion) represents a reasonable lower bound both because of the omission of interaction term effects and because it is estimated using OLS rather than with the spatial lag. Even so, this level of gross benefit considerably exceeds the estimated extension cost of $0.366 billion (in discounted 2004 dollars) and yields a B:C of 6.3. Our highest estimate of gross benefit is $6.62 billion for North Shore alone. If we add to this figure the $1.41 billion in benefit estimated for Rodney (taken from the broad estimate in Table 5), an upper bound for the gross benefit amounts to $8.03 billion, yielding a B:C of 21.9. For reasons given above, however, this is likely to represent an over-estimate of benefit.

Taking a conservative approach, and working with the lower bound, indicates that the Northern Motorway extensions comfortably met the New Zealand Government's requirement that major roading projects have a B:C of at least 4 (using a real discount rate of 10%). The higher estimates of net benefit indicate that it is possible that the B:C reached the *ex ante* anticipated ratio of 16 (for the ALPURT A project) despite the construction cost overruns of that project.

Reflecting the calculated net benefits, the extensions enabled considerable population and employment expansion near the new exits, and greatly enhanced the attractiveness (amenity value) of the resort towns to the north of Auckland. The investment therefore appears to have met the criteria required of it. In establishing this result, however, we make no claim as to whether the motorway extension provides greater or lesser benefits than would similar investments in public transport networks in this or other regions.

New investments, particularly the Northern Motorway extension to Puhoi and the newly opened Northern Busway, will inevitably produce further gross benefits for the northern Auckland region. Similarly, given our results, passenger transport upgrades elsewhere in Auckland - including the suburban rail network - can be expected to yield gross benefits for the region. An evaluation of the net benefits (and B:Cs) of these additional projects has yet to be undertaken, but could proceed in future using the methods in this study as suitable data come to hand.

References

Duranton, Gilles and Diego Puga (2004) "Micro-Foundations of Urban Agglomeration Economies" in *Handbook of Regional and Urban Economics, Vol 4,* Vernon J. Henderson and J F. Thisse, Eds., Amsterdam: North-Holland.

Grimes, Arthur & Yun Liang (2007a) "An Auckland Land Value Annual Database", Motu Working Paper 07-04

Grimes, Arthur & Yun Liang (2007b) "Spatial Determinants of Land Prices in Auckland: Does the Metropolitan Urban Limit Have an Effect?", Motu Working Paper 07-09

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

Maré, David & Jason Timmins (2006) “Geographic concentration and firm productivity", Motu Working Paper 06-08

McMillen, Daniel & John McDonald (2004) "Reaction of House Prices to a New Rapid Transit Line: Chicago's Midway Line, 1983-1999", *Real Estate Economics* 32, 463-486

Roback, J. (1982) "Wages, Rents and the Quality of Life", *Journal of Political Economy* 90, 1257-1278

Rosenthal, Stuart and William Strange (2004) "Evidence on the Nature and Sources of Agglomeration Economies" in *Handbook of Regional and Urban Economics, Vol 4,* Vernon J. Henderson and J F. Thisse, Eds., Amsterdam: North-Holland.

Sinclair Knight Merz (2001) *ALPURT Post Construction Cost Audit: 'Managing $100 million'*, Wellington: Transfund New Zealand & Transit New Zealand

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