



Auckland's Knowledge Economy: Australasian and European Comparisons

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Abstract

This paper examines one key theme of modern spatial economics relating to city development: Do the major cities within and across countries increasingly attract a disproportionate share of knowledge intensive economic activities? We describe trends in shares of knowledge intensive economic activities within five major New Zealand and five major Australian cities, and interpret these trends in light of modern economic geography theories. The paper is mainly descriptive, filling an information gap in relation to trends in knowledge intensity across New Zealand and Australian cities. We also compare developments in Auckland's industry knowledge intensity with those in eight European comparator cities. Since 1991, Auckland's share of employment within knowledge intensive sectors has increased at a faster pace than all four comparator New Zealand cities and all five Australian comparator cities. These trends indicate that intra-country agglomeration forces have more than offset the inter-country agglomeration forces for Auckland. However the other four New Zealand cities have experienced lower growth in their knowledge intensive sector shares than the five Australian cities, a result that is consistent with the existence of agglomeration forces acting across Australasia.

JEL Classification: R11, R12

Keywords: Agglomeration, knowledge intensity, Auckland

Executive Summary

This paper examines one key theme of modern spatial economics relating to city development: Do the major cities within and across countries increasingly attract a disproportionate share of knowledge intensive economic activities? We describe trends in shares of knowledge intensive economic activities within five major New Zealand and five major Australian cities, and interpret these trends in light of modern economic geography (spatial economics) theories. The paper is mainly descriptive, filling an information gap in relation to trends in knowledge intensity across New Zealand and Australian cities. We also compare developments in Auckland's knowledge intensity with those in eight European comparator cities. Key findings are as follows:

- Since 1991, the share of Auckland's employment within knowledge intensive sectors (including both medium/high-tech manufacturing and knowledge intensive services) has increased at a faster pace than for the four comparator New Zealand cities (Hamilton, Wellington, Christchurch, Dunedin).
- In addition, Auckland's knowledge intensive share has increased at a faster pace than for all five Australian comparator cities (Sydney, Melbourne, Brisbane, Adelaide, Perth).
- The trends for the five Australian cities relative to the four smaller New Zealand cities accord with modern spatial economics hypotheses on the importance of agglomeration forces for city development.
- Auckland is benefiting from agglomeration forces within New Zealand, leading to the country's knowledge intensive services sectors becoming more concentrated upon Auckland. While historically this has led to its knowledge intensive services sectors increasing at a more rapid rate than for the Australian cities, the same agglomeration forces could, in future, act to relocate services industries from Auckland to Australia.
- Within New Zealand, Auckland had the highest employment intensity in medium/high-tech manufacturing in 1991, but the subsequent fall in its share has resulted in Christchurch having the highest intensity in this sector. Given Auckland's size, it nevertheless still has the most employees in these industries.

- Across the ten Australasian cities, only Hamilton had a material increase in its medium/high-tech manufacturing share between 1991 and 2006, with Dunedin holding approximately constant. All other cities had declining shares.
- Four Australasian cities (Perth, Sydney, Auckland, Melbourne) increased their employment intensity in “high-tech plus financial” knowledge intensive services between 1991 and 2006; Adelaide and Brisbane kept constant intensity. By contrast, the four smaller New Zealand cities all had declining intensities in these sectors.
- Auckland had a lower employment share in medium/high-tech manufacturing in 2006 than any of the eight European comparator cities.
- Furthermore, relative to the European comparators, Auckland’s intensity in each of medium/high-tech manufacturing and high-tech services fell between 1996 and 2006. This is despite Auckland performing relatively strongly in these sectors in an Australasian (and especially New Zealand) context.
- Consequently, Australasian cities are shown to perform comparatively poorly in knowledge intensive activities relative to their European counterparts.
- In contrast to the industry-based measures of changes in knowledge intensity, occupation-based knowledge intensity measures show stronger increases for the five New Zealand cities (led by Auckland) than for the five Australian cities.
- A corollary of this contrast is that well qualified New Zealand employees have greater opportunities in knowledge intensive industries in Australia than in New Zealand. Consistent with this observation, almost three times as many knowledge workers left New Zealand for Australia over 2006-2008 than arrived from Australia.
- Within New Zealand, each of Dunedin, Christchurch and Hamilton appear to have strengths based around their university specialisations and/or major facilities (such as a base hospital). Wellington has clear strength in public administration.
- Auckland has greatly increased its strengths in knowledge intensive services, having had weak positioning in most of these fields in 1991. It has benefited from a relative shift of knowledge intensive services from smaller New Zealand cities to Auckland. However it is at risk of losing some of these services to larger Australian cities.

- Opportunities for Auckland's knowledge intensive development may arise from the city's strengths in medical, science and engineering education and research. The city currently has low health and only moderate (but falling) medium/high-tech manufacturing intensity despite its tertiary education and research strengths.
- The past two decades' history suggests, however, that an explicit strategy (involving partnership between central and local government, tertiary and research institutions, and private firms) may be required to capitalise on these potential strengths.

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Auckland's Knowledge Economy: Australasian and European Comparisons

1. Introduction

This paper examines one key theme of modern spatial economics relating to city development: Do the major cities within and across countries increasingly attract a disproportionate share of knowledge intensive economic activities? This topic is of particular importance to New Zealand and to its cities. Australasia (Australia and New Zealand) is distant from major global economic centres, while New Zealand is distant from the major Australian cities (Sydney and Melbourne). Within New Zealand, a city such as Dunedin (in the south of the South Island) is distant from the country's dominant city, Auckland (in the north of the North Island). If major agglomerations increasingly attract knowledge intensive economic activities, these locational characteristics have important implications for the development of New Zealand's cities.

We describe trends in shares of knowledge intensive economic activities within cities and interpret these trends in light of modern economic geography theories.⁴

⁴ We concentrate on shares of activity rather than numbers of employees in order to control for broader growth trends acting on countries and cities; our treatment is consistent with that of related European studies, e.g. European Commission (2003) and Eurostat (2008).

The mainly descriptive nature of the paper reflects the situation that little work has hitherto examined the facts on knowledge intensities in relation to Australasian cities. Our interpretations place these facts within the context of modern spatial analysis. Given our descriptive focus, we do not analyse the detailed micro processes that may lead to greater or lesser knowledge intensity within specific cities, although our concluding section raises issues in this direction for further examination in relation to Auckland.

Auckland is New Zealand's largest urban area,⁵ with an official Statistics New Zealand population estimate of 1,333,000 in 2009. It is almost four times as large as each of Christchurch and Wellington (386,000 each), almost seven times as large as Hamilton (200,000) and over eleven times as large as Dunedin (116,000). The five named cities are the only New Zealand urban areas that have population in excess of 100,000 and have a university headquartered within their boundaries. Of these five urban areas, Auckland has grown most rapidly since 1991. Between that year and 2009, population increases were: Auckland 52%, Hamilton 37%, Wellington 19%, Christchurch 27% and Dunedin 8%.⁶

International studies, summarised in the next section, demonstrate that knowledge intensive economic activities⁷ tend to cluster within larger agglomerations that both have more firms in similar industries and have firms involved in a wider range of activities that are required to complement the

⁵ We refer interchangeably between urban areas and cities. The latter term is interpreted as the greater metropolitan area rather than as an administrative unit. For instance, figures for "Auckland" relate to Statistics New Zealand's definition of the urban area; they do not reflect the administrative units known as Auckland Regional Council or Auckland City Council.

⁶ Napier/Hastings (123,000) and Tauranga (118,000) are both slightly larger than Dunedin, but neither have a university headquartered in their area, although Tauranga does have a satellite campus of University of Waikato. Between 1991 and 2009, the Napier/Hastings population grew by 12% and Tauranga's grew by 68%; thus the three fastest growing major cities in New Zealand since 1991 (Tauranga, Auckland, Hamilton) are all situated in the northern half of the North Island. Palmerston North (80,000), Nelson (59,000) and Rotorua (56,000) complete the top ten urban areas by population.

⁷ New Zealand's Department of Labour defines knowledge intensive industries as follows: "The knowledge economy consists of those sectors with a highly skilled workforce and which invest heavily in knowledge-based assets (intangibles) such as R&D, staff development, product design and development, and brand equity" (Department of Labour, 2009, p.4).

knowledge intensive firm. Cities exhibiting these characteristics tend to have high living standards relative to smaller, less knowledge intensive, cities within the same country. Given Auckland's size within New Zealand, plus the presence of three major universities within the city,⁸ Auckland can be expected to exhibit a higher concentration of knowledge intensive activities than other New Zealand cities.

While Auckland is dominant within New Zealand, comprising 31% of the country's population in 2009, it is only a second-tier city within Australasia. Two of the mainland Australian state capital cities have urban area populations that are much larger - Sydney 4.4 million and Melbourne 3.9 million; Brisbane at 1.9 million⁹ and Perth at 1.6 million are somewhat larger, while Adelaide at 1.2 million is of a similar size to Auckland. Auckland is therefore only the fifth largest urban area in Australasia.

Within a wider international context, Auckland pales still further in terms of city size. A feature of international development trends over the past two decades is that high value activities are becoming increasingly concentrated into larger cities (see next section). Given these global agglomeration trends, the development of Auckland is of particular importance for understanding New Zealand's development.

If one were to focus solely within New Zealand, the agglomeration trends should favour the employment growth of Auckland, and especially growth within its knowledge intensive industries. However, the same trends imply that Auckland's share of knowledge intensive activities may be on a declining trend relative to the major cities of Australia. Furthermore, even these latter cities may be on a

⁸ University of Auckland, Auckland University of Technology and Massey University – Albany campus.

⁹ The population of "South-East Queensland", being the statistical divisions of Brisbane, Gold Coast, Sunshine Coast and West Moreton, was 2.9 million in 2008 (see Australian Bureau of Statistics: www.abs.gov.au/Ausstats/abs@.nsf/mf/3235.0).

declining trend relative to still larger developed cities internationally that are well connected to global supply chains and global centres of intellectual activity.

Given these forces, this study examines how trends in Auckland's knowledge intensive activities have developed relative to those in comparator cities within New Zealand and Australia. We also provide a comparison of Auckland's knowledge intensive economic activities relative to "like" cities in Europe. For the Australasian data, we provide comparisons both in terms of industry (sector) and occupation. Sectoral comparisons are based on standard OECD and EU definitions of medium/high-tech manufacturing (HTM) and knowledge intensive-services (KIS); use of standard definitions enables us to interpret the Australasian city data in an international context. Occupational comparisons are based on Statistics Canada definitions of knowledge workers. Use of both sectoral and occupational definitions of knowledge intensive activities enables us to cross-check and interpret our findings using different methodologies.

Section 2 of the paper provides contextual information that underlies both the importance of knowledge intensive activities for regional and national prosperity and the patterns that one might expect to observe in relation to knowledge intensive activities for Australasia's cities. Our data sources are described in section 3, both in relation to the sectoral data and the occupational data. Section 4 provides detailed analysis of trends in the Australasian city data, informed by the contextual information described previously. The comparison with European city data is provided in section 5. Section 6 synthesises the findings of the paper, providing an interpretation of the observed trends, with remaining questions highlighted. The interpretations draw on modern spatial economics. Our approach does not preclude the importance of other factors for city development, such as regional or national institutions. However, within Australasia, institutions are broadly comparable across and within the two countries. By contrast, cities are more likely to be differentiated by geographical factors and it is these factors that are our focus.

2. Knowledge intensive activities: Context

Cities are places of wealth generation and trade. Despite occupying only a tiny percentage of the country's land area, New Zealand's top ten cities contain two-thirds of the nation's population. Individuals and families choose to live in a particular city in preference to all other cities, towns and rural areas in which they may legally reside. They make their location choice based on many factors, including historical, cultural, and family ties, availability of amenities and economic factors. A key economic factor is the availability and variety of remunerative employment. Thus the location choices of firms are also a crucial determinant of individuals' location choices.

It is well documented that cities in general, including major cities in New Zealand, embody a productivity and pay premium relative to less urbanised areas within the same country (MED et al, 2007; Maré, 2008; Stillman and Lewis, 2007). Furthermore, within Australasia, there is a productivity premium between the major Australian states and New Zealand (Grimes, 2005). Once a city has reached an important position in a country's economy, it is normal for it to maintain a leading role within that economy (Davis & Weinstein, 2002). However, such pre-eminence is not guaranteed. The products that once made Detroit a major engine of industry in the United States no longer give it that leading position (Klier and Rubenstein 2008); its unemployment rate is now close to 30% and whole neighbourhoods have been abandoned. Within New Zealand, Dunedin was the country's third largest city in 1901 (with 78% of Auckland's population),¹⁰ and it is now seventh. Whanganui was the country's sixth largest urban area in 1901, and it is no longer in the top ten; its once flagship industries based on flax collapsed as production and demand switched to other forms of fibre.

¹⁰ Source: New Zealand Official Yearbook, 1903.

Over the past two decades, the nature of economic production and trade has changed markedly as the information technology (IT) revolution alters the nature of business relations. McCann (2009), in analysing these issues in relation to New Zealand's development, notes that, in some respects the world has become "flatter" in the sense of Friedman (2007). Friedman argued that production of a wide range of products and services can now be undertaken within many newly industrialising countries. Leamer (2007) and McCann (2008), however, dispute the ubiquity of Friedman's claim to "flatness". Instead, they argue that there are two major forces at work in determining production locations.

The first, consistent with Friedman's thesis, is that improved IT and supply chain management processes pertaining to routinised (or codified) activities has enabled international "outsourcing" to low cost locations for certain activities. In particular, routine production of low value-added goods that are produced under conditions of constant returns to scale can be outsourced. Thus standard product manufacture and assembly is increasingly located in factories in East Asia or Eastern Europe; call centres for developed countries are increasingly located in East and Southern Asia.

The second force is that high value added activities are increasingly characterised by location in large agglomerations, with knowledge intensive inputs incorporating not just universities and research facilities, but also marketing, legal and financial services. The latter are complements to the research inputs. Those involved in bringing high value goods and services to market benefit from explicit and tacit knowledge gained through face to face contact with producers, customers, suppliers and others involved in the same process. This second force is essentially the antithesis of the first, at least with respect to knowledge intensive activities. Furthermore, transactions costs for knowledge intensive, non-standardised activities have risen in recent years despite the IT revolution because of the increased importance of timeliness, customisation, service quality and service delivery, each emphasising the

importance of “closeness to market” (Disdier and Head, 2008; Duranton and Storper, 2007). These factors have increased the importance of agglomeration for many knowledge intensive activities.

The first force is enabling a spreading out of lower value activities while the second is leading to a concentration of higher value activities in major agglomerations that have the required suite of knowledge intensive inputs. The effect of the two forces is to emphasise a core-periphery split: the core has major centres with high value added activities associated with strong knowledge intensive inputs, while the periphery is characterised by firms, and a workforce, pursuing more mundane and less lucrative production tasks.¹¹

McCann (2008) develops this process more formally at a macro-and inter-regional scale and also at a micro-individual urban scale (McCann 2007). These patterns have differing implications for the relationship between core-periphery locations of knowledge intensive manufacturing versus knowledge intensive services. The latter are key components of a core city given the importance of a suite of knowledge intensive services for high value added activities. By contrast, knowledge intensive manufacturing may be located in less agglomerated regions, especially near a university or other research facility relating to the manufacturing process. For instance, O’Uallachain (1999) finds that while patent activity in the United States is heaviest in the large metropolitan areas, in smaller areas it is affected significantly by the presence of a major university. This pattern is also observed within Europe, where the correlation coefficient between high-tech knowledge intensive services and regional GDP per capita (0.70) considerably exceeds that between medium/high-tech manufacturing and GDP (0.43) (European Commission, 2003).

¹¹ Baran (1957) emphasised a core-periphery split in relation to cross-country development patterns; Friedmann (1966) applied the concept to intra-country regional development, characterising core regions as metropolitan centres with high potential for innovation and growth.

Within New Zealand, Auckland is clearly the country's pre-eminent commercial city. Given the analysis above, one may hypothesise that over the past two decades Auckland will have cemented its position as the country's core city. This would imply that we will observe high value added production becoming an increasing proportion of Auckland's economy and that Auckland will have been capturing a larger proportion of New Zealand's high value added production.

At an Australasian level, however, Auckland is not at the core. Sydney and Melbourne have traditionally been the core cities, dominating both in terms of population and concentration of high value added activities such as financial firm headquarters. Brisbane, at least in population terms, is on a trajectory that may see it one day rival the two core cities; while Auckland may be on a par with Adelaide and Perth in terms of its economic role. At this spatial level, Auckland may therefore be regarded as the major city in a peripheral economy (Grimes, 2005) with specialisations appropriate for its location. If this is the case, Auckland may have experienced a relative loss of high value added activities to the core Australasian cities which, in turn, may be facing similar pressures with respect to major Asian knowledge hubs.

The question of whether Auckland can be viewed as a core or a peripheral city is at the heart of the analysis in this paper. Our approach in analysing this question draws on recent international empirical studies that highlight the industry and occupational mix within a city. These serve as markers of the intensity of high value added production in that city. In highlighting markers of such activity, we are careful not to prescribe a particular indicator as being a sufficient single measure of high value added production. A recent analysis of similar issues in Sweden (Mellander, 2008) notes the importance of testing and including alternative measures for such analysis. One approach uses industrial structure data to define measures of knowledge intensive (equated to high value added) industries; intertemporal comparisons across cities can then be made to

determine which regions are becoming relatively more dominant in the production of such activities.

Mellander notes that researchers who solely use industry data either explicitly or implicitly assume a high correlation between occupations that require high levels of knowledge handling and the industries defined as being knowledge intensive. However, a high correlation does not necessarily exist. For instance, one firm in a high-tech industry may outsource all its low-tech jobs, e.g. cafeteria workers, to an outside firm, while another may choose to employ its own cafeteria workers. An industry definition will include the cafeteria workers as belonging to the high-tech industry for the second firm but not the first.¹² Cross-country comparisons (especially where labour or contract laws differ) may inappropriately capture institutional employment features that provide misleading estimates of knowledge workers in one country relative to another.

Another feature highlighted by Mellander is the difficulty of adequately defining the set of high value added occupations (or industries). She differentiates between creative industries (and creative workers) and knowledge industries (and highly educated workers). Both types of industries (and workers) tend to congregate in larger agglomerations, both may contribute to high value added production and the two may be complements to each other. If they are complements then a focus just on knowledge industries will be incomplete without reference also to the share of creative workers (e.g. in advertising or design).

The need to consider both occupational and industry categories in analysing high value added production activities has been emphasised by Koo (2005) and Currid and Stolarick (2008) as well as by Mellander. In her research on Sweden,

¹² Another potential cause of confusion may arise where a “low-tech” industry outsources some knowledge intensive functions, such as accounting services, to an external provider. Use of an industry definition will find that the economy’s knowledge intensive share has risen despite no substantive change in the actual knowledge share.

Mellander ranked (3-digit) industries based (a) on their proportions of individuals in creative occupations (following Florida, 2002), and (b) on their proportions of highly educated individuals (i.e. a three year university degree or higher). Three industries appeared in the top ten industries according to both rankings, leaving fourteen other industries which ranked in the top ten on one definition but not the other. IT-intensive industries notably tended to rank highly on the creative industry definition but not on the knowledge industry definition.

Both definitions appear important as indicators of high value added industries. Mellander shows that, over 1993-2001, the top quartile of both creative industries and knowledge industries (by creative and knowledge intensity of employment shares respectively) had wage growth that exceeded the top quartile of either services firms or manufacturing firms in Sweden. The respective percentage remuneration increases for the top quartile of each definition of firm were: creative firms (60%), knowledge firms (59%), services firms (43%) and manufacturing firms (48%). In addition, the number of establishments grew faster for creative firms (33%) and knowledge firms (37%) than for either services firms (18%) or manufacturing firms (2%). Crucially, Mellander found that both creative firms and knowledge firms have a strong tendency to locate in larger market places measured by number of employees, number of establishments and labour income. Furthermore, labour income in both creative and knowledge industries is strongly related both to employee concentration and accessibility to population centres.

The European empirical evidence is consistent with the analysis in McCann (2009) that larger core agglomerations tend to attract a greater proportion of high value added activities than do peripheral areas. Within New Zealand, there is a small body of work that shows similar results. Maré (2008) demonstrates that productivity in 2006 was highly correlated with employment density both across New Zealand's regions and within the Auckland Region. Auckland, being the region with greatest density, exhibits a productivity premium relative to other

parts of New Zealand. This premium can be split into two broad categories: an industry composition effect and an independent location-specific effect. The composition effect reflects the differing sectoral make-up of the city relative to the rest of the country; since average productivity is higher for some sectors than others, a concentration of high value added industries results in higher average city productivity relative to other regions. On an unadjusted basis, Auckland Region has approximately 45% higher productivity than the rest of New Zealand; this premium falls to a little over 20% once adjusted for industry composition. The adjusted premium reflects agglomeration externalities of various forms that make firms within an industry more productive in denser areas than elsewhere; “localisation effects” (in which firms benefit from being situated close to other firms in the same industry) explain a material portion of the observed agglomeration externalities.

New Zealand’s Department of Labour (DOL, 2009) examines the prevalence of knowledge intensive industries at a regional level. As with previously cited studies, the report starts from the observation that a country’s knowledge intensive industries tend to be focussed around its major cities. In order to analyse this issue empirically, the paper defines a set of knowledge intensive sectors and examines employment in this set of sectors regionally over 2000-2008.

The DOL definition of knowledge intensive sectors is based on a UK study, and differs from the OECD/European Commission definition. To be classified as a knowledge intensive sector by DOL, an industry must satisfy two criteria: (i) at least 25 per cent of the workforce must be qualified to degree level, and (ii) at least 30 per cent of the workforce must be employed in professional, managerial and scientific and technical occupations. This definition, while using industry level data, takes account of occupation (defined principally by knowledge intensity rather than creativity). This definition is based on a UK study; its application to New Zealand data means that it identifies a unique sub-set of sectors within its

knowledge intensive industry category. As such, the study is not comparable with published international studies. In addition, the regional aspects of the study are conducted according to administrative units (Regional Councils and Territorial Authorities) rather than urban areas, which are economically more meaningful. Nevertheless, the findings are insightful.

At the Regional Council level in 2008, Wellington had by far the highest share of employment in knowledge intensive industries at 42%, with Auckland second at 33%; Nelson had approximately the same ratio as the national average (30%) and all other regions had below-national employment shares in knowledge intensive industries. The Wellington figure is indicative of its capital city status with high employment in government knowledge intensive sectors. This central government effect (which need not be a productivity enhancing factor) is observed in studies internationally.

DOL find that over the 2000-2008 period, Auckland experienced the highest increase in knowledge intensive employment with 37% growth compared with the 25% growth in its overall employment. The five New Zealand cities identified for our study (Auckland, Hamilton, Wellington, Christchurch and Dunedin) can be matched to their respective Regional Councils (Auckland, Waikato, Wellington, Canterbury, Otago). The DOL study shows that the three North Island Regional Councils each had knowledge intensive growth in excess of the region's overall employment growth, whereas the two South Island Regional Councils both had knowledge intensive employment growth less than overall employment growth.¹³

The study splits industries into private and public knowledge intensive sectors, where the public sector includes all industries within *Public Administration and Safety, Education and Training, and Health Care and Social Assistance*; all other

¹³ Furthermore, nine of the remaining eleven Regional Councils had knowledge intensive employment growth less than overall employment growth. In Nelson, knowledge intensive employment growth only marginally exceeded overall employment growth, while, in Gisborne the divergence was greater but the region started with a knowledge intensive employment share well below the national average.

sectors are allocated to the private category. Over 2000-2008, Wellington was the only region in which public sector knowledge intensive employment growth exceeded private sector knowledge intensive growth. This idiosyncratic capital city phenomenon (which may well reflect political preferences relating to size of government) provides reason for caution when including a capital city (especially one that is not the prime commercial centre) in cross-city analyses. For this reason, we downplay Wellington in our empirical analysis.

3. Data sources

We obtained Census data from Statistics New Zealand (SNZ) and the Australian Bureau of Statistics (ABS) on the number of persons employed by detailed industry and occupation in 10 Australasian cities from 1991 to 2006. Appendix 1 Table 1 describes the industry data, and Appendix 1 Table 2 describes the occupation data. As detailed below, several concordances across time and countries have been used to make our city data as consistent and comparable as possible, but the potential for definitional changes to affect comparisons at the margin should be borne in mind.

The Australian city data are based on the Australian Standard Geographical Classification concept of a "statistical division", which is equivalent to a metropolitan area.¹⁴ For example, Figure 1 shows the Melbourne Statistical Division. This spans a greater area than the equivalent "urban centre" which ABS defines as the contiguous built-up area. Data were obtained for the five major state capital cities of Sydney, Melbourne, Brisbane, Adelaide, and Perth.

¹⁴ ABS (2009) note that capital city statistical divisions are defined with consultation from planners "to contain the anticipated development of the city for a period of at least 20 years". In each case "information on transport patterns, telephone traffic between major cities and towns, retail shopping, fresh goods marketing, provincial newspaper circulation areas and coverage of principal radio stations were all used in delimiting these boundaries."

Figure 1: Melbourne Statistical Division



Source: ABS

New Zealand city data are based on Statistics New Zealand's concept of an "urban area", which is defined similarly to ABS's statistical division.^{15,16} The New Zealand cities are Auckland, Wellington, Christchurch, Hamilton, and Dunedin.

We used the industry data provided by the statistical agencies to calculate the number of persons employed in "high-tech manufacturing", "medium-high tech manufacturing" (together comprising HTM), and several categories of "knowledge intensive services" (KIS) for each census year. These definitions were developed by the OECD and Eurostat, and are described in Table 3 (Appendix 1). They are widely used in OECD publications such as the *Science, Technology and Industry Scoreboard* and European Union publications such as the *European Innovation Scoreboard*. To ensure consistency in comparison, we do not depart from the

¹⁵ Statistics New Zealand (2006): "The six criteria for including an area within an urban boundary are: 1) strong economic ties; 2) cultural and recreational interaction; 3) serviced from the core for major business and professional activities; 4) an integrated public transport network; 5) significant workplace commuting to and from the central core; 6) planned development with the next twenty years, as a dormitory area to, or an extension of, the central core."

¹⁶ An alternative to using an urban area definition is to use the concept of a labour market area (LMA) or labour catchment, defined according to commuting patterns. However LMAs are unlikely to be an appropriate city definition for examining agglomeration issues since firms can interact easily across LMA boundaries. For example, while Auckland has two LMAs (with the split being near the southern part of Auckland City), a firm with its office headquarters in the north still interacts daily with its warehouse in the south, as well as with customers, suppliers and others in each LMA.

OECD/EU definitions in applying this approach to Australasia. This means we are potentially adopting a Euro-centric view of knowledge intensive activities and this may not always be appropriate, for instance with regard to rural industries. As an example, dairy farming in New Zealand may be considerably more knowledge intensive than dairy farming in France. By restricting our analysis to cities, we mitigate, but do not entirely eliminate, this potential issue.

Eurostat's (2008) International Standard Industrial Classification definitions of these industries were converted to the Australia and New Zealand Standard Industry Classification (ANZSIC 93) using a concordance provided by ABS (1993). To make use of 1991 census data, we converted the ANZSIC 93 definitions to the Australian Standard Industry Classification (ASIC 83) and the New Zealand Standard Industry Classification (NZSIC 87) using a concordance in the same document. See Appendix 1 Table 5 for the full concordance.

For the occupation data, we adopted definitions of "knowledge workers" from Statistics Canada (Beckstead & Vinodrai, 2003). This is one of relatively few efforts to systematically classify occupations at a detailed level based on occupation type (managers, professional, and technicians), education and relative wages. As for the industry data, we apply the Statistics Canada definition directly to Australasian cities to ensure maximum comparability with an externally defined benchmark.

Statistics Canada's knowledge worker definitions are based on the 1991 Standard Occupational Classification (Canadian), for which there is no official concordance to New Zealand or Australian occupational classifications. We wrote a concordance to NZSCO 99 for the relevant occupations using the job titles and task descriptions used by both classifications. From this, we used official NZSCO 95, NZSCO 90, and ASCO 2nd Edition concordances to define categories of knowledge workers in these classifications. The classes of

knowledge workers defined by Statistics Canada are shown in Table 4 (Appendix 1), and the concordance in Table 6 (Appendix 1).

All data sources have been matched as rigorously as original sources allow. However, three issues arise with the industry data.

First, the 1991 data use two classifications (ASIC and NZSIC) both of which are different to the joint Australia-New Zealand 1996-2006 classification (ANZSIC). While efforts have been made to classify employment across industries consistently, this should be noted both when comparing 1991 data with data from later years, and in comparing Australian with New Zealand city data in 1991. Some ANZSIC industries can only be partially matched to previous industries, and judgement was used to decide how to include them. A 1991 industry was included where it was thought that a majority of workers would have been included in the equivalent ANZSIC industries.

Second, Australian and New Zealand census coding procedures differ, and have changed over time. To aid industry classification, it is common to combine information on the census industry with the person's employer name. Employer name may or may not be matched with other databases (e.g. the Business Frame) to give a more accurate detailed industry. This has been the case in New Zealand for all four censuses, and in Australia in 1991 and 1996, but was not used in the 2001 and 2006 Australian census.¹⁷

Third, where industry can only be determined from census response at the 1-, 2- or 3-digit level, Australian and New Zealand practices differ. Discussions with Statistics New Zealand have shown that when industry can only be matched at

¹⁷ Brady et al (2000) note: "The two coding procedures yielded significantly different data distributions. A 2% sample of 1991 Census responses was coded using both business matching and industry description procedures. Results showed that 45% of the responses were allocated different codes at the 4-digit (class) level of the classification on the basis of the coding procedure used. More importantly, 10% of the responses were allocated different 1-digit (division) level codes."

the 3-digit level, and there is an N.E.C “not elsewhere classified” industry at the 4-digit level, the respondent will be placed in this industry. If industry can only be determined at a 1 or 2 digit level, or there is no obvious 4-digit N.E.C. industry, the respondent is excluded altogether. In Australia where an industry can only be determined at a 1-, 2-, or 3-digit level, it is placed at this level and declared as “not further defined”. We have followed New Zealand practice and excluded Australian 1-, and 2-digit industries where not further defined, and only included 3-digit industries if there is a 4-digit N.E.C. category that would have absorbed those respondents in the New Zealand census.¹⁸

The occupation data suffers from more comparability issues than the industry data, as the eight series use five different classifications. Fortunately the New Zealand classifications do not change greatly over time, and there were few issues matching them. However, the Australian classifications are rather different from those of New Zealand, and the concordance relies more heavily on judgement. We opted against using the official concordance, as there are large networks of partially mapped occupations (e.g. one occupation in ASCO 2nd edition mapping to four occupations in NZSCO 99, each of which map to three occupations in ASCO 2nd edition). The lack of detail in the Australian 1991 data (4-digit only) meant that we chose not to include 1991 occupational data for the Australian cities. For 2006, 6-digit data was obtained for the Australian cities by dividing 4-digit data according to 2001 ratios.

The management occupations are not readily comparable across countries as it is difficult to consistently distinguish management occupations in knowledge intensive industries from those in retail, construction, and transport. We therefore examine total knowledge worker trends both including (TKW) and excluding (TKWX) management occupations.

¹⁸ We constructed Australian city data using various alternative exclusion rules and the results are broadly consistent across the different definitions.

4. Australasian evidence

4.1. Overview

The census data described above enable comparisons of developments in Auckland's industrial and occupational structures relative to those in other major New Zealand cities and relative to the five major state capitals in Australia. For each variable, Appendix 2 presents a graph of the five New Zealand cities and a separate graph for the five Australian cities plus Auckland. All variables are presented for each of the four available census years (1991, 1996, 2001, 2006) other than occupational data for Australia which begin in 1996. Appendix 2 also provides definitions for each of the variable names. For each graph, the order of the New Zealand cities is: Auckland, Hamilton, Christchurch, Dunedin, Wellington. Wellington is left out of the north-south ordering since it is an extreme outlier on many counts, reflecting its unique capital city industry and occupational structure. The ordering in the 'Australia' graphs is always: Sydney, Melbourne, Brisbane, Adelaide, Perth, Auckland. The scales are chosen independently for each graph.

Prior to analysing the knowledge intensive industrial and occupational structure, we present evidence on the growth in employment in each of the ten cities over the fifteen years 1991-2006 (see Figure 2). Total employment has grown more rapidly in Auckland than in the other major New Zealand cities (increasing 54% over the fifteen years following 1991), although growth in Hamilton (48%) and Christchurch (45%) has also been high. By contrast, Dunedin (29%) and Wellington (27%) have lagged considerably. In some respects, Hamilton may be viewed as part of a larger Auckland-Waikato conurbation, in which case the employment growth in the country's larger cities can be conceived as concentrating on two nodes: Auckland/Hamilton and Christchurch.

Figure 2: Employment Growth



See Appendix 2 for definitions

Figure 2 indicates that Auckland's employment growth over the fifteen years has also outstripped employment growth in any of the five major Australian cities, being fractionally ahead of Brisbane (50%) and Perth (47%). These two cities are notable both for being 'sunshine cities' (towards which there has been a global developed country trend in terms of population) and for being the capital cities of mineral-rich states (Queensland and Western Australia respectively).

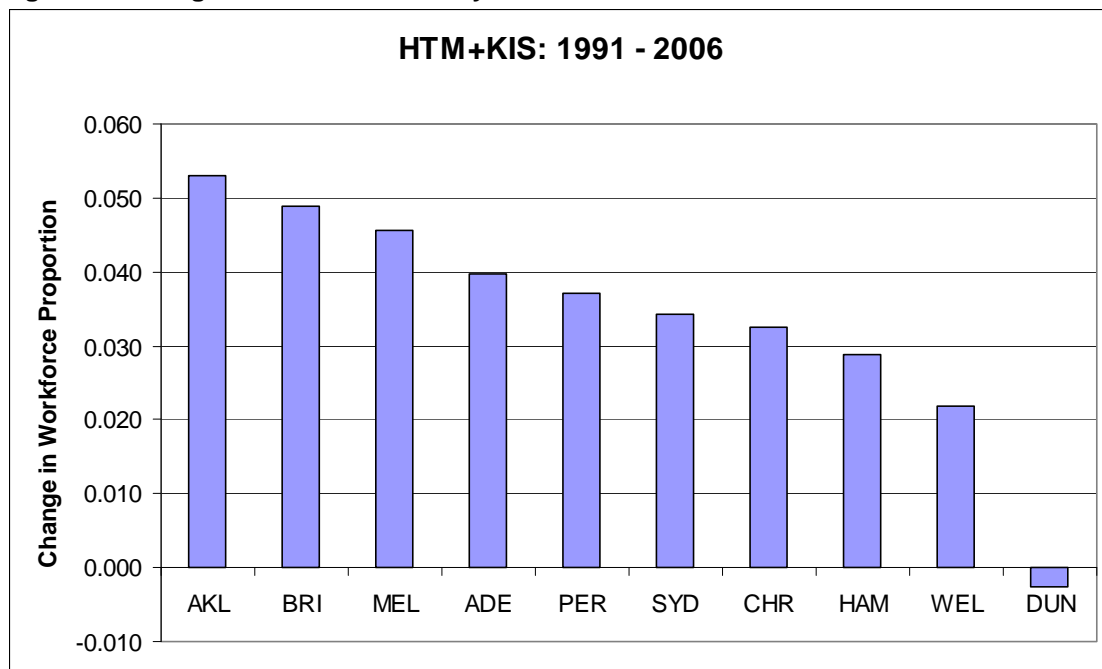
Employment growth in Auckland, Hamilton and Christchurch has therefore kept pace with that in Australia's fastest growing capital cities while substantially outstripping growth rates in Sydney (22%), Melbourne (27%) and Adelaide (15%).¹⁹

¹⁹ New Zealand was close to the height of recession at the time of the 1991 census; the country's unemployment rate in the first quarter of 1991 was 10.2% (source: Statistics New Zealand). However, this was only a little higher than Australia's unemployment rate of 9.3% at the same time (source: Australian Bureau of Statistics). Thus timing of recession is unlikely to have had a material influence on the cross-country growth comparisons.

4.2. Knowledge intensity by Industry

Given this overall employment context, we examine trends in knowledge intensive sectors across cities. Appendix 2 includes graphs for HTM+KIS, representing the proportion of employment that falls within the combined ‘medium/high-tech manufacturing’ (HTM) and ‘knowledge intensive services’ (KIS) categories. Figure 3 shows the change in the HTM+KIS share for each city between 1991 and 2006.²⁰

Figure 3: Change in HTM+KIS Intensity



See Appendix 2 for definitions

Excluding the capital city outlier (Wellington), Dunedin began the period as the dominant knowledge intensive New Zealand city with Auckland, Hamilton and Christchurch trailing well behind (see graphs in Appendix 2 for all industry share variables). Thereafter, Auckland’s share increased markedly and by 2006, it sat

²⁰ Figures 3 – 6 rely on consistent measurement practices in 1991 and 2006 (the beginning and end points of the industry change measures). As described in section 3, we consider that matches across time and countries are reliable for the industry data over this period, whereas we begin occupation data in 1996 owing to concern about 1991 occupation data. The levels graphs (Appendix 2) can be used to supplement our interpretations in the text for shorter time spans.

well above the other three cities. Dunedin's initial dominance reflects its historical status as a university and financial centre. Auckland's rise to pre-eminence within the country is consistent with the trends elucidated in McCann (2009) for knowledge intensive sectors to locate in a major agglomeration. By 2006, Auckland had become the primary knowledge intensive city within New Zealand (excluding Wellington).

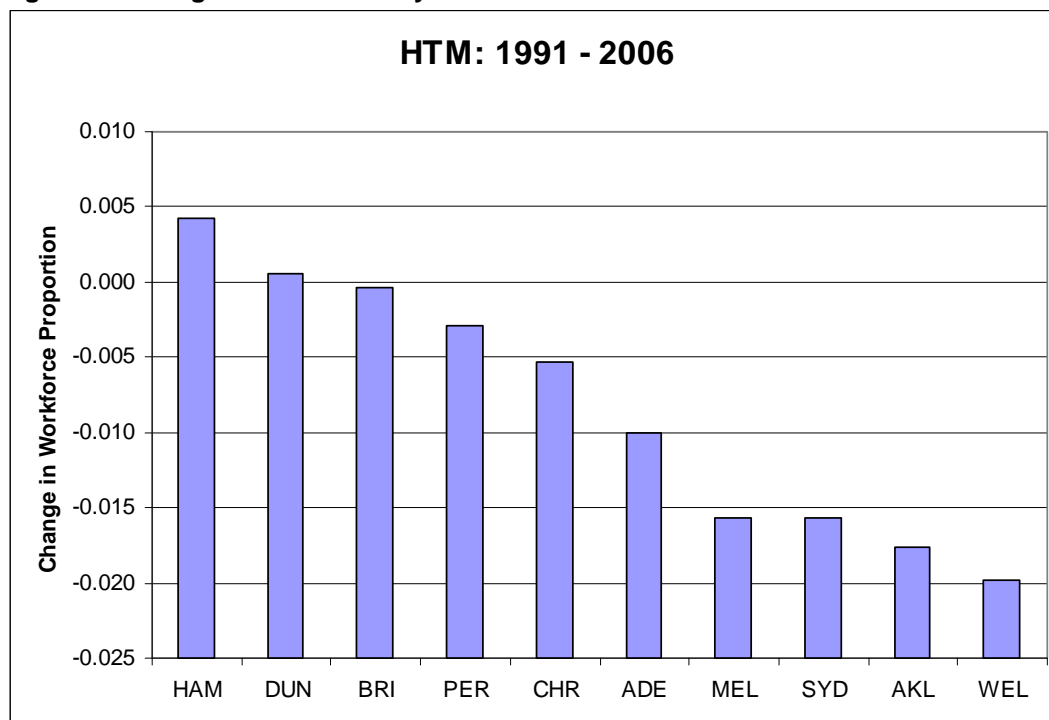
Relative to Australia, Auckland began the period with knowledge intensity equal to that of Sydney and ahead of the other four Australian cities. As described above, Auckland's knowledge intensity increased substantially over the fifteen year period; so too did the knowledge intensity of the Australian cities, particularly Brisbane and Melbourne. The latter had almost caught Sydney in knowledge intensity by 2006, creating a twin core city configuration within Australia. Nevertheless, Auckland retained a higher degree of knowledge intensity than any of the Australian cities in 2006 and had higher growth in knowledge intensity than any of the Australian cities. Its high relative knowledge intensity growth reflects the importance of agglomeration forces acting within New Zealand that more than offset the forces acting to drag knowledge intensive activities from New Zealand to Australia.

Our review of international empirical findings noted that agglomeration forces are not as strong for HTM as for KIS; for the former, the agglomeration tendencies may be modified by the presence of universities and other major research facilities. For some forms of services (e.g. health), patterns may also be modified by public investment choices over location of key facilities (e.g. base hospitals). By delving deeper into knowledge intensive sub-sectors, we uncover more information on the composition of the knowledge intensive sectors in each city.

Figure 4 graphs the change (over 1991 to 2006) in the proportion of employment accounted for by each city's medium/high-tech manufacturing (HTM); Appendix 2 contains the levels graphs. Within New Zealand, Auckland's (and Wellington's)

HTM intensity has fallen materially over time.²¹ Christchurch, with its comprehensive engineering school, now has the highest HTM intensity in New Zealand, with Auckland, Hamilton and Dunedin all having about three-quarters of Christchurch's intensity.²² Hamilton is the only city to have experienced a material increase in HTM intensity over the fifteen year period.

Figure 4: Change in HTM Intensity



See Appendix 2 for definitions

Within Australia, Melbourne and Adelaide have consistently been the leading cities in the HTM sectors, dominating HTM intensity in each of the four census years. Sydney and Auckland formed a second-tier group in 1991, but by 2006, both had similar HTM intensity to Brisbane and Perth. Overall, medium/high-tech manufacturing has comprised a declining share of employment across the major

²¹ Auckland's drop in HTM intensity between 1996 and 2001 in part reflects the closure of the Ford, Mazda, Toyota, Nissan and Honda assembly plants (and associated suppliers) in 1997/98 (source: *Te Ara: The Encyclopedia of New Zealand*, www.teara.govt.nz/en/cars-and-the-motor-industry/4).

²² Nevertheless, in 2006 Auckland still retained the highest *number* of people employed in the HTM sectors at 16,500 employees compared with Christchurch's 6,500 HTM employees.

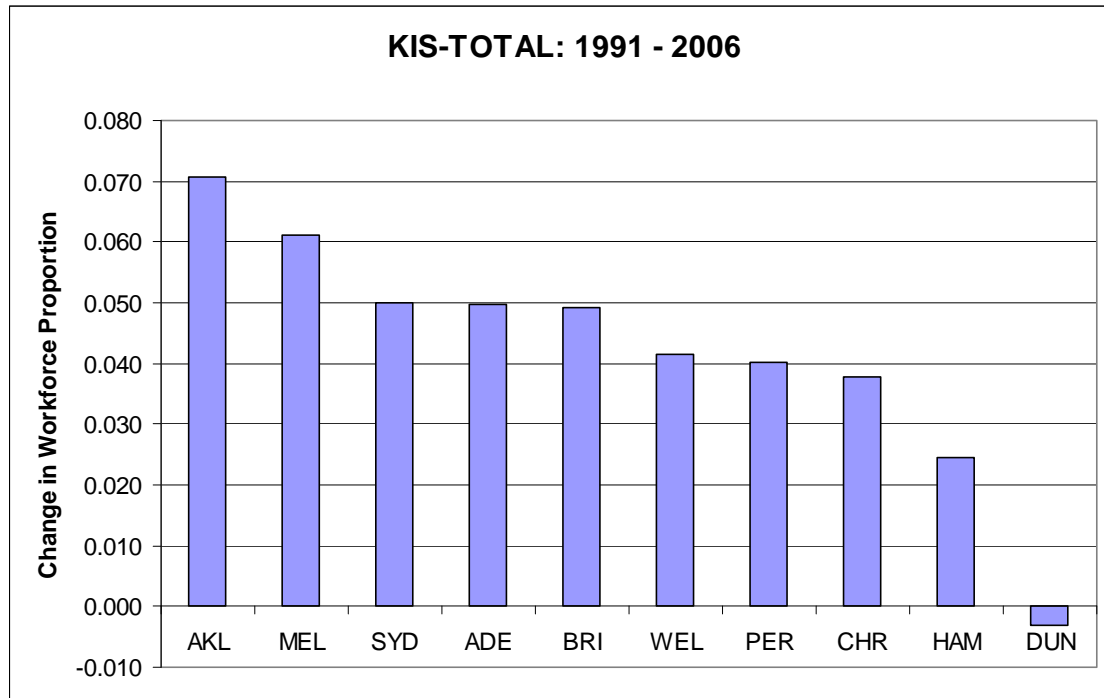
Australian and New Zealand cities over this period and has tended to cluster in three principal locations (of the ten cities studied) – Melbourne, Adelaide and Christchurch. Notably, the two core Australian cities (Sydney and Melbourne) plus New Zealand's major city and capital city (Auckland and Wellington respectively) have experienced the greatest falls in HTM intensity over this fifteen year period. Thus city-specific factors, rather than broader agglomeration factors, appear to have dominated developments with respect to cities' knowledge-based manufacturing sectors.

In contrast to the manufacturing trends, total knowledge intensive services (KIS-TOTAL) has comprised a strongly increasing share of employment in nine of the ten cities; only Dunedin has seen a (fractional) fall in its intensity (Figure 5). Wellington's capital city role has resulted in it remaining the leading New Zealand city for these sectors. Of the other four cities, Auckland began the period on a par with Christchurch and below Hamilton, with Dunedin being the dominant KIS city. By 2006, however, Auckland had achieved the highest KIS intensity of all (non-capital) New Zealand cities.

Relative to the Australian cities, Auckland was on a par with Sydney in 1991 and well ahead of the other four cities for KIS intensity. The agglomeration of knowledge intensive services within New Zealand towards Auckland (at least in a relative sense) saw Auckland outstrip the five Australian cities for growth in KIS intensity over 1991-2006. Four of the Australian cities had greater KIS-TOTAL growth than the four smaller New Zealand cities over this period, with Perth (the most peripheral city to Australia's dominant east coast) only a little behind Wellington and ahead of the other three New Zealand cities. Combined with Auckland's growth outstripping that of the other New Zealand cities, these outcomes are consistent with the cited spatial economic forces. The KIS-TOTAL figures indicate that Auckland remains the leading Australasian city for KIS while further asserting its dominance within New Zealand. Thus of the two forces acting on Auckland – relocation of KIS activities within New Zealand towards

Auckland versus the potential for KIS functions to disappear from Auckland to Australia – the former has more than offset the latter for the city.

Figure 5: Change in KIS-TOTAL Intensity

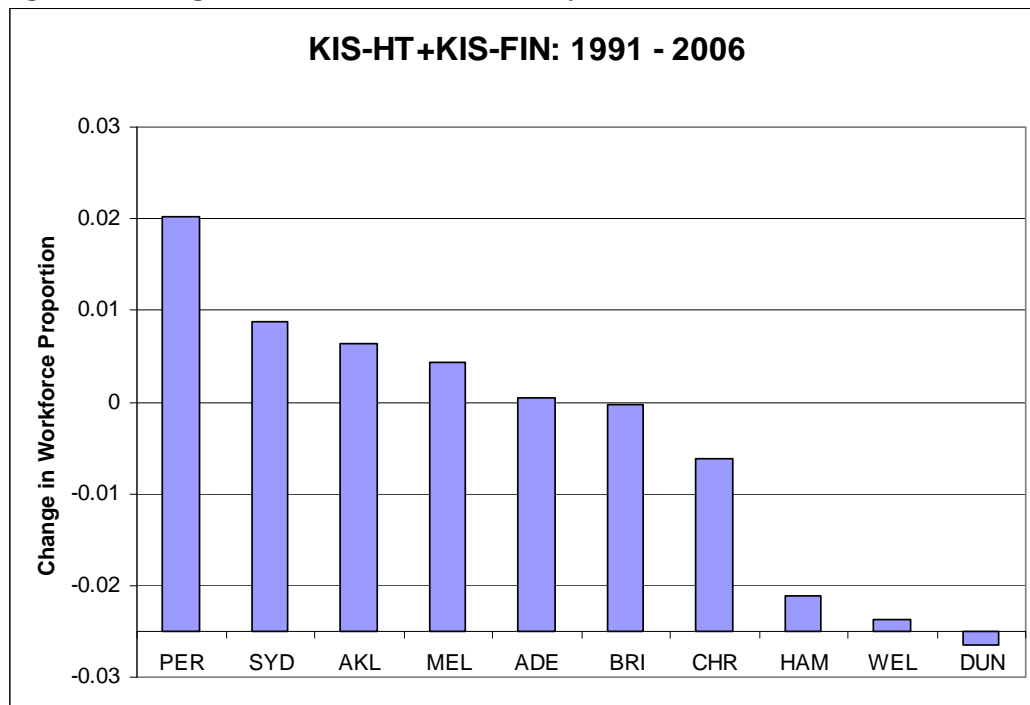


See Appendix 2 for definitions

We gain more insight into these respective forces by disaggregating KIS into various sub-sectors. Appendix 2 includes graphs for the four KIS sub-groups: 'High-Tech' (KIS-HT); 'Financial' (KIS-FIN); 'Market' (KIS-MKT); and 'Other' (KIS-OTHER). Table 3 (Appendix 1) defines the sectors included in each case. From the economic geography literature, 'High-Tech' and 'Finance' may be considered the two sub-groups that exhibit the strongest agglomerating forces and which contribute most to high income levels. The 'Market' sector, which includes real estate, business services and transport, may be conceived more as a sector that responds to other industries within the city, while the "Other" services sector may be determined primarily by central or state government choices with respect to health, education and the arts.

Figure 6 presents the change in intensity for KIS-HT + KIS-FIN for each of the ten cities over 1991 to 2006. Three of the Australian cities (Perth, Sydney, Melbourne) plus Auckland increased their intensity in these fields while Adelaide's and Brisbane's shares remained virtually constant. By contrast, all four of the smaller New Zealand cities had declines in their share of employees within high-tech and financial services. These results are again in keeping with the predicted trend towards clustering of key knowledge intensive services in major cities.

Figure 6: Change in KIS-HT + KIS-FIN Intensity



See Appendix 2 for definitions

Auckland asserted its dominance in each of the high-tech and finance fields within New Zealand (excluding Wellington) after starting with intensities below that of Hamilton in 1991. Relative to Australia, Auckland kept pace with Sydney and Melbourne in High-Tech services and remained second only to Sydney in

Financial KIS intensity.²³ By contrast, Adelaide, Brisbane and Perth (despite the latter's recent increase) remain very much peripheral cities in these fields.

With respect to Market KIS intensity, Auckland has consistently been the dominant city in New Zealand (excluding Wellington) and this dominance has increased over time. A particularly striking result is that Auckland has consistently outranked each of the Australian cities in this field, and has increased its Market KIS intensity relative to each of the Australian cities.

Market KIS includes real estate, renting, business services, and transport services which are primarily inputs to other 'front-line' production activities. It is possible that Auckland's high Australasian standing in this field reflects centralisation within New Zealand of such services in Auckland. However, the average intensity of this sector across Hamilton, Christchurch and Dunedin in 2006 (10.9%) is almost identical to that across the five Australian cities (11.1%); thus there is no reason to believe that Auckland's high intensity (15.6%) reflects a lack of other New Zealand city involvement in these fields. Another possibility is that Auckland's high 'Market' share reflects its relatively rapid population growth which requires support from activities such as real estate services.

The Market KIS figures are consistent with those in Hazledine (2001) for the national level. He showed that New Zealand's 'transactions' sector expanded markedly following the country's post-1984 reforms, both absolutely and relative to Australia. Without further information on the causes of this growth, it is impossible to place a normative judgement on whether the large share involved in Market KIS reflects positive value adding input or is a response to a bureaucratisation of procedures within New Zealand.

²³ The major parts of the financial sector in Australia and New Zealand held up well during the global financial crisis, and continued to contribute strongly to the cities with material financial sector presence.

Auckland is a significant laggard in Other KIS comprising health, education, culture, and recreation. In each of the four census periods, Auckland has a smaller employment share involved in this category than each of the other New Zealand cities; along with Sydney, it has a consistently low share relative to the other four Australian cities. Within New Zealand, Dunedin is by far the dominant city in this category, followed by Hamilton: both cities have universities and large base hospitals that are prominent employers in the city.²⁴ Adelaide is the dominant city in Australia for Other KIS (and, in particular, for health services²⁵) and it is Adelaide's prominence in this field that elevates Adelaide in the Total KIS standings. By contrast, the city is lowly ranked for the High-Tech, Market, and Financial KIS categories.

4.3. Knowledge intensity by Occupation

Most studies of knowledge intensity within economies adopt decompositions based on industrial structure as used above. However a few also adopt an occupation based decomposition (Beckstead and Vinodrai, 2003) and it is useful to compare insights using this method with the previous sectoral approach. (Appendix 3 provides a statistical examination of the relationship between the industry and occupation measures.)

Table 4 splits 'Total Knowledge Workers' (TKW) into eight occupational sub-groups. Appendix 2 includes employment intensity graphs for the New Zealand and Australian cities for each of these sub-groups together with TKW. We also present graphs for TKW excluding Management (TKWX) since, as noted in

²⁴ Another possible contributor to Auckland's low (and Dunedin's high) Other KIS share is Auckland's comparatively young (respectively Dunedin's comparatively old) age structure, given that health resources are more heavily targeted at the elderly population. (We thank Andrew Coleman for this suggestion.)

²⁵ In 2006, 12% of Adelaide's workers were in health services, compared to an average across the four other Australian cities of 9%. Excluding health services, Adelaide had 9% in Other KIS, the same as the average of the other four cities.

Section 3, the definitions used for the Management category may differ across the two countries.²⁶

The Australian graph for Total Knowledge Workers (Excluding Managers) shows Sydney's expected pre-eminence relative to other Australian cities, with Melbourne second. In 1996, Auckland ranked with the next tier of Australian cities; however, by 2006, Auckland eclipsed all the Australian cities on this measure. For TKW (Including Managers), Auckland's dominance was even more pronounced. Relative to the other New Zealand cities, Auckland is the leading city (excluding Wellington) on the Total Knowledge Workers definition. This dominance increased markedly between 1996 and 2001. Comparing TKW and TKWX indicates that Auckland's pre-eminent role in knowledge intensity within New Zealand arises because of its increasing dominance in managerial functions, rather than in more specialised knowledge areas. Auckland also dominates other New Zealand cities (excluding Wellington) in Business Professionals, and this dominance has increased markedly over time.

Perhaps surprisingly, given its relatively low levels of medium/high-tech manufacturing intensity, Auckland surpassed the other nine Australasian cities for Science and Engineering Professionals (SEP). The importance of this occupational group has grown steadily over time for all cities with Auckland experiencing the strongest growth. The rising share of SEP and falling share of STO (Science – Technical Occupations) for most cities may reflect qualifications inflation in the science and engineering field. If we add the two “science” intensities together, we find that Auckland's combined science intensity has increased over time (from 5.3% in 1991 to 6.1% in 2006), Hamilton and Christchurch have remained broadly steady while Dunedin's intensity has fallen.

²⁶ Hazledine found that New Zealand's increased transactions sector post-1984 could in part be attributed to a rise in the number of managers in New Zealand relative to Australia. Reflecting this result, Auckland is dominant in the Management occupational group, especially relative to each of the Australian cities.

By 2006, Auckland had the highest share of science-related occupations of the New Zealand cities.

Auckland has also consistently had slightly higher science intensity than any of the five Australian cities. Surprisingly, Adelaide has consistently had the lowest share of science-related occupations (4.7% in 2006) within Australia despite its dominance in the HTM field. This contrast between the industry and occupational results reflects the fact that, in 2006, 46% of the employees classified within HTM in Adelaide were in the motor vehicle assembly and component industry. This industry involves medium-high or high technology but many of the employees may not be in knowledge intensive occupations.²⁷ Moreover, the 2004 closure of the two Mitsubishi automobile plants in Adelaide displays the vulnerability of the knowledge intensive HTM sectors in the Adelaide economy to individual corporate decisions, and highlights the need to diversify that city's economic structure into a broader range of knowledge sectors and occupations in order to enhance the region's overall resilience in the face of globalisation (Beer and Thomas, 2009).

Auckland and Wellington rank consistently last in New Zealand on the two health occupation measures. In accordance with the industry result for Other KIS, the dominant New Zealand cities on these measures are Dunedin and Hamilton. Auckland also ranks last relative to the five Australian cities for the health occupation measures. Thus while Auckland has a prominent medical school and prominent fields of health research, this does not translate into an area of comparative advantage for the city in terms of employment numbers.

Auckland also tends to lag other New Zealand cities in the field of Education, Law and Social Science-related occupations (ELSS), but places well ahead of all five Australian cities in 2001 and 2006. By contrast, in 1996, Auckland had very

²⁷ The European Commission (2003) finds that the automobile industry to a large extent explains the top rankings of EU regions in terms of medium/high-tech manufacturing.

similar ELSS intensity (implying that Auckland's dominance in later years is not due to a classification difference between New Zealand and Australia).

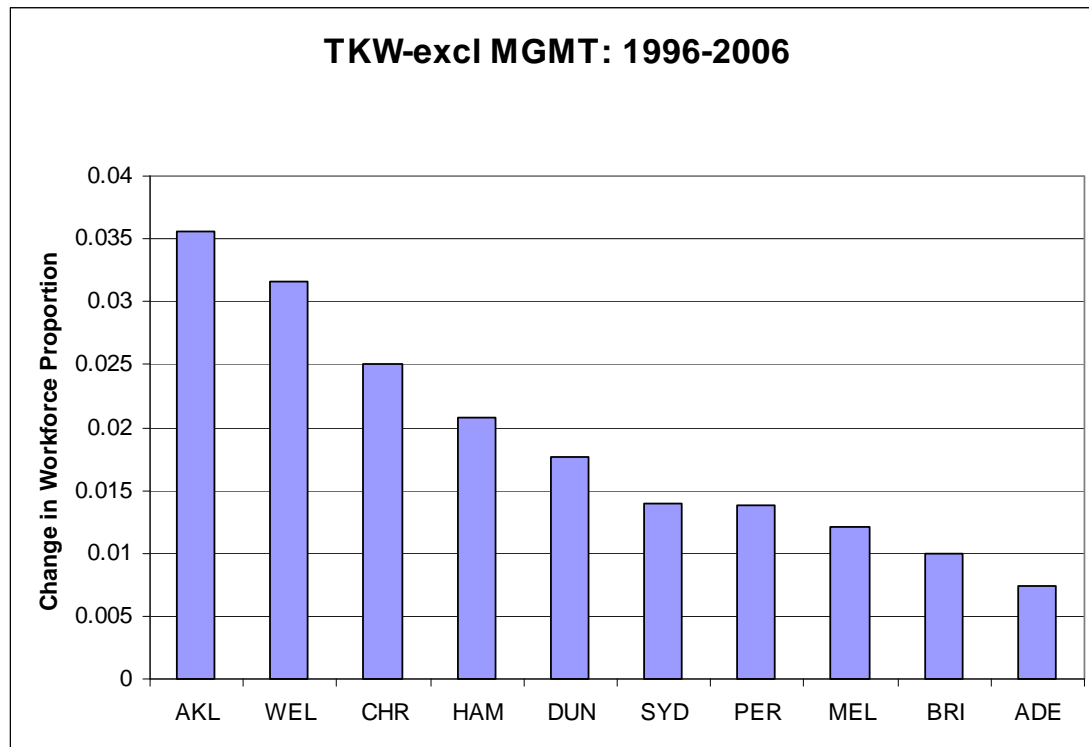
Auckland's high intensity relative to Australian cities on the ELSS measure is consistent with Hazledine's findings relating to the high rate of transactions occupations in New Zealand relative to Australia.

In keeping with the ELSS findings, Auckland has a moderate intensity of Arts and Culture Professionals (ACP) relative to other New Zealand cities (well behind Wellington, and a little behind Dunedin) but has substantially higher intensity in these fields than any of the Australian cities. Most Australian cities have stagnated or declined on ACP intensity since 1996, whereas Auckland and other New Zealand cities have increased steadily.

Overall, the occupational measures suggest that Auckland tends to have a relatively high rate of employees in knowledge intensive occupations relative to other New Zealand cities. It also has a high rate of employees in knowledge intensive occupations relative to the Australian cities.

Figure 7 graphs the change in the total knowledge worker (excluding managers) share for the ten cities over 1996 to 2006. In contrast with the industry knowledge intensity figures, the five New Zealand cities, led by Auckland, had the highest change in knowledge workers as a proportion of the workforce. Thus the relative under-performance of the smaller New Zealand cities with regard to changes in knowledge intensive industry shares does not appear to be attributable to a dearth of available knowledge workers within New Zealand cities. Instead, New Zealand cities have increased their available pool of knowledge workers relative to the five Australian cities.

Figure 7: Change in TKWX Intensity



See Appendix 2 for definitions

The contrast in results between the industry and occupation measures for the four smaller New Zealand cities suggests the potential for an outward migration of skilled New Zealanders to the major Australian cities. Moreover, the home market advantages of Australia suggest that the employment opportunities for skilled New Zealanders in Australian cities will be associated with personal wage increases (McCann 2009). Consistent with these observations, for the three calendar years following the end of our sample (2006-2008), 27,677 workers classified as “legislators, administrators, managers, professionals, technicians, associate professionals and trade workers” emigrated on a permanent/long term basis from New Zealand to Australia, compared with a flow of 9,775 in the opposite direction (source: Statistics New Zealand).²⁸

²⁸ These figures relate to recent *flows* of skilled migrants between the two countries. For information on skills of the existing *stocks* of migrants in the two countries, see Stillman and Velamuri (2010).

5. Comparison with European Regions

The prior analysis has compared Auckland with Australasian cities. Here we analyse developments in Auckland's knowledge intensive sectors relative to those of a selection of European city-regions. Data are available for 2006 and prior years using the same knowledge intensive sector definitions for the "NUTS2" definition of European Union regions.²⁹ Some of these regions are cities; others cover broader regions with a dominant city. Our choice of regions is based on a number of criteria designed to facilitate, as much as possible, a comparison across city-regions with similar characteristics.

First, we limit comparisons to cities in countries that, like New Zealand, have a comparatively high share of production in the Agriculture, Fishing and Forestry (AFF) sectors. Crawford et al (2007) indicate that a country's AFF share (i.e. its industrial structure) has implications for its overall research and development and patenting intensity. In the early 2000's New Zealand's employment share in the AFF sectors was approximately 8.5%, which is high by developed country standards; they identify six European countries with AFF sectors comprising at least 6% of total employment: Austria, Finland, Greece, Ireland, Portugal and Spain. These countries provide useful comparators not only because of their relatively high AFF intensities, but also because they are each peripheral to the core of Europe,³⁰ although of course they are considerably less peripheral, in a physical geography sense, than is New Zealand.³¹

Within these six countries we wish to choose cities that are: (a) of similar size to Auckland (i.e. approximately 1.0 - 1.5 million people); (b) not a capital city (since, from the New Zealand evidence, KIS intensity is related to capital city status); and (c) within a region that comprises just that city or at least has a dominant city

²⁹ See Eurostat: http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database.

³⁰ The core may be considered as the original six EEC countries plus the UK.

³¹ Most of the comparator countries had similar PPP-adjusted GDP per capita rankings to New Zealand in the early 2000s with rankings (out of 28 OECD countries) at 12, 15, 24, 7, 22, 21 respectively compared with New Zealand's rank of 20 (UNDP, 2001).

comprising the bulk of the workforce. These tests prove difficult to meet comprehensively. Table 1 lists the eight regions that conform most closely with these criteria (with added data on key cities within a region where applicable). The table denotes each region according to its dominant city, also listing its country and formal NUTS region name. The population and population density for each region is listed, together with comparative information for the Auckland Urban Area.

Table 1: European Comparator Cities plus Auckland

City	Country	Region Name	Population (million) 2006	Density (pop/km ²) 2006
Linz	Austria	Oberosterreich ^a	1.404	118
Vienna	Austria	Wien	1.658	4107
Helsinki	Finland	Etela-Suomi ^b	2.605	64
Athens	Greece	Attiki	4.017	1055
Dublin	Ireland	Southern & Eastern ^c	3.121	86
Lisbon	Portugal	Lisboa ^d	2.787	950
Barcelona	Spain	Cataluna ^e	7.011	218
Valencia	Spain	Comunidad Valenciana ^f	4.700	202
Auckland	New Zealand	Auckland Urban Area	1.273	1185

Sub-regional populations and densities:

^a The population of Linz (Linz-Wels) was 0.542 with population density 315.

^b The population of Helsinki (Uusimaa) was 1.366 with population density 214.

^c The population of Dublin was 1.191 with population density 1299.

^d The population of Lisbon (Grande Lisboa) was 2.016 with population density 1465.

^e The population of Barcelona was 5.214 with population density 675.

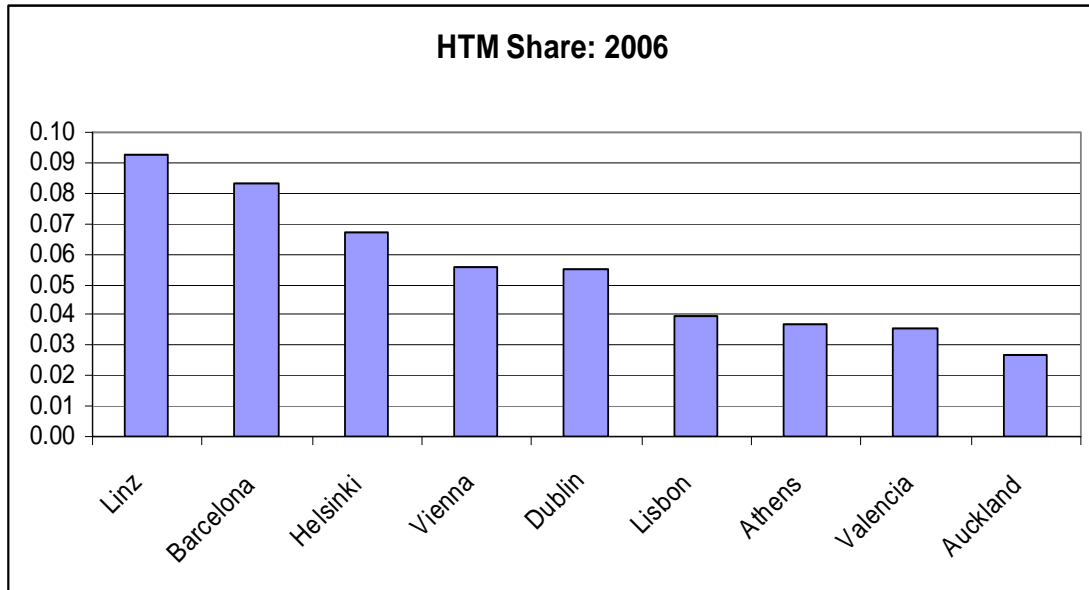
^f The population of Valencia was 2.404 with population density 222.

The cities included in our sample include one or two cities from each of the six listed countries. Of the eight cities, only three are not capital cities (Linz, Barcelona, Valencia). The Australasian data indicates that capital city status is most relevant to inflating knowledge intensive services rather than HTM. Regional populations vary from 1.4 million to 7.0 million, representing larger city-regions than Auckland.

Figure 8 graphs the HTM intensity for the eight European cities plus Auckland in 2006. Auckland ranks last of these nine cities in HTM intensity. The top two Australian cities by HTM intensity (Adelaide and Melbourne) both rank below the top five of the eight comparators, while Christchurch is on a par with Valencia,

the lowest ranking European comparator. Thus while HTM activity is not heavily oriented towards large agglomerations, we nonetheless observe that medium/high-tech manufacturing is more prevalent within these European peripheral cities than within (the even more peripheral) Australasian cities.

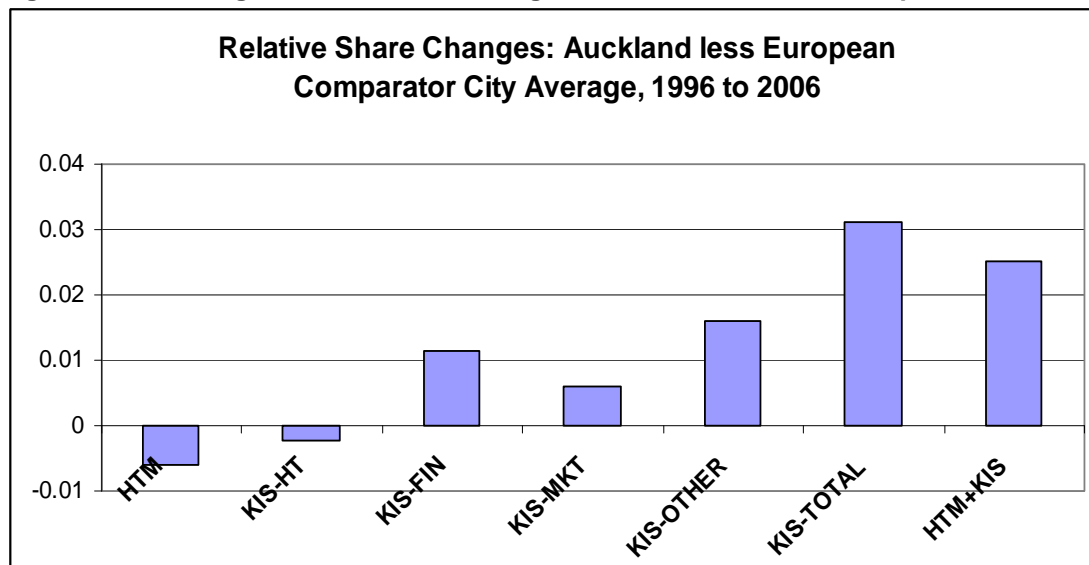
Figure 8: HTM, European Cities and Auckland



See Appendix 2 for definitions

For KIS intensities, we examine changes in shares between 1996 and 2006 in order to abstract from capital city and other city-specific characteristics. By doing so, we can examine whether the trend observed in Australasia for agglomeration of KIS away from the periphery towards the centre is observed also when comparing Auckland with its European comparators. We drop Dublin and Helsinki since data are not available for these cities prior to 2001. We take the average change (between 1996 and 2006) in workforce share for each of Auckland's knowledge intensive sectors less the average change in the corresponding share for the six comparators, and plot the difference in share changes in Figure 9.

Figure 9: Knowledge intensive share changes, Auckland relative to European cities



See Appendix 1 for definitions

Figure 9 indicates that relative to the six comparator cities, Auckland's employment share in both medium/high-tech manufacturing and high-tech services has fallen. By contrast, Auckland's share has risen in the other three knowledge intensive services sectors relative to its comparators. Auckland's largest relative share increase was in KIS-OTHER; as noted earlier, many of the

decisions in this sector are related to central and/or local government choices. Auckland also increased its relative share in KIS-MKT and KIS-FIN, potentially reflecting a clustering of such services within Auckland (from other parts of New Zealand) compared with trends in the selected European cities (for which financial and market services may have been drawn more towards the core of Europe). Overall, Auckland increased its share in knowledge intensive activities relative to these comparators, but this overall increase disguises Auckland's relative fall in high-tech services and medium/high-tech manufacturing.

6. Interpretation and conclusions

In 1991, Auckland was New Zealand's dominant city in terms of employment share in medium/high-tech manufacturing (HTM). By contrast, it was ranked almost equal lowest of the five New Zealand cities for its total knowledge intensive services (KIS) share. Auckland therefore had a relatively more important role in knowledge intensive manufacturing than in services within New Zealand in 1991.

By 2006, the situation had changed markedly. Auckland was by then second only to Wellington in terms of its Total KIS share, and Wellington has an idiosyncratically high share due to its capital city role. However, Auckland's role in HTM intensity had fallen markedly to rank the lowest of the four non-capital New Zealand cities. Christchurch, influenced by its engineering school, had taken over top slot in HTM intensity after 1991 (although Auckland still has a considerably greater number of employees in HTM than does Christchurch).

Relative to the five major Australian cities, Auckland ranked mid-way for HTM both in 1991 and 2006. Over these fifteen years, however, it fell further behind the leading HTM cities, Melbourne and Adelaide. In addition, both Brisbane and Perth closed some of their gaps relative to Auckland. Overall, Auckland's importance in Australasian HTM declined over the period.

In 1991, Auckland was ranked almost equal with Sydney for Total KIS, and well ahead of the other four Australian cities as well as the four other New Zealand cities. By 2006, Auckland's importance as a knowledge intensive services city had increased still further relative to both the Australian and New Zealand comparator cities. It appears to have benefited from a relocation of New Zealand's knowledge intensive services away from the smaller centres to the country's largest commercial centre.

Within the 2006 Total KIS share, Auckland ranked top in New Zealand (excluding Wellington) for high-tech services and ranked on a par with Sydney and Melbourne in this field. Sydney was the dominant financial KIS centre but Auckland ranked ahead of all other cities, while Auckland ranked ahead of all cities in terms of Market KIS. Its main KIS shortfall was a lagging position relative to cities in both New Zealand and Australia for Other KIS that includes health, education, culture and recreation.

In occupational terms, Auckland scores highly across both countries in 2006 for Management, Business Professionals, and Science and Engineering Professionals. Relative to other New Zealand cities, Auckland has a low share in Education, Law and Social Science occupations but has a very high share in these fields relative to Australia. Similarly, Auckland is mid-ranked within New Zealand for Arts and Culture Professionals but has a much higher share in these occupations than does any of the Australian cities. One occupational area in which Auckland has a low share, relative to cities in both countries, is health - both Health Professionals and Other Health Occupations. This result is consistent with the city's low share for Other KIS that includes the health sector.

Taking the industry and occupation results in their entirety, Auckland has increased its dominance within New Zealand for knowledge intensive industries. It is undoubtedly the core city within New Zealand. Auckland also maintains higher knowledge intensity relative to major Australian cities. Within Australia,

Sydney and Melbourne have almost equal knowledge intensity, albeit with Sydney stronger in services and Melbourne in manufacturing. Knowledge intensive sectors are split between the two cities whereas, in New Zealand, knowledge intensive activities have been concentrating upon Auckland. The other three (non-capital) New Zealand cities (Hamilton, Christchurch, Dunedin) and three Australian cities (Brisbane, Adelaide, Perth) remain relatively peripheral to the dominant Australian cities and dominant New Zealand city. However knowledge intensity within the peripheral Australian cities is increasing at a faster rate than in the peripheral New Zealand cities.

These trends are consistent with the insights derived from an understanding of the global economic geography forces acting on the two countries. The forces favouring agglomeration of non-routinised activities have led to a considerable strengthening in Auckland's positioning *within* New Zealand for knowledge intensive services. While the same forces are acting to carry some of these functions *away* from New Zealand to the major Australian cities, Auckland has nevertheless maintained a major KIS role. However there has been a weakening in knowledge intensive activities for other New Zealand cities relative to Australia.

In contrast with knowledge intensive services, location of medium/high-tech manufacturing appears to be driven more by historical forces, such as the location of tertiary education and research facilities. These forces include the role of the car industry in Adelaide and the influence of the engineering school in Christchurch. Auckland's initial relative strength in HTM has been dissipated over the period.

This loss, and Auckland's relative weakness in the health field, raises some important issues about the relationship of the tertiary sector to the broader economy within Auckland. New Zealand has traditionally had two comprehensive engineering schools (Auckland and Christchurch) and two medical schools (Dunedin and Auckland). Our analysis shows that Dunedin has

a strong health focus while Christchurch has a strong HTM focus, in accordance with their respective tertiary specialities.

By contrast, Auckland has relatively modest shares in both fields. Its low health intensity is perhaps surprising given the calibre of its medical school. This result possibly reflects a comparatively young age structure in Auckland. Alternatively, a strong private sector (non-health) presence in the city may have influenced successive governments to distribute major public services (such as health) to other locations that have smaller private sectors. Nevertheless, this result raises the question of whether broader health investments have been integrated sufficiently with Auckland's leading health research and educational facilities. Similarly, there may be insufficient coordination between high-tech manufacturing opportunities and the engineering and science schools within the city.

Relative to the European comparators, Auckland has the lowest HTM share; and all other Australasian cities (even the leading HTM cities of Adelaide, Melbourne and Christchurch) also have low relative HTM shares. Since 1996, Auckland has had declining shares in both HTM and high-tech services (KIS-HT) relative to the European comparators, but has had increasing shares in the other knowledge intensive services categories. Overall, the Australasian cities are relatively low-tech relative to the European comparators that are themselves located in the periphery of Europe. Seen in this light, Auckland is one of a number of cities within a region (Australasia) that is peripheral to the world's knowledge economy.

One other finding of the paper is of note. New Zealand cities have high shares of knowledge workers (defined by occupation) relative to the Australian cities. This leaves New Zealand cities at risk of losing their comparatively talented workforces to the Australian cities that have higher shares of knowledge intensive industries.

Auckland dominates all other non-capital cities within Australasia for its share of Science and Engineering Professionals. A strategy that builds on Auckland's science and engineering occupational (and educational) strength, and that increases the leverage obtainable from its health research, may offer opportunities for greater knowledge intensive growth within New Zealand's premier city. Such a strategy could form the basis of a "constructed advantage" within Auckland (Cooke and Leydesdorff, 2006). Trends in industry shares over the past two decades suggest that such a constructed advantage may not arise in the absence of a deliberate strategy formulated in partnership by central and local government, tertiary and research institutions, and private firms. This paper provides information and interpretation that could provide a factual underpinning for such a partnership intent on designing an effective city development strategy.

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Appendix 1: Data and concordance

Table 1 Industry data

Variable	Cities	Classification
Number of employed persons by 4-digit industry, 1991	Sydney, Melbourne, Brisbane, Adelaide, Perth	ASIC 83
Number of employed persons by 4-digit industry, 1996	Sydney, Melbourne, Brisbane, Adelaide, Perth	ANZSIC 93
Number of employed persons by 4-digit industry, 2001	Sydney, Melbourne, Brisbane, Adelaide, Perth	ANZSIC 93
Number of employed persons by 4-digit industry, 2006	Sydney, Melbourne, Brisbane, Adelaide, Perth	ANZSIC 93
Number of employed persons by 5-digit industry, 1991	Auckland, Hamilton, Wellington, Christchurch, Dunedin	NZSIC 87
Number of employed persons by 6-digit industry, 1996	Auckland, Hamilton, Wellington, Christchurch, Dunedin	ANZSIC 96 NZ v4.0
Number of employed persons by 6-digit industry, 2001	Auckland, Hamilton, Wellington, Christchurch, Dunedin	ANZSIC 96 NZ v4.1
Number of employed persons by 6-digit industry, 2006	Auckland, Hamilton, Wellington, Christchurch, Dunedin	ANZSIC 96 NZ v4.1

Table 2 Occupation data

Variable	Cities	Classification
Number of employed persons by 4-digit occupation, 1991	Sydney, Melbourne, Brisbane, Adelaide, Perth	ASCO 1st Edition
Number of employed persons by 6-digit occupation, 1996	Sydney, Melbourne, Brisbane, Adelaide, Perth	ASCO 2nd Edition
Number of employed persons by 6-digit occupation, 2001	Sydney, Melbourne, Brisbane, Adelaide, Perth	ASCO 2nd Edition
Number of employed persons by 4-digit occupation, 2006	Sydney, Melbourne, Brisbane, Adelaide, Perth	ASCO 2nd Edition

Number of employed persons by 4-digit occupation, 1991	Auckland, Hamilton, Wellington, Christchurch, Dunedin	NZSCO 90
Number of employed persons by 5-digit occupation, 1996	Auckland, Hamilton, Wellington, Christchurch, Dunedin	NZSCO 95
Number of employed persons by 5-digit occupation, 2001	Auckland, Hamilton, Wellington, Christchurch, Dunedin	NZSCO 99
Number of employed persons by 5-digit occupation, 2006	Auckland, Hamilton, Wellington, Christchurch, Dunedin	NZSCO 99

Table 3 Industry Classifications for Knowledge intensive Industries

	Description
Medium-high and high-tech manufacturing	Transport equipment (incl. aerospace, motor vehicles), machinery (electrical and non-electrical, chemicals incl. pharmaceuticals)
High-tech knowledge intensive services	Communications, computing, R&D
Financial knowledge intensive services	Finance, insurance
Market knowledge intensive services	Real estate, renting, business services, transport
Other knowledge intensive services	Health, education, culture, recreation

Source: Eurostat (2008)

Table 4 Occupation Classifications for Total Knowledge Workers

	Description
Management	Managers excl. retail, construction, transport, protective services
Business professionals	Accountants, human resources professionals (excl. personnel officers), financial advisors and traders
Science and engineering professionals	Physical and life scientists, engineers, architects, mathematicians, computing professionals
Science – Technical occupations	Technicians in the physical and life sciences, engineering, architecture, technical inspectors, transportation officers and controllers
Health professionals	Health diagnosing and treating professionals, pharmacists, dieticians, nutritionists
Other health occupations	Nurses, medical technologists and technicians (excl. dental health)
Education, law and social science-related	Judges, lawyers, social scientists, policy analysts, university lecturers, teachers
Arts and culture professionals	Librarians, archivists, conservators, curators, writers, translators, creative and performing artists

Source: Beckstead & Vinodrai (2003)

Table 5 Industry concordance

ISIC rev. 3 description	ISIC rev. 3	ANZSIC 93/96	ASIC 83 (using ANZSIC 93 concordance)	NZSIC 87 (using ANZSIC 93 concordance)
<i>High-tech knowledge intensive services</i>				
Post and telecommunications	64	71	5900, 5113	72
Computer and related activities	72	783	6381	8323
Research and development	73	781	8461	93200
<i>Financial knowledge intensive services</i>				
Financial intermediation, except insurance and pension funding	65	73, 773	613, 615, 616	81110, 81120, 81130, 81210, 81492, 81220, 81250, 81230, 81240, 81290, 81330
Insurance and pension funding, except compulsory social security	66	74	623	82110, 82302, 82200, 82120, 82130
Activities auxiliary to financial intermediation	67	75	617, 6240	81310, 81420, 81491, 82301
<i>Market knowledge intensive services</i>				
Real estate activities	70	771, 772	6321, 6322, 6310	11198, 831
Renting of machinery and equipment without operator and of personal and household goods	71	774, 951	5711, 6390	71170, 71321p, 71939, 83300
Water transport	61	63	53	7121, 7122
Air transport	62	64	54	7131
Other business activities	74	15, 782, 784, 785, 786, 9522, 9523	16, 633, 637, 638-6381, 3342, 9361, 8462, 8491	832-8323-83298, 11251, 123, 133, 291, 2201, 511, 521, 9202, 9203, 9592
<i>Other knowledge intensive services</i>				
Recreational, cultural and sporting activities	92	91, 92, 93	91, 825	94110p, 94121, 94122, 94130, 94141, 94150, 94142, 93109p, 94209p, 94505, 94507p, 94509p, 34201p, 83402, 94202, 94201, 94301, 94302, 94303, 94305, 94502, 94503, 94504, 94506, 94401, 94402, 94304, 94203, 94301, 94302, 94303, 94305, 94502, 94503, 94504, 94506, 94401, 94402
Health and social work	85	86, 87	81-8153, 8304, 8305	
Education	80	84	82-825	931
<i>High tech manufacturing</i>				
Aerospace		2824	3244	38450
Pharmaceuticals		2543	2763	35220
Computers, office		2841	3341, 3352, 3369	

machinery

Medium-high tech manufacturing

Electronics-communications	2849, 2842	3351, 3352	38320
Scientific instruments	283	3341, 3481, 3343, 8153, 3343, 3352, 3357, 3367, 3369	39520, 38510, 93323
Electrical machinery	2852, 2853, 2854, 2859	3355, 3356, 3357, 3484	38391, 38392, 38399, 38310
Motor vehicles	281	3231, 3232, 3233, 3234	38210p, 38431, 38432, 33202, 38210, 38439
Chemicals--excl pharmaceuticals	253, 254, 2212	2115p, 2751, 3487p, 2752, 2753, 2754, 2755, 2761p, 2762, 2764, 2765, 2766, 2767, 2768, 2343, 2344, 2957p	3512, 352-35220
Other transport equipment	2823	3243	38420
Non-electrical machinery	286, 2851	3353, 3361, 3362, 3369, 3368, 3164, 3367, 3363, 3365, 3366, 3354	38220, 38260, 38230, 38210, 38331, 38339p,

Table 6 Occupation concordance

Knowledge workers - Statistics Canada

	NZSCO99	NZSCO95	NZSCO90
Management	11, 121, 12211, 12212, 12213, 12215, 12216, 12219, 1222-12223, 1223, 1224, 1225, 12261, 12262, 1227, 1228	11, 121, 12211, 12212, 12213, 12215, 12216, 12217, 1222, 1223, 1224, 1225, 12261, 12262, 1227, 1228	11, 121, 12211, 12212, 12213, 12215, 12216, 12217, 1222, 1223, 1224, 1225, 12261, 12262, 1227, 1228
Business professionals	2411,2413-24134, 3311, 33241	2411,24131, 24132, 24133, 3311, 33241	2411,24131, 24132, 3311, 33241
Science and engineering professionals	21, 221	21, 221	
Science - technical occupations	311, 31211, 314, 315, 321-32112, 33242, 338, 7242, 72431	311, 31211, 314, 315, 321, 338, 7242, 72431	311, 31211, 314, 315, 321, 338, 7242, 72431
Health professionals	222, 23412, 3223	222, 23412, 3223	222, 23412, 3223
Other health occupations	223-22317, 3133, 32112	223-22317, 3133	223-22317, 3133
Education, law and social science-related	23-234, 23413, 24122, 242-2423, 2441, 2442, 2443, 2446	23-234, 24122, 242, 2441, 2442, 2443, 2446	23-234, 24122, 242, 2441, 2442, 2443, 3332

Arts and culture professionals	243, 3361, 3362, 33634, 3364, 3365, 3366	243, 3361, 3362, 33634, 3364, 3365, 3366 (note 33634 "commercial designer" includes NZSCO99 "interior designer")	243, 3361, 3362, 33634, 3364, 3365, 3366 (note 33634 "commercial designer" includes NZSCO99 "interior designer")
Management	ASCO 2nd 1111/11, 1111/17, 1111/79, 1112, 1192, 1193, 121, 122, 123, 1291, 1292, 1293, 1295, 1296, 1299, 2213, 2294/15, 3211-13		
Business professionals	2211, 2212, 2221, 2294/11, 2294/13, 3211/11, 3212/11, 3212/13, 3212/15, 3212/79, 3213		
Science and engineering professionals	21-2114/15-2122-2128, 2231/11, 2231/13, 2231/15, 2231/21, 2231/79, 2293, 2312-23, 2523, 2542-17		
Science - technical occupations	2114/15, 2122, 2128, 2231/17, 2231/19, 2541, 2542-2542/17, 2543, 3112, 312, 3991, 3992, 3999/13, 4114/15, 4114/85, 4314, 4315, 4316/11		
Health professionals	231-2312/23, 2381, 2382, 2383, 2384, 2385, 2386, 2387, 2388, 2392, 2393, 2399/13, 2399/15		
Other health occupations	2321, 2323, 2325, 2326, 2391, 3111		
Education, law and social science-related	1111/13, 1111/15, 2291/17, 2322, 241-2414, 242, 2492, 2493, 2521/11, 2521/13, 2522, 2529		
Arts and culture professionals	2292, 2299/11, 2299/13, 2299/15, 2491-2491/79, 2531, 2533/15, 2534, 2535, 2536-2536/17, 2538/11, 2538/13, 2549/11, 2549/21		

Appendix 2: Variable Definitions and Graphs

Industry variables (expressed as share of total city employment)

HTM	Medium-high and high-tech manufacturing.
KIS-TOTAL	Total knowledge intensive services.
HTM+KIS	Sum of HTM and KIS-TOTAL.
KIS-HT	High-tech knowledge intensive services.
KIS-FIN	Financial knowledge intensive services.
KIS-MKT	Market knowledge intensive services.
KIS-OTHER	Other KI services (health, education, culture, recreation).

Occupation variables (expressed as share of total city employment)

MAN	Management.
BUS	Business professionals.
SEP	Science and engineering professionals.
STO	Science – Technical occupations.
HPRO	Health professionals.
HOTH	Other health occupations.
ELSS	Education, law and social science related.
ACP	Arts and culture professionals.
TKW	Total knowledge workers.
TKWX	Total knowledge workers excluding management.

Employment variable

EMPNORM	Total employment normalised to 1.0 in 1991.
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Notes:

See tables 3 – 6 for further details of each variable.

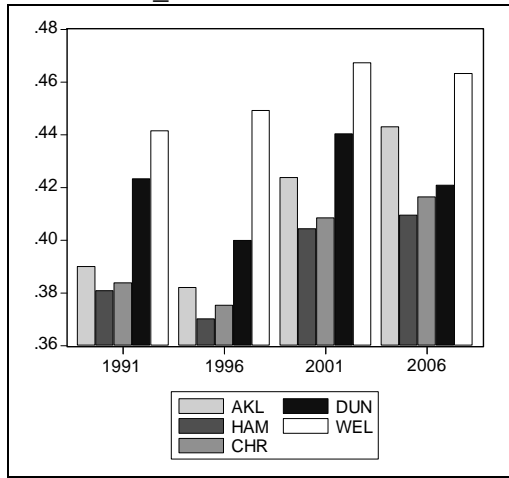
A graph suffix _NZ denotes graph of New Zealand cities.

A graph suffix _A denotes graph of Australian cities plus Auckland.

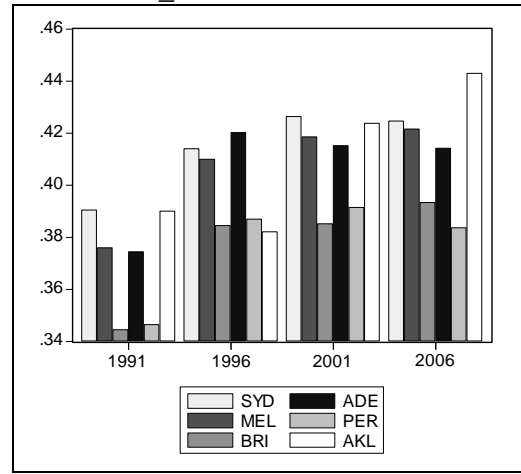
Table A1: Australasian City Abbreviations

Abbreviation	City Name
AKL	Auckland
HAM	Hamilton
WEL	Wellington
CHR	Christchurch
DUN	Dunedin
SYD	Sydney
MEL	Melbourne
BRI	Brisbane
ADE	Adelaide
PER	Perth

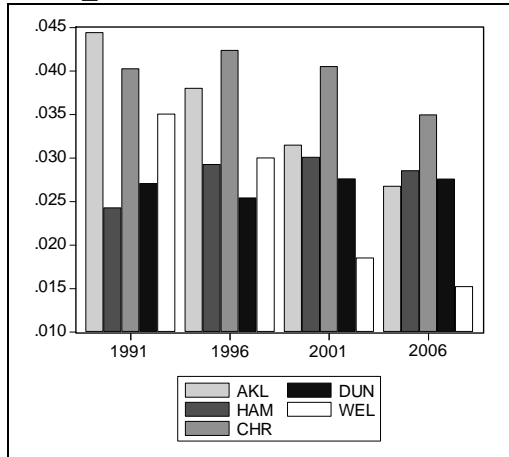
HTM+KIS_NZ



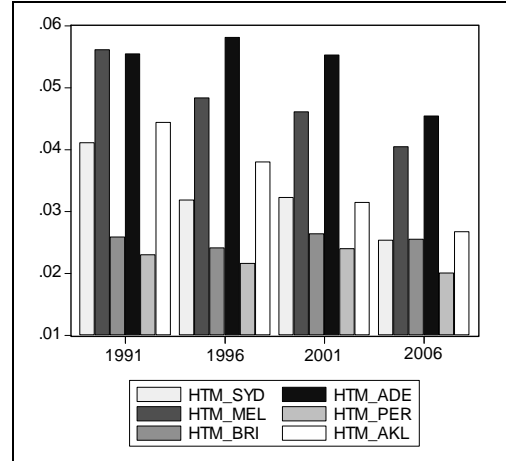
HTM+KIS_A



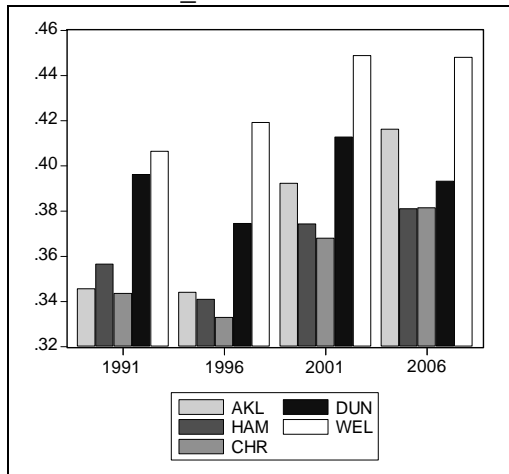
HTM_NZ



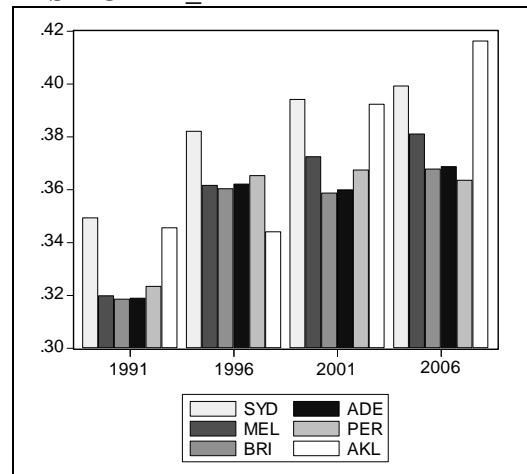
HTM_A



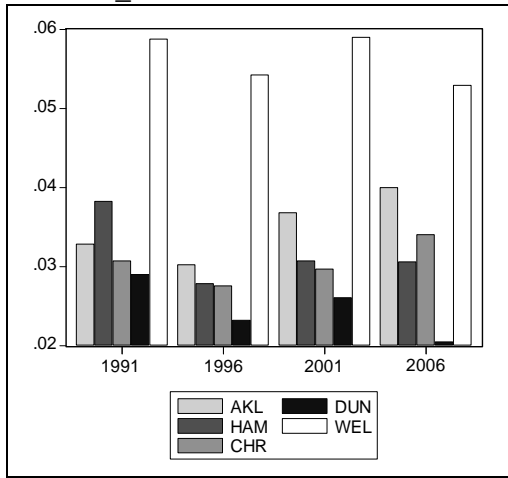
KIS-TOTAL_NZ



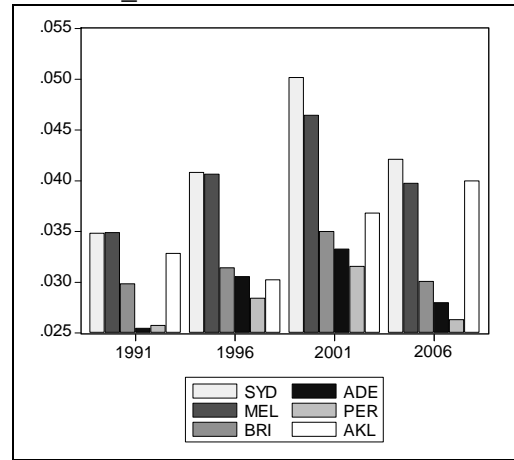
KIS-TOTAL_A



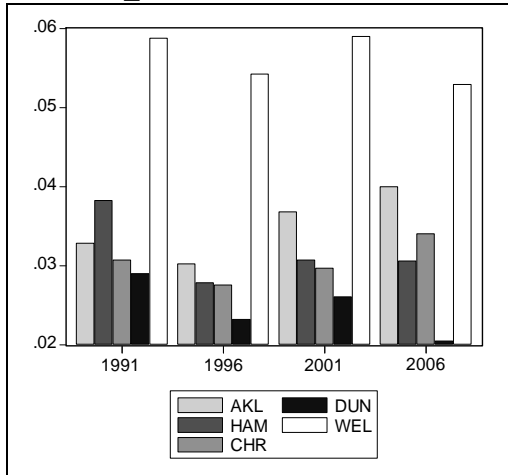
KIS-HT_NZ



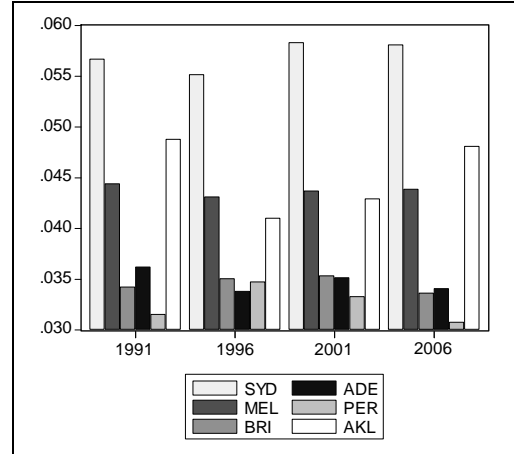
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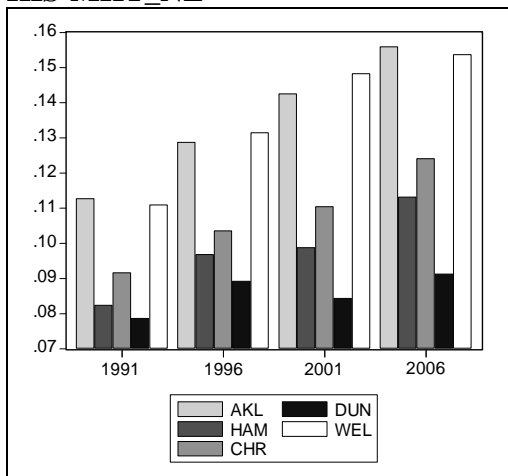
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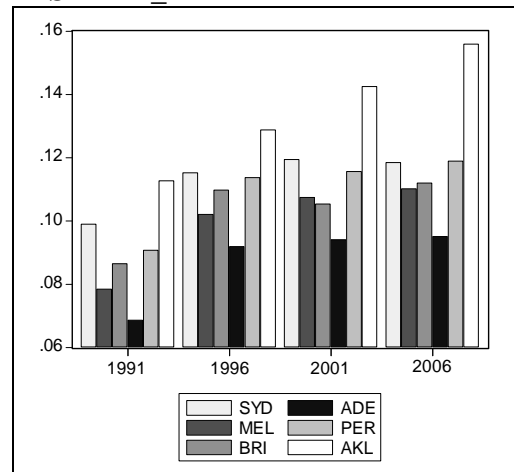
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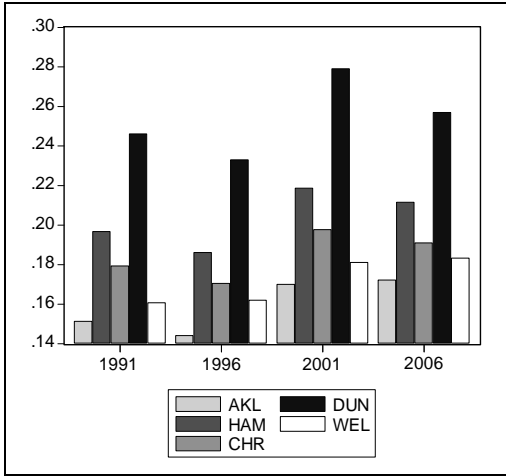
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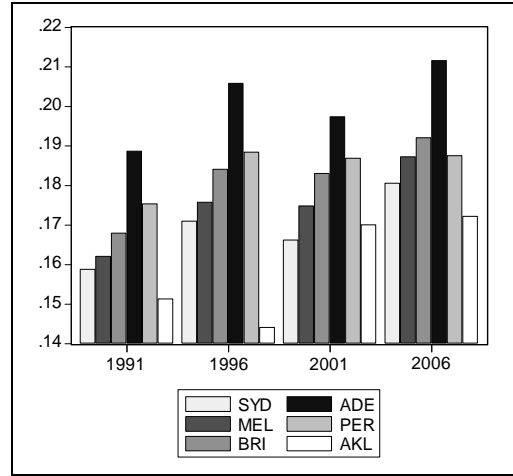
KIS-MKT_A



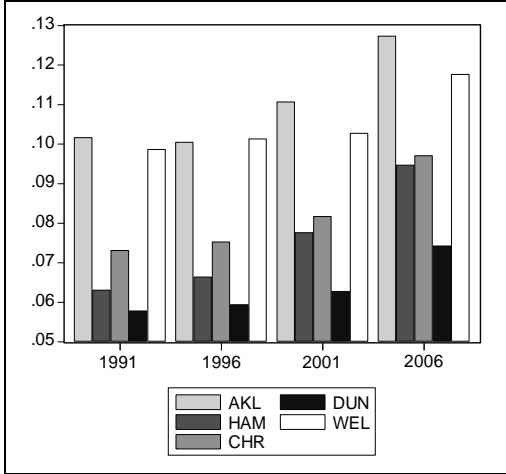
KIS-OTHER_NZ



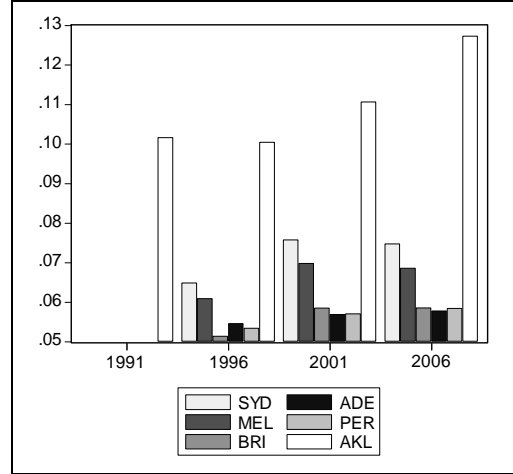
KIS-OTHER_A



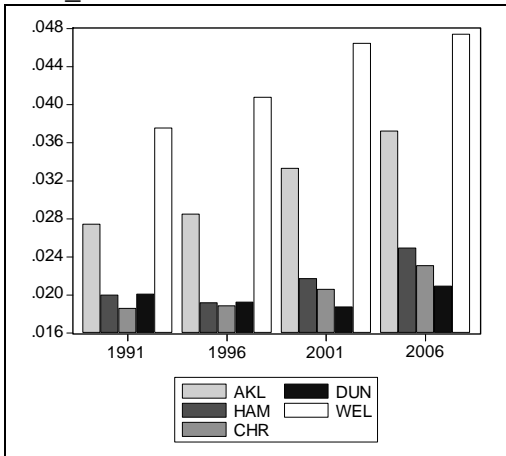
MAN_NZ



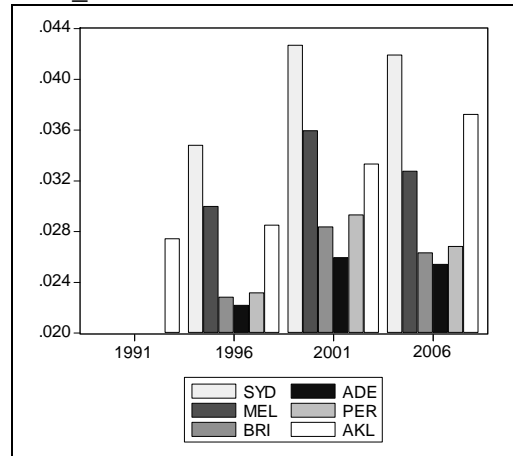
MAN_A



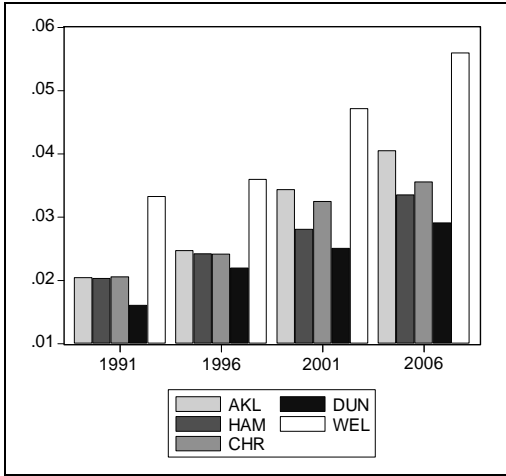
BUS_NZ



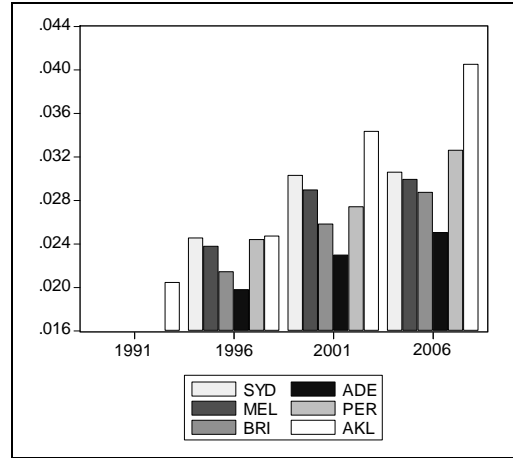
BUS_A



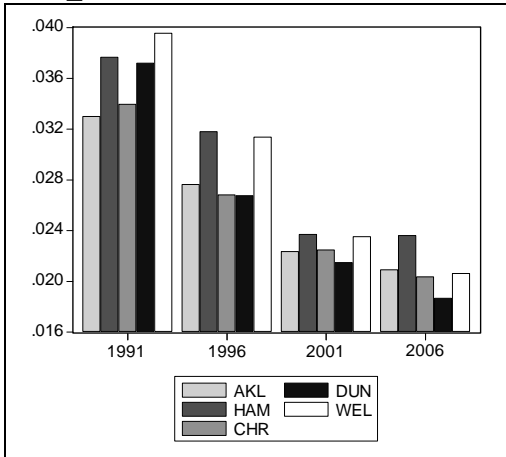
SEP_NZ



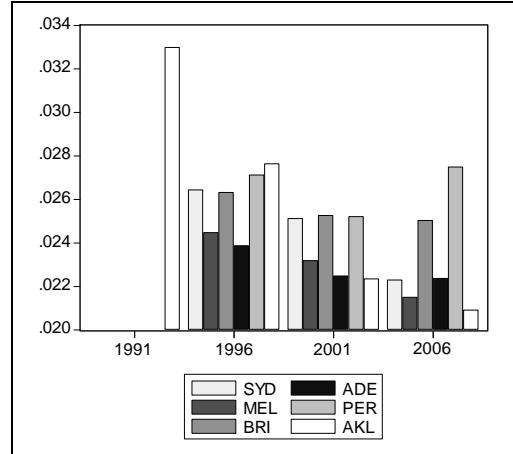
SEP_A



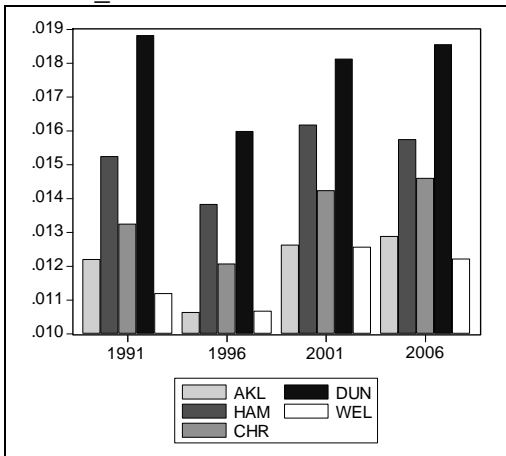
STO_NZ



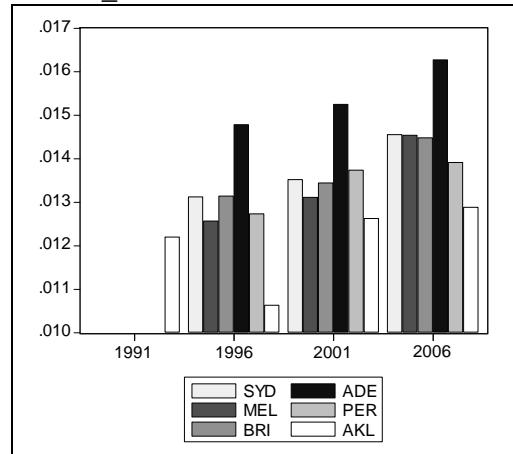
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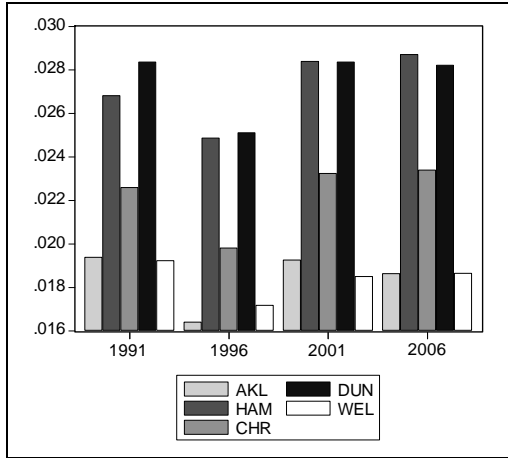
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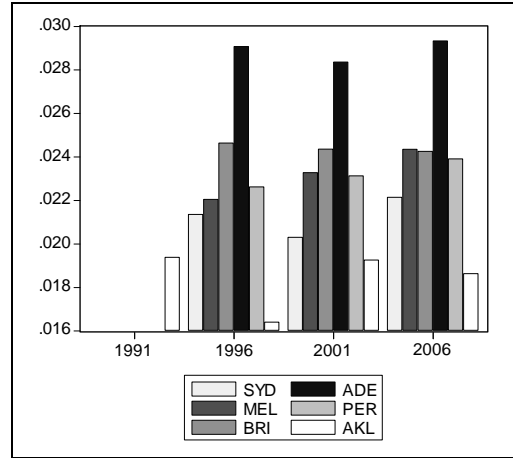
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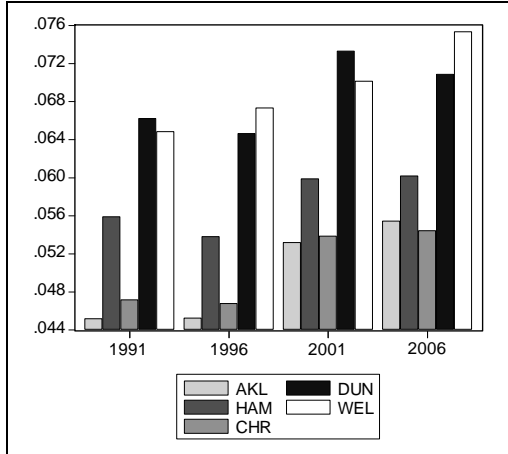
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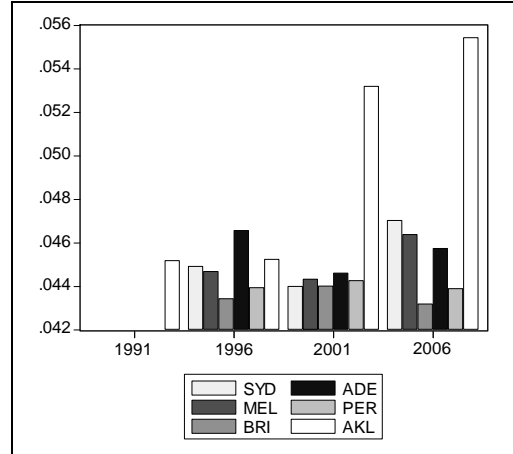
HOTH_A



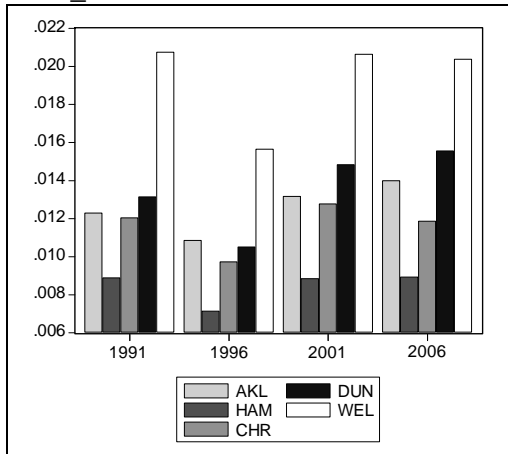
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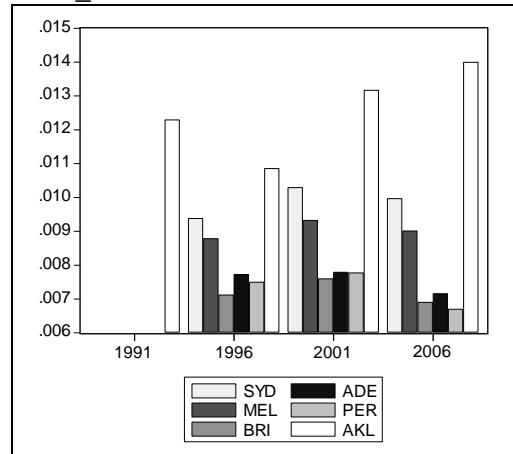
ELSS_A



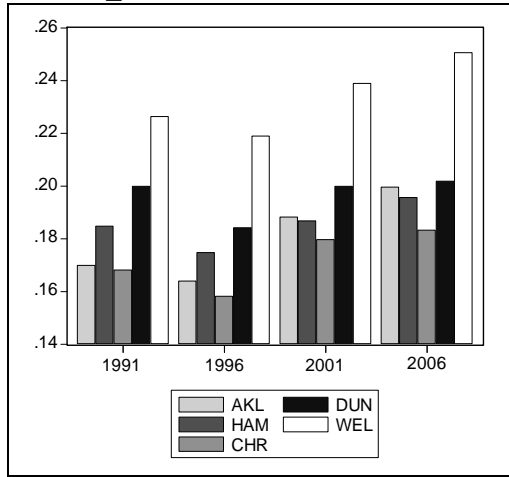
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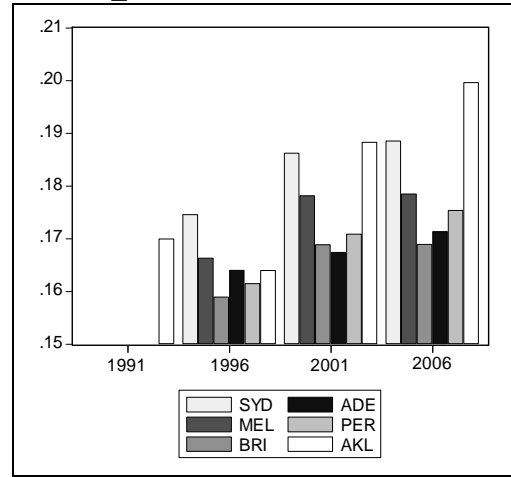
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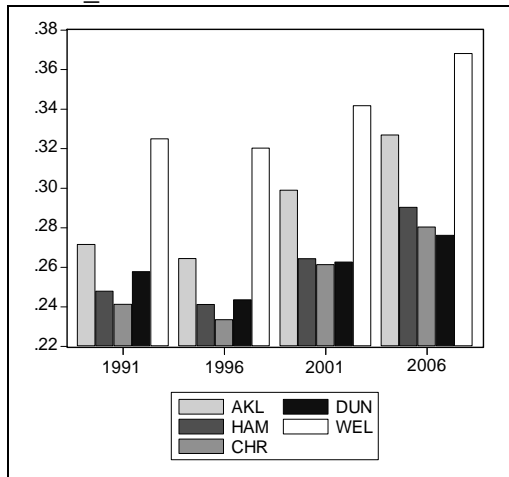
TKWX_NZ



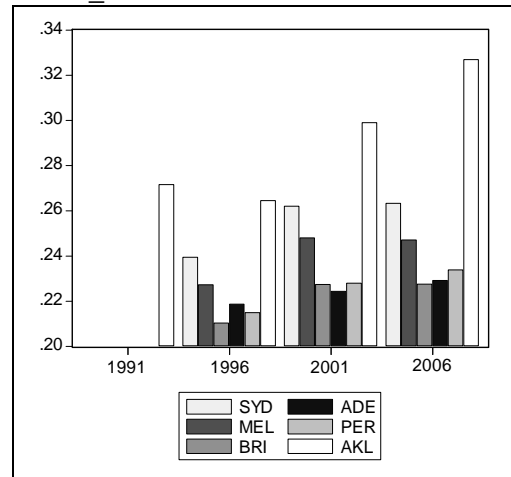
TKWX_A



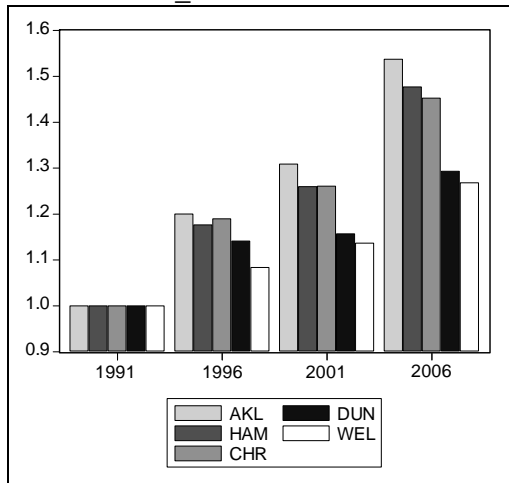
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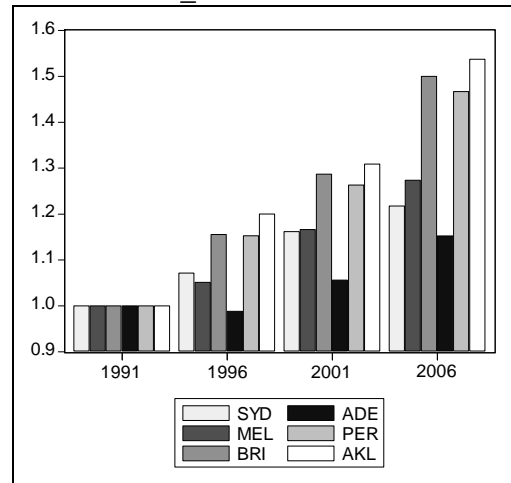
TKW_A



EMP_NORM_NZ



EMP_NORM_A



Appendix 3: Relationship between Industry and Occupation Measures

The analyses in sections 4.2 and 4.3 present trends in knowledge intensity using both industry and occupational measures. Here we analyse the relationship of the skill intensities (i.e. the occupation measures) to the knowledge intensive industry shares (i.e. the industry measures). We control for city-specific characteristics and for global changes in technologies and tastes over time through a regression framework incorporating fixed effects for each city and for each time period. The fixed effects control for city-specific effects (that are constant for that city over time) and for time-specific effects (that affect each city identically over time). Having controlled for these effects, we examine whether there are significant associations between occupational intensities and industry knowledge intensity. We cannot determine causality from these associations, but they do indicate which occupation shares accompany each of the industry shares.

Table A2 presents the results from a set of panel regressions. Each cell provides the result from a regression of the specific industry measure on the specific occupation measure, where the regression also includes city fixed effects, year fixed effects and a constant term. The number in the cell is the coefficient on the occupation measure in that regression. Thus the first cell in the table indicates that a 1 percentage point increase in the share of total knowledge workers (TKW) amongst city employees is associated with a 0.98 percentage point increase in the share of HTM+KIS (medium/high-tech manufacturing plus knowledge intensive services) in city employment. Because of the possibility of changing definitions amongst different levels of science and health workers over time, we aggregate SEP and STO into SCIENCE, and aggregate HPRO and HOTH into HEALTH. In addition to regressing the Industry measures on the Occupational measures, we regress the normalised employment in a city (EMP NORM) on the Occupational measures to examine the association between occupational structure and overall employment growth (controlling for city and year characteristics). In presenting the results, we present only relationships that are significant at the 5% level (noting the few degrees of freedom) and indicate those that are significant at the 1% level (bolded). A blank cell indicates no significant relationship at the 5% level.

Table A2: Relationship between Industry and Occupation Knowledge intensity

Industry KI Measure	Occupation KI Measure							
	TKW	TKWX	MAN	BUS	SCIENCE	HEALTH	ELSS	ACP
HTM+KIS	0.98	1.64	1.31			5.64	3.94	4.67
HTM		-0.43		-1.06				
KIS-TOTAL	1.08	2.07	1.17			5.63	4.55	4.95
KIS-HT	0.21	0.31	0.32	0.91	0.56			
KIS-FIN								
KIS-MKT	0.52	0.92	0.63	2.18	1.34		1.13	
KIS-OTHER		0.75				5.33	3.15	4.38
EMPNORM			4.16		11.20			

Notes: The number in a cell is the coefficient in a panel regression of Industry knowledge intensity on Occupational knowledge intensity plus constant, city and time fixed effects. All variables are defined in Appendix 2 except SCIENCE=SEP+STO and HEALTH=HPRO+HOTH. All estimates are significant at 5%; bolded figures are significant at 1%; blank indicates not significant at 5%. Unbalanced panel, N=35.

Several results stand out. First, total knowledge worker intensity (either including or excluding managers) is strongly associated with Total KIS intensity (and hence also with HTM+KIS) and with each of High-tech KIS and Market KIS. Second, medium/high-tech manufacturing (HTM) is not positively related to any of the occupational categories. Third, High-tech KIS is significantly associated with each of MAN (management), BUS (business professionals) and SCIENCE, suggesting a complementarity amongst these occupations for this industry. Similarly Market KIS is related to these skills plus ELSS (which includes law). Fourth, Other KIS (health, education, culture, recreation) is closely related to the relevant occupational categories of HEALTH, ELSS (education, law, social sciences) and ACP (arts and culture professionals). Fifth, growth in city size has only one significant association at the 1% level; that is with SCIENCE occupations. The coefficient implies that an increase of 1 percentage point in the SCIENCE occupational share is associated with an 11.2% increase in city employment between 1991 and 2006, holding other factors constant.³² At the same time, the SCIENCE occupational intensity does not alter the share of city employment in knowledge intensive industries (HTM+KIS), suggesting

³² City size is also associated with Management intensity, although this coefficient is less significant and could be an artefact of Auckland's rapid growth in both size and management occupations.

that there is no clear causal nexus from SCIENCE occupations to city size, at least through an increase in the share of knowledge intensive industries.