The importance of spatial differences in total factor productivity: New Zealand, 2001-2016

By

R.I.D. Harris[a]
(Department of Economics & Finance, Durham University Business School, and Research Associate, New Zealand Productivity Commission)

Abstract

Using firm-level panel data and estimating production functions for 37 industries, covering the 2001-16 period, this paper finds that firms in the Wellington region are on average about twice as productive as those in the rest of the South Island (which has the lowest average productivity). As to whether 'place' effects are the major explanation for such spatial differences, or whether 'firm mix' is more important, this study finds that agglomeration plays only a minor role in determining firm level productivity levels, while the importance of spatial factors in accounting for the differential between productivity in Wellington and other areas was generally very small.

Keywords: Productivity; TFP; Cities; Regions; New Zealand

JEL classifications: C23; D24; R12

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1. Introduction

In a recent report the OECD (2020) argue "… productivity growth … has been falling since the beginning of the century in many OECD nations accompanied by the increasing interregional divergence in productivity performance within countries. The mainstream economics research, which studies the drivers of productivity at the level of industries and firms, appears to be ill-equipped to offer solutions that would reverse the widening gap across regions. An explicit focus on the spatial (subnational) dimension of productivity is needed in order to better understand the recent productivity dynamics and to devise policy solutions able to boost aggregate productivity growth and to decrease interregional inequality" (p. 7). The current paper is an attempt to provide such an explicit focus for one such OECD member (New Zealand) that is acknowledged to have a longstanding productivity problem, especially in terms of underperformance when compared to its nearest neighbour Australia.[1]

Indeed, in recent years there seems to be a clear consensus emerging that a major cause of such underperformance relates to the size and geographic location of the country; analysis by the OECD has pointed to it having the most extreme geographical isolation from large markets and lowest market potential of any developed economy including having a very high reliance on land-based exports and the lowest level of export diversity of any advanced economy (OECD, 2008a,b; WORLD BANK, 2008). CONWAY (2018, p.46) draws a similar conclusion stating that "on balance, weak international connection is the key explanation for (New Zealand's) "technology disconnect" …. This challenge of weak international connection is compounded by small and geographically segmented domestic markets".[2]

Thus, it is perhaps not surprising that MCCANN (2009) came to the conclusion that "… on the principle of Occam's Razor, economic geography therefore provides a much more powerful diagnosis of New Zealand's current productivity performance than many other institutional, structural or macroeconomic arguments" (p. 300). He goes on to argue that "… the only … ways that New Zealand can possibly narrow the labour productivity and wage gaps between the two countries [cf. Australia] are by … increasing New Zealand's domestic agglomeration effects … (by) increasing local knowledge spillovers and innovations" (pp. 301-2). A key point, concerning this argument, is that while there may good reasons for recognising the importance of Auckland (or even a larger city-region area) in generating higher aggregate productivity levels (and growth) – based on scale/home market effects – the supposition that this results in spillovers such that other areas (and/or lower productivity firms in Auckland) can benefit from the ability to 'catch up' is an untested assumption. Thus a major aim of this paper is to examine the extent to which co-location of firms in New Zealand are associated with spillover effects that lead to higher productivity levels.

Recent work by the OECD (cf. the opening paragraph) notes a growing divide between well-performing and lagging regions and suggests that "… across OECD countries regional productivity growth follows mainly two models: countries where regions' catching up drives overall productivity growth and countries where the most productive region dominates and economic strength becomes increasingly concentrated" OECD, (2018a, p. 16). As will be seen in the evidence presented below, this study finds little evidence of catch up of lagging regions in productivity terms, but rather increasing evidence of domination by the two main city-regions

[1] The OECD (2019) point to a continuing decline (relative to the leading OECD countries) in labour productivity (in aggregate it was 73.5% of the OECD average for GVA per worker in 1991, falling to 64.2% by 2017) while Australia during this period has maintained a relative ranking of around 90%, with the USA at 110%.

[2] Others have drawn similar conclusions e.g., LEWIS AND STILLMAN (2007) state "… New Zealand struggles to achieve higher productivity because of the small size of its domestic market and its distance from markets in other countries… these factors limit competition, create higher transport costs and other barriers for exporters, and slow down technology adoption" (pp.31-32).

of Wellington (the capital) and Auckland (by far New Zealand's largest urban area[3]). This spatial imbalance matters, as explained by the OECD (op. cit.), for at least two main reasons: the first relates to McCann's concept of the 'geography of discontent'[4], whereby letting some regions fall behind can have negative consequences for social cohesion, as such regions lack the resilience to allow them to adapt to the challenges and opportunities created by globalisation and industrial transition and this can lead to " … a challenge to the country's institutional and governance structures" (McCann, 2016). The second, related, reason why spatial imbalances in productivity matter is that wage growth, and thus living standards, "… requires that productivity keeps pace with wage increases" (OECD, 2018a, p. 16). Imbalances imply untapped potential in increasing national productivity (growth) by improving the performance of all regions, which leads to the issue of whether and how government policy should respond (e.g., in response to market imperfections). Given that this paper presents evidence of spatial domination in New Zealand, it is relevant to speculate that while the consequences (in terms of a drag on aggregate productivity and engendering 'discontent') may not be perceived as severe at the moment, it is possible that, say, in 20 years from now current trends may have worsened the situation significantly. Being appraised of the current situation, and how the economic geography of productivity differences are likely to develop, is important especially in terms of government policy.

The rest of this paper is set out as follows: in the next section, the existing (limited) evidence of spatial differences in productivity in New Zealand are presented, as well as an overview of the approach taken here to measure the contribution of spatial factors to overall productivity growth, including the difficulties inherent in trying to separate out 'place' from 'firm mix' effects. Section 3 then discusses the data and the model estimated in order to obtain firm-level estimates of total factor productivity (TFP, the preferred measure) for 2001-16; there is a particular emphasis on how spatial co-location is measured here as a means of capturing (Marshallian) localisation spillovers. The results from this modelling of TFP are then presented in section 4 showing the extent to which there are spatial differences in TFP levels across broad regions (and, in a longer version of this paper, the travel-to-work areas (TTWAs).[5] The rest of this section considers the extent to which any spatial differences can be attributed to 'place' effects or whether differences across space are due to 'firm mix'. Lastly, section 5 measures the contribution of different locations (broad regions and, in the longer version, certain major TTWAs) to productivity *growth* between 2001 and 2016, which also considers the decomposition of such growth into productivity changes between continuing firms (within and between such firms), separately from new firm entry and firm closures. The summary and conclusion at the end of the paper also includes the role of policy in this area.

Figure 1 around here

2. SPATIAL PRODUCTIVITY DIFFERENCES IN NEW ZEALAND: EVIDENCE AND CAUSES

Labour productivity differences at a regional level are available from the OECD regional statistics database (OECD, 2018b). The latter (Figure 1.6, OECD, 2018b) shows that of the countries covered, New Zealand was ranked 24th from 35 countries (excluding Luxembourg which has no regional breakdown) in terms of the range between lowest and highest GVA per worker values. With a range of US$26.5 thousand (in constant PPP), this compares with an

[3] Data for 2018 shows that the population (and population density) of Auckland, Christchurch and Wellington were 1.5m (2418 per km^2), 377 thousand (1,278 per km^2), and 215 thousand (1,918 per km^2), respectively. Next comes the 'capital' of the Waikato region – Hamilton – with 169 thousand (1,534 per km^2). Only three other urban areas (Tauranga, Lower Hutt and Dunedin) have populations above 100 thousand (and only just for Lower Hutt and Dunedin).
[4] McCann (2019, footnote 2).
[5] Figure U.1 in the unpublished appendix shows the location of the TTWAs.

average range of US$20.9k for the countries covering New Zealand down to Japan. In contrast, regional productivity differences for the USA, Australia and the UK were US$66.5 thousand, US$44.9 thousand and US$42.8 thousand, respectively. In summary, spatial labour productivity differences at the TL2 level (regional council boundaries) in New Zealand were relatively narrow by OECD standards.

Figure 1 uses the same OECD data to consider the range over time for New Zealand. Excluding the relatively small region of Taranaki,[6] which benefited from especially mining of oil and gas and dairy farming,[7] the difference in labour productivity between the region with the highest (Wellington) and the lowest (mostly Northland) values remained stable throughout the period under consideration, while national labour productivity growth was modest (an average of 0.99% p.a. over 1999-2016).

There are a range of factors that determine total factor productivity (i.e., efficiency and technical progress) at the firm level, the data source used here.[8] These have been reviewed extensively elsewhere (cf. HARRIS AND MOFFAT, 2012, 2015, 2017, and HARRIS, 2019; as well as OECD, 2020), and therefore the reader is pointed to these earlier papers (and a longer version of this paper available online) for details (see Table A.1 in the appendix for details and sources). Two variables not included in previous work are intended to proxy unobserved and observed skill mix of the workers employed in each firm, and these are based on the methods employed by MARÉ ET. AL. (2017).

Concerning the role of spatial factors in determining (differences in) productivity levels and growth, Figure 4.1 in OECD (2020) provides a synthesis of the extant literature; they point out that although certain drivers (the south west corner identified in their Figure 4.1) are designated as the main factors usually identified specifically as spatial factors, all the other drivers (often treated as aspatial) cover "… many resources (including human capital, R&D and others) (that) are not uniformly distributed geographically" (p.16). The literature review provided in OECD (2020, Chapter 5) looks at the mainstream economics literature for each of the drivers surrounding the productivity outcome in the centre, and then considers the literature that takes on a spatial dimension, although the majority of the latter often concentrates on the sub-national dimension where there are differences in, say, industry-mix or endowments of (tangible and intangible) assets (i.e., such literature is applying standard economic analysis at different spatial levels). The essential question that is not directly tackled is of being able to separate the role of 'firm-mix' versus 'place' where differences in average aggregate productivity between spatial areas can arise from: (i) differences in firm characteristics or 'mix' (the extent to which a geographical area has relatively more firms with positive or negative productivity-enhancing characteristics, such as belonging to a multinational company or exporting, or engaging in doing R&D, that are known to lead to higher productivity); and/or (ii) firms with the same characteristics that generally enhance productivity (as just set out) perform better in certain locations (such as a city) – that is, there are productivity enhancing factors (external 'spillovers') linked to particular locations that are missing or less evident in other locations.

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[6] Taranaki is located on the west coast of New Zealand's North Island (280 km south of Auckland); the largest urban area is New Plymouth (ranked 13th in the country for size with a population in 2018 of 57,600 and density of 763 persons per km^2).

[7] Based on Statistics NZ employment data (available from http://nzdotstat.stats.govt.nz/), the location quotient for Taranaki was 4.3 for Dairy Cattle farming and 34.7 for oil and gas, on average over 1999-2016.

[8] TFP is the preferred measure, rather than labour productivity, since the latter is positively influenced by substitution between the factors of production – e.g., increases in capital- or intermediate-input intensity (relative to the use of labour) – as well as by TFP itself (i.e., movement towards the 'best-practice' production frontier, as efficiency improves, or movement out of the 'best-practice' frontier, through technological change).

Given the focus of this paper, the emphasis is on the productivity advantages or disadvantages that firms derive from their location which will be captured by the 'spatial' variables in the empirical (regression-based) analysis. These are an attempt to capture spatial spillovers or agglomeration externalities - potential benefits that accrue to firms from being located in the vicinity of large concentrations of other firms - as well as other, more general, 'place – or spatial – effects' attributed to factors such as the quality of the infrastructure (e.g., access to quality transport networks, access to specialised knowledge in universities or R&D hubs). Most studies on agglomeration take a similar prior position as in MARÉ AND GRAHAM (2013) that "firms in locations with dense economic activity are more productive than firms in less dense areas" (MARÉ AND GRAHAM, 2013). The underlying literature that describes the mechanisms that give rise to such Marshallian (locational) and Jacobian (urbanisation) agglomeration externalities (such as DURANTON AND PUGA, 2004, and OVERMAN *et al.* ,2009) have been discussed in detail elsewhere (see HARRIS ET. AL., 2019, pp. 469-472). In this study we include a measure for urbanisation economies (see Table A.1 for a discussion of the 'diversity' variable), but we proxy MAR localisation externalities using a co-location/distance index which is explained in the next section. The extant literature also tries to capture other 'place effects' using dummy variables to proxy for the wider impacts of being located in particular geographic areas (e.g., city and/or region dummies), and this approach is also taken here.

The impact of firm entry and exit on productivity is also considered (in Section 5 below); the likely relative effects of firm selection (defined by COMBES et. al., 2012, p. 2545, as "… the inability of weak firms to survive when faced with tougher competition in larger markets") and agglomeration advantages in more dense (urban) locations helps to explain whether firms located in cities tend to have higher productivity because of co-location spillovers or whether they have characteristics that provide higher productivity levels needed to survive in more competitive markets. COMBES et. al. (op. cit.) found that in France higher productivity in cities was dominated by firm selection, not the benefits of agglomeration.

With respect to previous studies for New Zealand on agglomeration effects, CONWAY (2018. p.46) notes that firm-level analysis finds no evidence of technology spillovers from relatively productive foreign-owned firms operating in New Zealand to lower-productivity domestic firms (DOAN ET. AL., 2015; CONWAY ET. AL., 2015), while MARÉ AND GRAHAM (2013) found that a 10% increase in agglomeration density is associated with a 0.66% increase in firm productivity, although there are significant differences across industries. We shall discuss the Maré and Graham (op. cit.) results (as well as their methodology) in more detail below, when presenting the distance index used here and the results obtained when considering co-location on TFP.

It is recognised that, given both the data and the econometric methods available, that attempts to separate out spatial (i.e. 'place') from other factors, when there are clearly complex interrelationships between where a firm locates and how it performs, are at best partial and approximations.[9] As will be seen in the next section, and just alluded to above, the current approach measures firm-level productivity using a regression model with a set of spatial variables included; thus, it is possible to show what are the marginal impacts of such spatial variables having controlled for the impact of firm-level productivity-enhancing characteristics. The complex interaction between, say, the region the firm is located in and whether it is foreign-owned, is not explicitly modelled because introducing a significant number of interaction terms impacts negatively on the model estimated (here a system-GMM estimator) in terms of passing necessary exogeneity requirements and also in getting sensible parameter estimates that can

[9] The OECD (2020) report notes: "The academic research increasingly challenges the linear model of economic performance and instead gravitates to a systemic approach in which a dense web of local factors (institutions, regulations, networks, FDIs, MNEs, universities, human capital and others) work in tandem to promote or suppress innovation, entrepreneurship and other central indicators of economic vibrancy, which enhance productivity." (p. 41)

be adequately interpreted. It is likely that in not directly modelling how spatial factors and firm-level characteristics interact that this biases downwards the importance of such spatial drivers.

3. DATA AND MODEL ESTIMATED

Using firm-level panel data covering 2001-16 from the Longitudinal Business Database (LBD) of Statistics NZ, estimates of TFP are obtained from estimation of log-linear Cobb-Douglas production functions (including fixed-effects) using system-GMM (BLUNDELL AND BOND, 1998) to address the issues of endogeneity inherent to production function estimation.[10] The model is based on the approach used in EHRL (2013):

$$\tilde{r}_{it} \equiv y_{it} + p_{it} - p_{It}$$
$$= \left(\frac{\sigma-1}{\sigma}\right)(\alpha_i + \alpha_E e_{it} + \alpha_M m_{it} + \alpha_K k_{it} + \alpha_X X_{it} + \alpha_T t) + \frac{1}{\sigma}(r_{It} - p_{It}) + \varepsilon_{it} \qquad (1)$$

where $\tilde{r}_{it}$ is revenue, y_{it} is output, p_{it} is price, e_{it} is employment, m_{it} is intermediate inputs, k_{it} is the capital in firm i at time t.[11] X_{it} is a vector of variables determining TFP (as set out in Table A.1 below). Since individual firm level prices (p_{it}) are not observed, and firm's nominal gross output is therefore deflated by *industry* price (p_{It}) to obtain output in constant prices, then if firm prices depart systematically from the average industry price level, estimating the production function results in biased parameter estimates because of the omitted firm price variable; hence, $(r_{It} - p_{It})$ (the natural logarithm of real industry output) is included to address any omitted price bias (EHRL, 2013, sets out the full model), with σ being the elasticity of demand obtained from the firm's demand function (hence, $(\sigma/\sigma - 1)$ measures the mark-up or mark-down – see CASELLI et. al., 2018 – of price over marginal cost, and thus the extent to which firms exploit market power). ε_{it} is an error term capturing both demand and production shocks (i.e., $\varepsilon_{it} = \varepsilon_{it}^{d} + \varepsilon_{it}^{s}$); and e_{it}, m_{it} and k_{it} are treated as endogenous.

Logged TFP can be calculated as the level of (logged) output that is not attributable to factor inputs– i.e., TFP is due to efficiency levels and technical progress – having corrected for omitted price bias:

$$ln\widehat{TFP}_{it} = \tilde{r}_{it} - \frac{1}{\hat{\sigma}}(r_{It} - p_{It}) - \left(\frac{\hat{\sigma}-1}{\hat{\sigma}}\right)(\hat{\alpha}_E e_{it} + \hat{\alpha}_M m_{it} + \hat{\alpha}_K k_{it}) \qquad (2a)$$

$$= \left(\frac{\hat{\sigma}-1}{\hat{\sigma}}\right)(\hat{\alpha}_i + \hat{\alpha}_X X_{it} + \hat{\alpha}_T t) + \hat{\varepsilon}_{it} \qquad (2b)$$

Equation (1) was estimated in dynamic form (and then solved to obtain long-run parameter estimates) separately for 37 industry sub-groups based on NZSIOC (level 3) 4-digit sectors. The detailed results from estimating equation (1) are not the main focus in this paper and so are provided in an unpublished appendix (Table U.1). The elasticities of output with respect to the factor inputs that are used to calculate $ln\widehat{TFP}_{it}$ are presented in Table 1[12] (along with the diagnostic tests associated with each of the 37 equations estimated). Of particular note is that

[10] A longer version of this paper sets out the importance of including firm/plant fixed effects and tackling issues of endogeneity of factor inputs and thus discusses alternative estimation strategies popular in the literature, with reasons for preferring the system-GMM approach. It also sets out in more detail the modelling approach, as well as robustness tests.

[11] The preference is to use a linear time trend to proxy technological progress, rather than include 'year' dummy variables which pick up such influences as changes in the level of utilisation of factor inputs.

[12] If in equation (1) the elasticity of $\tilde{r}_{it}$ *wrt* factor inputs is denoted by $\hat{\beta}_{E,M,K}$, where for example $\hat{\beta}_k = \frac{\hat{\sigma}-1}{\hat{\sigma}}\hat{\alpha}_k$, then output elasticities can be recovered from the estimated revenue and demand elasticities using $\hat{\alpha}_k = \frac{\hat{\sigma}}{\hat{\sigma}-1}\hat{\beta}_k$. The results presented in Table 1 were obtained using this approach.

the time trend (proxing technical progress) was significantly negative in 14 of the 37 industries covered (e.g., metal products and utilities); significantly positive in 13 industries (e.g., horticulture & fruit growing, telecoms and other retailing) and not statistically different to zero in 10 industries. Overall, the estimates obtained are economically sensible and pass tests of the validity of the instruments used (the Hansen test) and tests of second-order autocorrelation.

(Table 1 around here)

As discussed in section 2, MAR localisation economies are usually proxied by some aggregate measure at a predefined spatial level (e.g. the percentage of industry output located in the spatial district in which the plant or firm is located). The approach taken in this study is to use a more direct measure of the extent to which a plant is 'co-located' with other plants in the same industry (SCHOLL AND BRENNER, 2016).[13] That is, the location of every plant in each area unit is used to calculate the distance between area units (there are 2,020 such units in New Zealand) in kilometres between all pairs of plants in each industry, using the following formula:

$$Distance_i = \sum_{j=1, j\neq i}^{J} e^{-x(d_{i,j})} \times \frac{E_j}{\sum_{k=1, k\neq i} E_k} \quad (3)$$

where J is the number of observations; x is the rate of decay of the function; and $d_{i,j}$ is the distance between the area unit centroids in which plant i and j are located;[14] E_j is the number of employees in plant j; and $\sum_{k=1,k\neq i} E_k$ is the total employment in all other plants, except plant i, in the industry.[15] Once the distance index for each plant was obtained, if the firm was a multi-plant enterprise the plant level index was then weighted by its share in firm employment, to obtain a firm-level distance index.

(Figure 2 around here)

In the distance variable included in equation (1), a distance decay function of 0.05 was used (i.e., $e^{-0.05(d_{i,j})}$), but low decay {$e^{-0.01(d_{i,j})}$) and a high decay ($e^{-0.10(d_{i,j})}$) indices[16] were also tried without major changes in the results obtained (although the value of 0.05 preferred did give the 'best' results in terms of statistical significance). Figure 2 shows the average (logged) values, obtained from the industry-level distance specification, across area units in 2016, based on plants from all 64 industries (aggregated to firm-level).[17] Spatial proximity is strongest in areas such as Auckland and the adjacent northern part of the Waikato region, Wellington, the Picton area at the top of the South Island, Christchurch and Dunedin.

4. DIFFERENCES IN PRODUCTIVITY LEVELS ACROSS SPACE

Estimates of *ln* TFP were calculated for each firm for 2001-16 using equation (2a), and annual

[13] 64 separate NZSIOC industries were used, rather than the 37 used in the estimation of equation (1). This is the most disaggregated sector level we were able to use (alongside 2,020 area units).

[14] If plants i and j are located in the same area unit $d_{i,j}$ is assumed to be half of the distance between that area unit and the closest (distinct) area unit. Note, road distance is used based on Google Maps, and not straight-line distance between two points (the latter would not be meaningful in relatively inaccessible areas of New Zealand).

[15] Note in equation 3, individual plant distance indices are weighted by their size - thus making the assumption that larger plants with the same distance pattern to a smaller plant have a larger weighted distance score. This is because larger plants are more likely to have a potentially larger spillover effect and/or are more able to absolve spillovers due to their size – a result in line with the finding for New Zealand that absorptive capacity is much lower in smaller firms – see Figure 1 and Table 3 in Harris and Le (2019).

[16] Figure U.2 in the unpublished appendix shows the impact of different decay functions on the calculation of the distance index.

[17] See also Figure U.3(a) which shows all three distance decay functions; and Figure U.3(b) shows a similar outcome is achieved when the 64 industries are aggregated to 'clusters' – the longer version of the paper explains how 'clusters' were measured.

output-weighted averages of the elasticities reported in Table 1. That is, a common (average across industries) technology is used, rather than the individual industry estimates of the $\hat{\alpha}_{E,M,K}$. This is necessary because of the need for a multi-lateral index of TFP (see CRAIG ET. AL., 1995; and in particular BARTELSMAN AND WOLF, 2018, section 18.3.3, who point to the need to make comparisons across industries using a reference technology).[18] The common technology estimates of *ln* TFP were then aggregated to provide (weighted) means[19] at two levels of geography: (i) broad regions; and (ii) travel-to-work areas (as constructed by PAPPS AND NEWELL, 2002).

(Table 2 around here)

Table 2 produces mean and median aggregate values for the whole period, 2001-16, and for two sub-periods divided by the start of the Great Recession of 2008. Regions are ranked highest to lowest (based on the 2001-16 median scores).[20] As can be seen, the Wellington region has the highest overall productivity level, whichever measure is used and across time, although the difference between it and Auckland is small. Both Table 2 (and Figure U.4 in the online appendix) show that the gap between the two major cities has grown slightly since 2008, and this is mainly because firms in Wellington at the top end of the productivity distribution have opened up a larger gap.

In terms of the gap across regions, and using median scores for 2001-16, firms in Wellington are on average about twice as productive as those in the rest of the South Island, given the 0.313 median score for Wellington and a gap of 0.347. Auckland is close behind Wellington, and then there is a 0.113 gap between Auckland and Canterbury. The differences in average (median) values between Canterbury and other regions (excluding the rest of the South Island) is relatively small (0.042).[21]

The results presented so far confirm that there existed substantial differences in average productivity levels across different spatial areas – cf. Wellington and Auckland city-regions, versus other areas. Thus, in the rest of this section information is provided on the extent to which these differences can be attributed to 'place' effects (i.e., productivity enhancing factors linked to particular locations), or whether differences across space are due to 'firm mix' – the extent to which a geographical area has relatively more firms with positive or negative productivity-enhancing characteristics (i.e., output elasticities – cf. equation 1). The role of such 'place effects' are looked at in terms of: (a) the extent to which, *cet. par*. being located in certain regions is associated with higher TFP once the impact of other covariates are controlled for; (b) whether co-location is associated with spatial spillovers; and (c) consideration of the relative importance of TFP differences arising from both the non-spatial and spatial impacts included in equation (1).

(a) Marginal effects of location on productivity

The parameter estimates for the regional dummy variables included in equation (1) show the extent to which, *cet. par*., being located in certain regions is associated with higher TFP once the impact of size (as captured by factor inputs) and other covariates (e.g., age, foreign ownership,

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[18] Note, the results obtained using equation (2a) and a common technology were modified for presentational purposes by subtracting the mean value across all firms and years from each firm-level estimate.

[19] Note, these are means of the (common technology) firm-level estimates of *ln* TFP weighted to ensure the LBD data is representative of the annual population of firms in operation in New Zealand.

[20] Figure U.4 in the online appendix presents the (cumulative) distribution of *ln* TFP for each region for the two sub-periods.

[21] The longer version of the paper also presents analysis for travel-to-work areas confirming that at a finer level of spatial disaggregation, the dominance of Wellington and Auckland, and that the change in relative TTWA rankings across 2001-2007 and 2008-2016 is relatively small.

and labour-skills) are controlled for. The benchmark region chosen was Auckland (hence all the dummy variables for other regions included are expressing deviations from the largest city).

(Table 3 around here)

Table 3 shows that in 14 of the 37 industries covered, there were no statistically significant regional effects; and in a further 7 industries only 1 out of potentially 6 regional dummy variables was significant. Thus, in nearly two-thirds of the industries (cet. par.) regional effects were weak or non-existent.[22] Table 3 (final column) also reports the impact of the diversity variable (proxying Jacobian urbanisation economies); these were significant and positive in only four industries (cattle & grain farming, where the effects were small; construction services, where an increase of around one standard deviation in the diversity index resulted in just under a one percent increase in TFP;[23] in rail, water, air & other transport a 0.04 increase results in a 1.9% increase in TFP; while in information and media services a 0.04 increase in diversity increases TFP by just over 12%). Urbanisation economies were significant and negative in three industries: in textiles, leather & clothing a 0.02 increase in diversity resulted in a -3.3% change in TFP, while in building construction and administration & support services, a 0.04 increase in diversity resulted in a cet. par. change in TFP of -5.3% and -7%, respectively. For most industries (30 out of 37) there was no statistically significant effect on productivity.

This (marginal) analysis helps in understanding the results presented above when considering overall regional TFP differences; while it points to Auckland and Wellington having particular locational advantages (and/or the lack of disadvantages) for most industries (with the exception of some sectors of agriculture in the case of Auckland), it also suggests that *cet. par*. regional effects (as captured by the dummy variables) were not particularly strong. In addition, during this period, urbanisation economies were largely unimportant across the travel-to-work areas of New Zealand.

(Table 4 around here)

(b) Spatial spillover effects on TFP

Table 4 produces the main results showing the (*cet. par.*) impact of the distance function (measuring MAR spillovers at the industry-level using the medium decay function)[24] for firms of different sizes in the 37 industries covered; Figure U.5 (in the online appendix) produces a graphical version for those 9 industries where MAR spillovers were largest. There is evidence (albeit sometimes statistically weak) that spillovers occurred in 18 sectors with evidence that the effect of greater co-location on smaller firms was generally much smaller or negative (similar results with respect to plant size and spillover effects were found using broadly the same approach and data for Great Britain – see HARRIS ET. AL., 2019). For example, in cattle and grain farming (AA12), where the impact of spillovers was largest across all sectors, the effect of a 1% increase in the distance index on firms employing 5 workers was to increase TFP by 0.1%, increasing to 0.16% for those employing 10, and 0.3% (0.4%) for firms employing 50 (200) employees. Given that the overwhelming majority of firms in New Zealand in this and other sectors are small, typically employing less than 20 workers, it can be seen that for most firms spillover effects (even when statistically significant) were small and not a major factor in determining overall TFP levels.

[22] The longer version of this paper looks at the results in Table 3 in more detail, by industry. The essential message here is that regional effects were weak or non-existant.

[23] A one standard deviation increases is around 0.02 (see Table A.1), and given this is a semi-log parameter estimate, the impact of such a change in diversity is $100 \times dTFP/TFP = 100 \times 0.478 \times 0.02 = 0.96\%$.

[24] The results using the low and high decay functions, not shown here, produced even fewer statistically significant results, especially with ($e^{-0.10(d_{i,j})}$).

The larger impact of co-location for larger firms can be attributed to presumably that they have sufficient absorptive capacity to take advantage of inter-firm spillovers. The absorptive capacity of a firm especially in terms of its ability to internalise potential external knowledge spillovers (which for TFP may be more important in the long run than other sources of spillovers) is a key component of firm heterogeneity. As HARRIS AND LE (2019, p.290) explain "… like the ability of an individual to learn, absorptive capacity is not just about firms being able to benefit from spillovers but rather using knowledge from the external environment to improve their productivity; if firms are not able to learn, then new strategies or technology that are designed to help firms become more productive are likely to have only limited impact." Harris and Le, *op. cit.*, show that in the New Zealand context, absorptive capacity levels are strongly and positively associated with firm size, especially in the primary and manufacturing sectors. As discussed in HARRIS ET. AL. (2019), others have also demonstrated the importance of absorptive capacity.

As mentioned in section 2, MARÉ AND GRAHAM (2013) found that a 1% increase in agglomeration density in New Zealand area units (the same geographic unit as used here in the construction of the distance index) is associated with a 0.07% increase in firm productivity, with significant differences across fairly broadly defined industries. The most important point to note about their methodology is that it is more aligned to a measure of urbanisation (or Jacobian) economies, rather than Marshallian localisation economies, as proxied by the distance index used here. They construct measures of effective density based on the sum of two components: total employment in an area i weighted by the average distance between jobs *within* that area, plus the sum for all other j areas ($j \neq i$) of employment in those areas weighted by the distance between area i and area j (see equation 2 in MARÉ AND GRAHAM, op. cit.). While the overall productivity effect as stated above is relatively small, they find larger impacts of between 0.14-0.18% in property & business services, communication services, finance & insurance, and education (and they also find that such spillovers generally benefit smaller firms rather than larger ones). In the present study, there is little evidence of any significant intra-industry spillovers in property & business services or communication services (covered here by rental & hiring, and information media services plus telecoms, internet & library services), and education is not included in this study.[25] While there are significant differences in the methodology and the results obtained, both this study and MARÉ AND GRAHAM (op. cit.) suggest that agglomeration plays only a minor role in determining firm level productivity levels.

(c) The role of spatial and non-spatial factors on TFP

In this sub-section, differences arising from both the non-spatial and spatial impacts included in equation (1) are considered, with the latter including where the firm is located (in terms of broad region dummies) as well as the extent to which plants co-locate in each area unit (represented by measures of urbanisation and agglomeration), Note, it is expected that all of these spatial variables capture different aspects of 'spillovers', with different locations (e.g., a single city) experiencing a mix of potentially diverse impacts.

To provide estimates of the relative role of non-spatial and spatial effects, equation (2b) has been disaggregated into two parts reflecting the different effects, and then differences between each broad region and Wellington (as the benchmark) are calculated. That is, the (weighted) average *ln* TFP differences are defined as:

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[25] As reported in section 4(a), this study found in the information and media services industry that a 0.04 increase in diversity increases TFP by just over 12%; no significant effects were found in the other sectors found to have relatively larger agglomeration effects in Maré and Graham.

$$\sum_{it}^{N^r} ln\widehat{TFP}_{it}^r/N^r - \sum_{it}^{N^W} ln\widehat{TFP}_{it}^W/N^W = \sum_{it}^{N^r} \hat{\alpha}_{X\in NS}(\bar{X}_{it}^r - \bar{X}_{it}^W) + \sum_{it}^{N^r} \hat{\alpha}_{X\in S}(\bar{X}_{it}^r - \bar{X}_{it}^W) \quad (4)$$

where N^r is the number of firms i across time t in r (the broad regions), and N^W is the number of firms in W (Wellington); $X \in NS$ are the non-spatial determinants (e.g., *ln* age, foreign ownership, and labour-skills) listed in Table A.1; $X \in S$ are the spatial determinants (i.e.., diversity index, distance index, and region dummies); and $\hat{\alpha}_X$ are the estimated output elasticities for the X variables (see Table U.1). Note, the constant term from the regression measuring average fixed effects is included in the non-spatial part of equation (4), but this cancels out across firms within an industry. The error term in equation (2b) has also been ignored because its average value was close to zero across firms in 2001-16 and it includes demand shocks, ε_{it}^d (Table 1 shows that R^2 – calculated as the correlation squared between predicted and actual $\tilde{r}_{it}$ in equation (1) – was very high for each of the production functions estimated).[26]

(Table 5 around here)

Table 5 presents the results from applying equation (4) to disaggregate the difference between (weighted) average *ln* TFP in each region and Wellington. The last row of data shows average *ln* TFP for Wellington disaggregated into non-spatial and spatial effects, to provide benchmark figures.[27] The results show that the importance of spatial factors in accounting for the differential between productivity in Wellington and other areas is generally very small: using the mean values in Table 5, it accounts for between –2.3 to 13.8% for Otago through to the rest of the South Island. Only in Auckland are spatial effects important, accounting for over –43% of the city's small average *ln* TFP difference with Wellington (noting that this difference mostly disappears when median values are used in equation 5).[28]

(Table 6 around here)

5. PRODUCTIVITY GROWTH AND SPATIAL LOCATION

The previous section looked at differences in productivity levels; the final comparison made is with respect to differences across geographical areas in terms of the growth of *ln* TFP from 2001 to 2016. Table 6 presents the results from a decomposition of aggregate productivity growth (FOSTER ET AL., 1998) into: the (within-plant) contribution of firms operating in both 2001 and 2012 that internally increased their productivity; the between- firm contribution of reallocations of output share between firms operating in both 2001 and 2012; and the contribution of entering and exiting firms.[29] The first set of results headed 'contribution' shows that overall New Zealand's TFP growth in 2001-2012 was 1.1% p.a., of which Auckland contributed 0.76% p.a., leaving only 0.33% p.a. to be contributed by all other regions (and Canterbury accounted for nearly 40% of this non-Auckland contribution). Since the results in the first column are dependent not only on productivity growth but also the relative size of the

[26] The fact that equation (2b) includes an error term, comprising both demand and supply shocks, theoretically matters (Foster, et. al., 2017); but the empirical importance depends on the relatively contribution of ε_{it} (and its components) to measuring l$n\widehat{TFP}_{it}$; on average across 2001-16, it had little impact in the present study.

[27] I.e., $\sum_{it}^{N^W} ln\widehat{TFP}_{it}^W/N^W = \sum_{it}^{N^W} \hat{\alpha}_{X\in NS}(\bar{X}_{it}^W) + \sum_{it}^{N^W} \hat{\alpha}_{X\in S}(\bar{X}_{it}^W)$

[28] Disaggregating *ln* TFP differences into spatial and non-spatial components has also been undertaken using industries (rather than regions), with the industry with the highest productivity value (Finance & insurance) used as the benchmark. The results are shown in Figure U.6, confirming that spatial factors are not the major influence on productivity level differences at an industry level.

[29] The decomposition approach is set out in the appendix. The underpinning Schumpeterian model of resource allocation across firms (see Aghion et. al., 2013, for full details), which includes the notion of 'creative destruction' (Schumpeter, 1943), is briefly discussed in Harris (2020).

economy, the figures in the final column divide those in column (1) by output shares (not shown) in 2001.

Thus, Auckland contributed over 69% of the country's aggregate TFP growth, and its relative contribution was still the largest after taking account of the fact that the Auckland region accounted for an average of over 38% of output in 2001. Most of this large contribution to productivity was due to continuing firms increasing their productivity both internally (accounting for 0.32% p.a. of the 0.76% p.a. contribution) and through firms in Auckland, that had higher productivity, gaining larger market shares from other firms located in Auckland and/or elsewhere (this accounted for 0.15% p.a. growth). The other major influence on TFP growth in the region was the opening of new, relatively more productive plants (operating with better technology). Firms that exited had a relatively small impact, and in fact the loss of –0.09% p.a. TFP growth shows that these closing firms actually had above average productivity levels (when the expectation is that firms that close are usually the least efficient).[30]

Canterbury also performed relatively well in terms of TFP growth (both in actual and relative terms), with most of the increase due to the opening of new firms over 2001-16. Wellington would have contributed much more than it did if the strong 'within-firm' improvements had not been largely cancelled out by the gain in output shares by firms that either had poor TFP in 2001 or for whom TFP declined over the period. The largest contribution to more modest TFP growth in the Waikato was the closure of less productive firms, while Otago benefited most from 'between-firm' productivity growth as well as the entry of new firms, offset to some extent by a decline in 'within-firm' productivity. Note, Otago did relatively much better than Wellington and the Waikato if the size of each region is also taken into account. Lastly, the strong performance of Auckland, and to a much lesser extent Wellington and the Waikato, was not mirrored in the performance of the rest of the North Island; the latter contributed negative TFP growth as firms that were open throughout the 2001-16 period underperformed.

The results presented in Table 6 also show the extent to which the 'market' acts to reallocate resources towards more efficient firms; most of the 1.1% p.a. on average increase in *ln* TFP was achieved through either firms in existence throughout becoming internally more productive (mostly in Auckland and Wellington), rather than a reallocation of market shares towards better firms (in the same or other regions, the main exceptions being in Auckland and Wellington but with opposite effects); or through the opening of more productive, new firms (again Auckland dominates, but there is more of a spread across other geographic areas compared to within-in firm TFP growth). The closure of inefficient firms resulted in the smallest contribution to overall productivity growth (indeed a negative contribution, where on average more efficient firms were closed), suggesting that many smaller, less efficient firms were able to survive in small and geographically segmented domestic markets (Conway, 2016), especially in Auckland and Wellington where firm closures had the largest effect of lowering productivity.[31]

[30] It is interesting to note that the two regions with largest unexpected negative impact, from firm exits on aggregate productivity, were the two major cities, where market competition ('selection effects' as discussed in COMBES et. al., 2012) is likely highest. Higher productivity due to firm entry – in part indicating higher competition and/or lower barriers to new firm entry – was also prevalent, suggesting that while exiting firms in Auckland and Wellington had above average productivity levels (relative to the national average), their productivity was not sufficiently high to overcome stronger selection (competition) effects prevalent in the major cities. Further work is clearly needed to investigate the extent to which selection was happening.

[31] The longer version of this paper gives results for the largest TTWAs, in line with the results in Table 6 but with more disaggregated information for the regions outside of Auckland, Canterbury and Wellington.

5. SUMMARY AND CONCLUSIONS

Using firm-level panel data and estimating production functions for 37 industries, covering the 2001-16 period, this paper finds that firms in the Wellington region were on average about twice as productive as those in the rest of the South Island (which had the lowest average *ln* TFP across the broad regions of New Zealand). They also confirm the importance placed by MCCANN (2009) on recognising the importance of Auckland, although in the analysis presented here it is actually Wellington that comes first in New Zealand's productivity rankings.

Having found these differences, the paper then considers whether 'place' effects are the major explanation for such spatial differences, or whether 'firm mix' is more important. The role of such 'place effects' was looked at firstly in terms of the extent to which, *cet. par*. being located in certain regions is associated with higher TFP once the impact of other covariates are controlled for. It was found that *cet. par*. regional effects were not particularly strong. In addition, during this period, urbanisation economies were largely unimportant across the travel-to-work areas of New Zealand. 'Place effects' were also considered in terms of whether co-location of plants (as measured by a distance index) was associated with spatial productivity spillovers; there was evidence that (fairly modest) MAR spillovers were present in only around half of the industries considered, with the effect on smaller firms generally much lower or negative, and thus it can be concluded that for most firms spillover effects were not a major factor in determining overall TFP levels. Together with the results obtained on the importance of Jacobian urbanisation economies, this study has found that agglomeration plays only a minor role in determining firm level productivity levels.

Thirdly, 'place' effects were looked at in terms of the relative importance of TFP differences arising from both the non-spatial and spatial impacts included when estimating industry production functions. The results showed that the importance of spatial factors in accounting for the differential between productivity in Wellington and other areas was generally very small; only in Auckland are spatial effects important, accounting for over –43% of the city's *small* average *ln* TFP difference with Wellington.

Having looked at spatial differences in productivity levels, this study also considered differences across geographical areas in terms of the growth of *ln* TFP from 2001 to 2016. The results showed that Auckland contributed over 69% of the country's aggregate TFP growth. As to other areas, Canterbury accounted for nearly 40% of the non-Auckland contribution. Thus, Wellington city did less well in terms of productivity growth, although its contribution was still significant.

The above results lead to the conclusion that, while there is support for the argument that location matters in terms of productivity differences in New Zealand, it is more likely that this is due to scale/home market effects rather than agglomeration effects resulting from co-location.[32] Moreover, this study provides evidence of domination by the two main city-regions of Wellington (the capital) and Auckland. It also finds little evidence of catch up of lagging regions in productivity terms. This raises the policy issue of whether the New Zealand government should more actively intervene to attempt to 'level-up' productivity across the country, on the grounds that otherwise this could have negative consequences for social cohesion (particularly in the future if differences grow), as wage levels and overall living standards fall behind in other areas. This, of course, depends on what determines underlying (productivity) growth – is the 'market' likely to be self-equilibrating (i.e., in the neoclassical model factor flows will ensure that regions that are lagging behind their peers have the capacity

[32] Clearly, having better, detailed spatial measures of other characteristics of different areas (such as infrastructure, housing and other labour force characteristics as these impact on different firms) could result in a different conclusion – and therefore further analysis is clearly warranted.

to "catch up" with leading regions; cf. BORTS 1960) or will place-specific assets encourage cumulative-causation and virtuous cycles, so that economic inequalities become entrenched (e.g., the Kaldor model of regional growth – cf. DIXON AND THIRLWALL, 1975 – and the evolutionary economic geography approach – cf. BOSCHMA AND MARTIN, 2010)

In addition, imbalances imply untapped potential in increasing national productivity (growth) by improving the performance of all regions. However, whether spatial imbalances act as a drag on national productivity also depends on the underlying mechanisms that lead to differences in regional (productivity) growth. The results presented here on productivity growth between 2001-16 provided little evidence of a (spatial) reallocation of market shares to firms with higher productivity, or the closure of the least productive firms. This suggests that competition between firms is limited, because (i) many smaller, less efficient firms are able to survive in small and geographically segmented domestic markets; and (ii) because for larger firms there is evidence (corroborated by the estimates reported in Table 1) of extensive price-cost mark-ups in certain sectors (e.g., manufacturing, wholesale trade, motor retail, and especially financial services). With regard to the latter, and the spatial distribution of economic capacity, NZIER (2014, especially Table 3), showed that the strong interconnectedness of New Zealand's regional economies through common business ownership (of larger firms) meant that growth was significantly dominated in most regions by common 'national' factors, affecting all regions jointly (exchange rates, interest rates and global economic conditions)[33]

This suggests policies that foster greater competition (including increasing exporting at the extensive and intensive margins, as well as factors that increase firm absorptive capacity – see HARRIS AND LE, 2019) are more likely to increase productivity at the spatial level, than are spatial policies themselves that attempt to bring about a non-market based reallocation of productive resources across New Zealand's geographical areas (e.g., through differentiated 'help' to areas with lower productivity, such as R&D grants, help with firm start-ups, or similar schemes). As BOUDEVILLE (1966) notes: "… if the objective were to maximise, in a given period, the income of each region, national growth might be slowed down to a considerable extent. National resources are always limited, regional productivities are unequal, and regional interconnections different. Investment in less productive, less well endowed regions would put a brake on the development of more productive ones. Investment in regions less closely linked with the economic core of the nation … would (result in) a lower impact in total growth".

While this paper only deals with New Zealand, the methodology can be used for other countries with comparable firm- or plant-level data; indeed, the author is currently engaged in using similar data and a similar approach to consider the relative importance of spatial factors in determining productivity in Great Britain. An exploratory study by the ONS (2019) shows that labour productivity in Britain is dominated by London and to a lesser extent the South East region, with differences between other regions relatively small. Additionally, there is some evidence to suggest that most of the differences across regions is more to do with firm-level characteristics rather than industry-mix. Calculating TFP using the econometric approach adopted here, it will be possible to test how important spatial factors are in another OECD country which this time is not constrained by its size and geographic location in the way that New Zealand is.

[33] They point to some exceptions: the natural resource exposure of Taranaki, and strong urban effects in Wellington and Auckland.

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Appendix

The Haltiwanger-type approach

Consider the contribution of different sub-groups of firms in an attempt to explain productivity growth in any period. Individual firm-level TFP is aggregated as follows:

$$\ln \widehat{TFP}_t = \sum_j \sum_i G_j \times \theta_{ijt} \ln \widehat{TFP}_{ijt} \tag{A.1}$$

where G_j is a set of mutually exclusive dummy variables indicating whether a firm belongs to subgroup j[34] and θ_{ijt} is the share of (real) gross output for firm i in subgroup j at time t. The growth of aggregate TFP is therefore given by:

$$\Delta \ln \widehat{TFP}_t = \ln \widehat{TFP}_t - \ln \widehat{TFP}_{t-k} \tag{A.2}$$

Following Foster, Haltiwanger and Krizan (2001), TFP is decomposed into five components as follows:

$$\begin{aligned}\Delta \ln \widehat{TFP}_t = &\sum_j \sum_{i \in S} G_j \times \theta_{ijt-k} \Delta \ln \widehat{TFP}_{ijt} + \\ &\sum_j \sum_{i \in S} G_j \times \Delta\theta_{ijt} \left(\ln \widehat{TFP}_{ijt-k} - \ln \widehat{TFP}_{t-k}\right) + \\ &\sum_j \sum_{i \in S} G_j \times \Delta\theta_{ijt} \left(\Delta \ln \widehat{TFP}_{ijt}\right) + \\ &\sum_j \sum_{i \in E} G_j \times \theta_{ijt} \left(\ln \widehat{TFP}_{ijt} - \ln \widehat{TFP}_{t-k}\right) - \\ &\sum_j \sum_{i \in X} G_j \times \theta_{ijt-k} \left(\ln \widehat{TFP}_{ijt-k} - \ln \widehat{TFP}_{t-k}\right)\end{aligned} \tag{A.3}$$

The first component shows the contribution from improvements in TFP within firms that survived from $t - k$ to t (denoted by S), the second term shows the contribution from reallocations of output shares between firms that were open in $t - k$ and t and the third term shows the contribution from the coincidence of increases in productivity and increases in output shares in firms open in $t - k$ to t. The final two terms capture the contribution from firms that entered between $t - k$ and t (denoted E) and firms that exited between $t - k$ and t (denoted by X). If the observed growth in TFP is a selection effect, this term should be positive.

[34] E.g., firms in different regions.

Table A.1: Definitions of variables used in production function, sources, and means and standard deviations by broad sector, 2001-2016, New Zealand

Variable		Source	Agriculture, Fish, Forestry		Mining, Manufacturing, Utilities		Services	
			$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}$	σ
ln gross output	value of sales of goods and services (in NZ$), less the value of purchases of goods for resale, with an adjustment for changes in the value of stocks of finished goods and goods for resale, deflated at the level-3 NZSIOC industry using PPI for outputs	Fabling and Mare (2015)	11.009	2.86	12.097	1.99	11.700	2.04
ln intermediate inputs	the sum (in NZ$) of purchases and total expenses (excluding salaries and wages, bad debt write-offs, interest paid, and depreciation) deflated at level-3 NZSIOC industry using PPI for inputs	Fabling and Mare (2015)	10.823	1.88	11.410	1.91	10.676	1.83
ln employment	the number of FTE workers at the firm including working proprietors	Fabling and Mare (2015)	0.393	0.79	0.554	1.12	0.458	1.11
ln capital	the cost of capital services (in NZ$) comprising depreciation costs; capital rental and leasing costs; and the user cost of capital (the value of total assets, multiplied by an interest rate equal to 10%), deflated by a four-quarter average of the Capital Goods Price Index (All groups)	Fabling and Mare (2015)	10.706	1.47	9.497	1.64	9.739	1.65
ln distance	*ln* distance index based on road distance in km between plant and all other plants in each NZSIOC 64 industry, aggregating plants using employment to obtain firm index (medium decay, $e^{-0.05(d_{i,j})}$)	Google Maps plus above employment data	-4.297	1.82	-4.047	2.42	-4.125	3.12
Foreign	dummy variable coded 1 if firm was foreign-owned	LBD as explained in Fabling and Mare (2019), IR4, BOS	0.012	0.11	0.020	0.14	0.028	0.17
$\hat{\theta}_n$	average for firm of time constant worker fixed effect representing the portable earnings premium of worker *n*, and reflects unobserved skills factors such as their labour market experience, qualifications, ability and motivation relative to their age-cohort, during the period	equation (3) in Maré et. al. (2017)	-0.123	0.21	-0.074	0.19	-0.078	0.24
$X'_{it}\hat{\beta}$	coefficient on *ln* (FTE-adjusted annual earnings) in the base year (over ALL firms – not just the production sample) to capture observed skills (based on demographic effects)	equation (3) in Maré et. al. (2017)	10.563	0.19	10.592	0.18	10.539	0.17
ln age	Age of firm (year minus date of opening)	LBD as explained in Fabling and Mare (2019), BOS	2.312	0.86	1.972	0.99	1.820	0.97
Diversity	Proportion of 64 NZSIOC industries present in each of the 140 TTWAs of NZ (proxying urbanisation economies)	Own calculations based on LBD as explained in Fabling and Mare (2019)	0.069	0.12	0.027	0.02	0.045	0.04

Table A.1: (cont.)

Herfindahl	Herfindahl index of industry output	Own calculations based on LBD as explained in Fabling and Mare (2019)	0.015	0.06	0.019	0.04	0.025	0.05
Auckland	proportion of firm employment in Auckland	LBD as explained in Fabling and Mare (2019)	0.070	0.26	0.317	0.46	0.378	0.48
Waikato	proportion of firm employment in Waikato	LBD as explained in Fabling and Mare (2019)	0.115	0.32	0.100	0.30	0.081	0.27
rest upper North Island	proportion of firm employment in rest of Upper NI	LBD as explained in Fabling and Mare (2019)	0.228	0.42	0.146	0.35	0.117	0.32
Wellington	proportion of firm employment in Wellington	LBD as explained in Fabling and Mare (2019)	0.036	0.19	0.096	0.29	0.121	0.32
rest lower North Island	proportion of firm employment in rest of lower NI	LBD as explained in Fabling and Mare (2019)	0.113	0.32	0.068	0.25	0.056	0.23
Canterbury	proportion of firm employment in Canterbury	LBD as explained in Fabling and Mare (2019)	0.183	0.39	0.139	0.35	0.129	0.33
Otago	proportion of firm employment in Otago	LBD as explained in Fabling and Mare (2019)	0.068	0.25	0.050	0.22	0.045	0.21
rest South Island	proportion of firm employment in rest of SI	LBD as explained in Fabling and Mare (2019)	0.139	0.35	0.064	0.24	0.051	0.22

Table 1: (Long-run) Output elasticities obtained from estimating equation (1) used to obtain TFP estimates

Industry (NZSIOC)	*ln* intermediate inputs α_M	*ln* employment α_E	*ln* capital α_K	Time trend α_T	mark-up σ/(σ−1)	N	N (firms)	Pseudo-R^{2a}	AR(2) z-statistic p-value	Hansen test p-value
Horticulture & fruit growing (AA11)	0.413***	0.535**	0.203*	0.021***	1.028	9,783	2,001	0.997	0.129	0.460
Sheep, Beef cattle and grain farming (AA12)	0.777***	0.509**	0.106*	-0.006***	0.958	15,243	2,994	0.999	0.240	0.191
Poultry, deer & other livestock (AA14)	0.627***	0.252***	0.167***	0.015***	0.939***	3,084	630	0.997	0.176	0.564
Forestry & logging (AA21)	0.727***	0.417***	0.293***	-0.007	0.907**	3,321	696	0.996	0.102	0.694
Support services to agriculture, forestry, fishing & hunting (AA32)	0.628***	0.279***	0.181***	-0.007**	1.002	525	192	0.998	0.403	0.607
Mining (BB11)	0.696***	0.396***	0.223***	0.002	0.895***	1,533	300	0.985	0.247	0.676
Manufacturing										
Food beverage & tobacco (CC1)	0.717***	0.145**	0.077**	-0.004***	0.958**	12,198	2,403	0.996	0.156	0.301
Textile, leather & clothing (CC21)	0.688***	0.262***	0.168*	0.015***	1.020	6,150	1,107	0.994	0.954	0.149
Wood & paper products (CC3)	0.674***	0.348***	0.092**	0.005***	1.040***	9,087	1,524	0.996	0.217	0.656
Printing (CC41)	0.649***	0.327***	0.104***	-0.003**	1.046	5,718	1,035	0.996	0.862	0.138
Petrol, chemical, polymer & rubber (CC5)	0.723***	0.210***	0.198**	0.001	1.124***	5,943	978	0.994	0.123	0.456
Non-metallic minerals (CC61)	0.647***	0.283***	0.156***	0.001	1.028	2,991	543	0.997	0.621	0.188
Metal products (CC7)	0.766***	0.274***	0.125*	-0.015***	1.196***	14,661	2,328	0.997	0.715	0.172
Transport equipment (CC81)	0.655***	0.564***	0.142*	-0.011***	1.212***	5,529	1,005	0.994	0.398	0.581
Machinery & other equipment (CC82)	0.730***	0.305***	0.093**	0.009***	1.073***	13,911	2,301	0.994	0.549	0.196
Furniture & other manufacturing (CC91)	0.671***	0.243***	0.097**	-0.001	0.981	7,713	1,353	0.997	0.193	0.62
Utilities (DD1)	0.553***	0.299***	0.178***	-0.015***	1.019	2,427	528	0.997	0.203	0.712
Building construction (EE11)	0.625***	0.328***	0.079***	-0.001	1.005	4,878	1,053	0.999	0.963	0.701
Heavy & civil engineering construction (EE12)	0.438***	0.611***	0.166*	-0.011***	1.007	5,589	1,020	0.992	0.328	0.141
Construction services (EE13)	0.711***	0.246***	0.056*	0.008***	0.999	75,921	15,774	0.995	0.416	0.106
Wholesale trade (FF11)	0.364***	0.357***	0.347***	0.005*	1.036***	57,840	11,106	0.987	0.239	0.187
Motor retail (GH11)	0.433***	0.514***	0.200***	0.005*	1.062***	16,086	2,883	0.990	0.280	0.111

Supermarkets, stress, specialised retailing (GH12)	0.584***	0.230***	0.211***	0.002	1.006	18,726	4,290	0.992	0.240	0.243
Other retailing (GH13)	0.384***	0.310*	0.378*	0.025***	0.916**	61,743	12,399	0.989	0.168	0.116
Accommodation & food services (GH21)	0.548***	0.259***	0.155***	0.003***	0.913***	60,831	15,654	0.994	0.501	0.099
Road transport (II11)	0.447***	0.311***	0.208***	-0.005***	0.985***	16,623	3,441	0.997	0.581	0.266
Rail, water, air & other transport (II12)	0.508***	0.290***	0.192***	0.013***	1.008	2,691	645	0.987	0.137	0.713
Post, courier support & warehousing (II13)	0.446***	0.428***	0.110**	-0.009***	1.017	7,281	1,614	0.995	0.389	0.321
Information media services (JJ11)	0.600***	0.188***	0.121***	0.001	0.962	5,250	1,233	0.997	0.463	0.731
Telecoms, internet & library services (JJ12)	0.551***	0.292***	0.156***	0.036***	1.018	1,785	483	0.988	0.828	0.654
Finance & insurance (KK1_)	0.540***	0.375***	0.263**	-0.010***	1.133***	10,197	2,382	0.983	0.689	0.147
Auxiliary finance & insurance services (KK13)	0.274***	0.703***	0.088*	-0.009	1.252***	3,267	825	0.982	0.240	0.110
Rental & hiring (LL11)	0.371***	0.534***	0.267*	-0.006	1.093	288	126	0.999	0.609	0.908
Professional, technical & scientific services (MN11)	0.323***	0.416***	0.344***	-0.003*	1.081***	75,687	17,280	0.992	0.149	0.184
Admin & support services (MN21)	0.279**	0.390***	0.294**	-0.007**	0.983	27,690	6,771	0.988	0.977	0.206
Arts & recreational services (RS11)	0.502***	0.310***	0.164***	0.007***	0.939	8,016	1,959	0.996	0.173	0.127
Other services (RS21)	0.418***	0.345***	0.366***	-0.007***	1.041	49,821	9,753	0.993	0.207	0.116

***/**/* significant at 1/5/10% level . Note, pseudo-R^2 is calculated as the correlation squared between predicted and actual $\tilde{r}_{it}$ in equation (1); the values are an indicator of 'goodness-of-fit' which is usually high in such dynamic panel-data production function models.

Source: Table U.1

Table 2: (weighted) mean *ln* TFP, 2001-2016, by broad regions (common output elasticities)

	2001-16		2001-2007		2008-2016	
Regions[a]	mean	median	mean	median	mean	median
Wellington	0.279	0.313	0.201	0.283	0.341	0.336
Auckland	0.242	0.304	0.185	0.280	0.281	0.320
Canterbury	-0.019	0.191	-0.104	0.130	0.044	0.233
Otago	0.024	0.183	-0.049	0.138	0.077	0.213
Waikato	0.016	0.179	-0.047	0.137	0.066	0.209
Rest of Lower North Island	-0.019	0.152	-0.086	0.109	0.037	0.185
Rest of Upper North Island	-0.076	0.149	-0.156	0.103	-0.013	0.183
Rest of South Island	-0.553	-0.034	-0.566	-0.066	-0.542	-0.007
Gap (highest-to-lowest)	0.832	0.347	0.767	0.349	0.883	0.343
Gap (Auckland with Canterbury)	0.261	0.113	0.289	0.150	0.237	0.087

[a] Sorted by median 2001-16 values

Table 3: Long-run parameter estimates for region dummies and urbanisation economies obtained from estimating equation (1)

Industry	Waikato	rest upper North Island	Wellington	rest lower North Island	Canterbury	Otago	rest South Island	Urbanisation
Horticulture & fruit growing (AA11)	0.116**	0.071	-0.100	0.071	0.060	-0.070	0.108	0.034
Sheep, Beef cattle and grain farming (AA12)	0.157**	0.232***	0.236***	0.215***	0.133*	0.183***	0.235***	0.075**
Poultry, deer & other livestock (AA14)	0.02	0.027	-0.159**	-0.013	-0.101**	-0.115*	-0.018	0.208
Forestry & logging (AA21)	0.086	0.046	0.054	-0.065	0.136	-0.177	-0.066	-1.065
Support services to agriculture, forestry, fishing & hunting (AA32)	0.252***	0.172***	0.148*	0.015	0.089	0.077	0.165*	-0.076
Mining (BB11)	-0.113	-0.033	-0.194	0.183	-0.099	-0.091	-0.088	0.073
Manufacturing								
Food beverage & tobacco (CC1)	0.001	-0.019	0.018	-0.017	0.006	0.036	0.027	-0.048
Textile, leather & clothing (CC21)	-0.083	-0.086	-0.073	-0.040	-0.066	-0.164***	-0.070	-1.639**
Wood & paper products (CC3)	0.030	-0.013	-0.011	-0.043*	0.006	-0.019	-0.038*	-0.137
Printing (CC41)	-0.015	-0.048**	-0.015	-0.024	-0.001	-0.016	-0.011	-0.393
Petrol, chemical, polymer & rubber (CC5)	-0.036	0.001	0.041	0.043	-0.015	-0.060	0.059	-0.152
Non-metallic minerals (CC61)	-0.091***	-0.068***	-0.033	-0.080***	-0.009	-0.061*	-0.054*	-0.706
Metal products (CC7)	-0.034*	-0.008	-0.025	-0.002	-0.037***	-0.038	-0.042*	0.656
Transport equipment (CC81)	-0.120***	-0.049	0.024	-0.074	-0.071***	-0.151***	-0.047	1.334
Machinery & other equipment (CC82)	-0.041*	-0.038	-0.013	-0.043	-0.041**	-0.047	-0.079***	0.223
Furniture & other manufacturing (CC91)	-0.048**	-0.008	0.012	-0.018	-0.027*	0.011	0.005	-0.519
Utilities (DD1)	0.033	0.019	0.070*	0.020	0.007	0.126***	-0.036	-0.515
Building construction (EE11)	-0.148***	-0.074*	-0.022	-0.129***	-0.092***	-0.103***	-0.084**	-1.333**
Heavy & civil engineering construction (EE12)	-0.077	-0.082***	-0.064*	-0.079*	-0.045	-0.060	-0.073	0.100
Construction services (EE13)	-0.017*	-0.021*	-0.009	-0.022*	0.015	-0.007	-0.007	0.478***
Wholesale trade (FF11)	-0.032	-0.032	-0.040	-0.052	0.007	-0.088*	-0.050	-0.403
Motor retail (GH11)	-0.038	-0.021	-0.005	-0.027	0.045	-0.001	0.038	0.466
Supermarkets, stress, specialised retailing (GH12)	0.001	-0.008	0.015	0.006	0.020	0.0042	-0.003	-0.027
Other retailing (GH13)	0.023	0.006	0.015	0.041	0.030	-0.018	0.018	-0.799
Accommodation & food services (GH21)	0.001	0.005	0.013	-0.002	0.004	0.005	-0.005	0.011
Road transport (II11)	0.007	0.001	0.016	0.005	0.009	0.026	-0.003	0.474*

Rail, water, air & other transport (II12)	0.031	-0.013	0.034	0.170*	-0.019	-0.025	0.036	-0.542
Post, courier support & warehousing (II13)	-0.086	-0.091**	-0.096*	-0.104*	-0.025	-0.102	-0.116**	-0.670
Information media services (JJ11)	-0.043	-0.055	-0.032	-0.065	-0.060	-0.019	-0.016	3.032**
Telecoms, internet & library services (JJ12)	-0.038	-0.148***	0.097	-0.061	0.046	-0.152**	-0.018	0.765
Finance & insurance (KK1_)	0.055	-0.057	0.04	-0.001	0.073	0.039	0.021	0.690
Auxiliary finance & insurance services (KK13)	-0.035	-0.257*	-0.09	-0.155	0.032	-0.113	0.18	1.766
Rental & hiring (LL11)	-0.045	-0.131	-0.216	-0.583***	-0.101	-0.237	0.422	0.232
Professional, technical & scientific services (MN11)	-0.034	-0.046*	0.076***	-0.023	-0.020	-0.005	-0.033	0.525
Admin & support services (MN21)	0.018	0.032	0.001	0.113*	0.025	0.073*	0.069	-1.746***
Arts & recreational services (RS11)	-0.043	-0.045	0.024	-0.069	-0.033	-0.029	-0.025	0.256
Other services (RS21)	0.008	0.021	0.022*	0.028	0.046***	0.041**	0.036*	-0.339

***/**/* significant at 1/5/10% level

Source: Table U.1

Table 4: Long-run (weighted) impact of *ln* Distance index based on 64 (4-digit) industry (medium decay, $e^{-0.05(d_{i,j})}$) on TFP by size of plant, 2001-2016 (New Zealand)

Industry (NZSIOC)	Distance × 5 employees	Distance × 10 employees	Distance × 50 employees	Distance × 200 employees
Horticulture & fruit growing (AA11)	0.027*	0.043	0.080	0.112
Sheep, Beef cattle and grain farming (AA12)	0.097**	0.158*	0.300*	0.422*
Poultry, deer & other livestock (AA14)	0.000	0.011	0.037	0.059
Forestry & logging (AA21)	-0.039***	0.004	0.104*	0.191**
Support services to agriculture, forestry, fishing & hunting (AA32)	0.012*	0.015*	0.022*	0.028*
Mining (BB11)	-0.058***	-0.035**	0.019	0.066
Manufacturing				
Food beverage & tobacco (CC1)	0.002	0.000	-0.004	-0.008
Textile, leather & clothing (CC21)	-0.005	-0.005	-0.005	-0.004
Wood & paper products (CC3)	-0.002	0.007	0.028*	0.046*
Printing (CC41)	0.001	0.008*	0.024***	0.037***
Petrol, chemical, polymer & rubber (CC5)	0.009	0.009	0.008	0.006
Non-metallic minerals (CC61)	-0.004	-0.003	-0.001	0.001
Metal products (CC7)	0.000	0.001	0.005	0.008
Transport equipment (CC81)	-0.009	0.010	0.053*	0.091*
Machinery & other equipment (CC82)	-0.002	0.004	0.017	0.028
Furniture & other manufacturing (CC91)	0.004	0.005	0.008	0.011
Utilities (DD1)	0.012	0.014	0.019	0.023
Building construction (EE11)	0.026***	0.033***	0.048***	0.061*
Heavy & civil engineering construction (EE12)	-0.010**	0.006	0.045***	0.078***
Construction services (EE13)	0.003*	0.005	0.010	0.014
Wholesale trade (FF11)	0.006	0.016	0.038	0.058
Motor retail (GH11)	0.008	0.022***	0.056***	0.084***
Supermarkets, stress, specialised retailing (GH12)	-0.002	-0.005	-0.013	-0.020
Other retailing (GH13)	-0.009	0.001	0.024	0.044
Accommodation & food services (GH21)	0.007***	0.010***	0.018***	0.025***
Road transport (II11)	0.009**	0.010***	0.012	0.015
Rail, water, air & other transport (II12)	0.003	0.002	0.000	-0.002
Post, courier support & warehousing (II13)	0.017***	0.022**	0.033**	0.042*
Information media services (JJ11)	0.006	0.008	0.013	0.017
Telecoms, internet & library services (JJ12)	-0.001	-0.003	-0.007	-0.01
Finance & insurance (KK1_)	0.035***	0.048***	0.080***	0.107***
Auxiliary finance & insurance services (KK13)	0.012	0.019	0.036	0.051
Rental & hiring (LL11)	0.001	-0.012	-0.041	-0.067
Professional, technical & scientific services (MN11)	0.007	0.013	0.026	0.037
Admin & support services (MN21)	0.038***	0.041***	0.048	0.054
Arts & recreational services (RS11)	0.017*	0.026*	0.047	0.065
Other services (RS21)	-0.011	-0.007	0.003	0.011

***/**/* significant at 1/5/10% level

Source: based on Table U.1

Table 5: Differences compared to Wellington of mean and median *ln* TFP 2001-16 by broad region: contribution of spatial and non-spatial factors (common output elasticities)

	Mean			Median		
	Non-spatial[a]	Spatial[b]	*ln* TFP[c]	Non-spatial[a]	Spatial[b]	*ln* TFP[c]
Auckland	-0.053	0.016	-0.037	-0.008	-0.001	-0.009
Otago	-0.235	-0.020	-0.255	-0.129	-0.001	-0.130
Waikato	-0.245	-0.018	-0.263	-0.132	-0.002	-0.134
Rest of Lower North Island	-0.305	0.007	-0.298	-0.159	-0.002	-0.161
Canterbury	-0.278	-0.020	-0.298	-0.121	-0.001	-0.122
Rest of Upper North Island	-0.306	-0.049	-0.355	-0.162	-0.002	-0.164
Rest of South Island	-0.781	-0.051	-0.832	-0.345	-0.002	-0.347
Wellington[d]	0.260	0.019	0.279	0.311	0.002	0.313

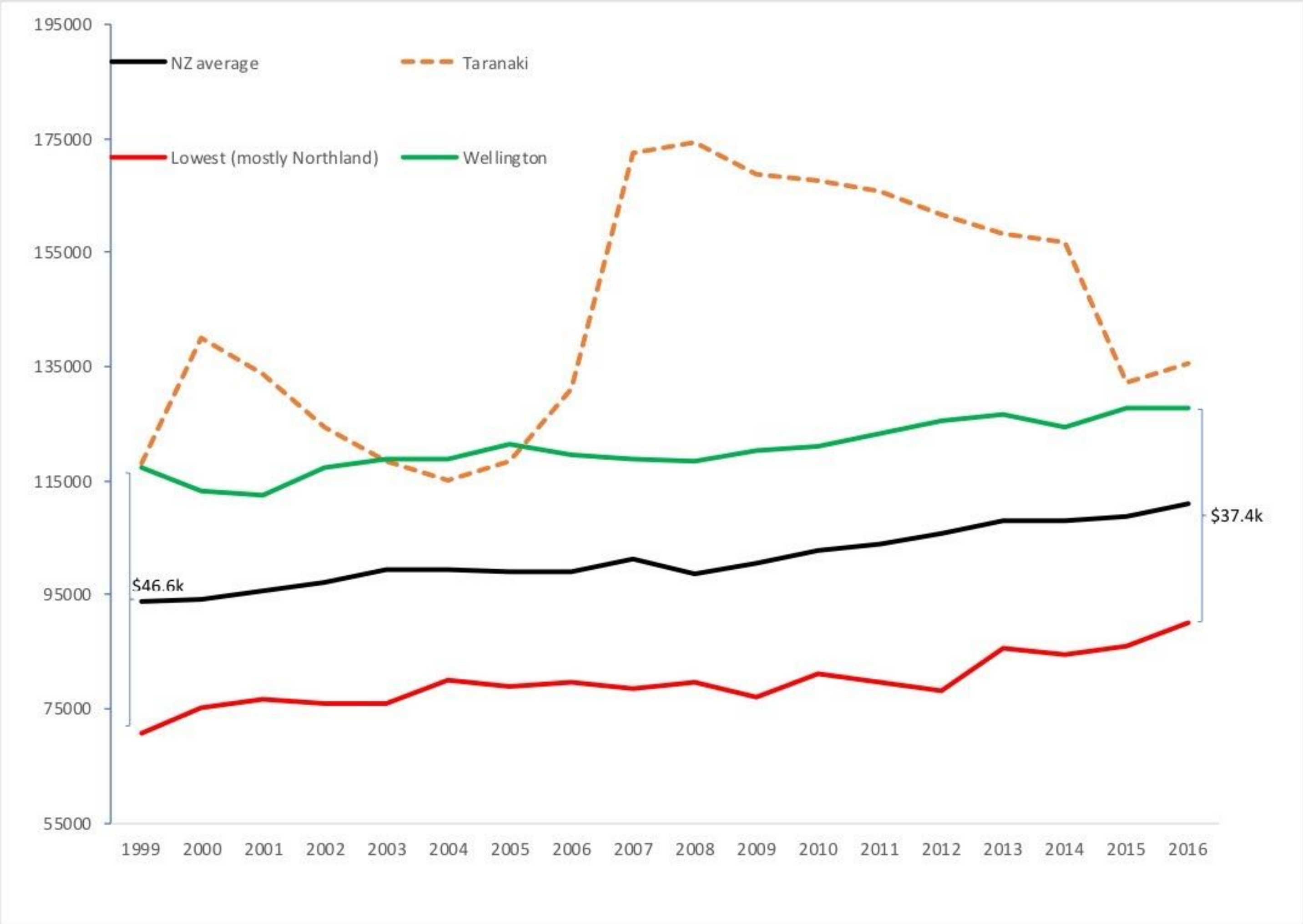
[a] $\sum_{it} \hat{\alpha}_X (\bar{X}^r_{it} - \bar{X}^W_{it})$ where $X \in$ non-spatial determinants (e.g., *ln* age, foreign ownership, and labour-skills)) listed in Table A.1; r refers to region and W to Wellington.
[b] $\sum_{it} \hat{\alpha}_X (\bar{X}^r_{it} - \bar{X}^W_{it})$ where $X \in$ spatial determinants (i.e.., diversity index, distance index, and region dummies) listed in Table A.1; r refers to region and W to Wellington.
[c] (weighted) mean or median for region minus Wellington value – source Table 2.
[d] benchmark figures for Wellington

Table 6: Productivity growth decomposition, New Zealand broad regions, 2001-16 (figures are average p.a. percentages)

	TFP growth	Decomposition of TFP growth[a]				
Regions	Contribution	Within-firm	Between-firm	Entry	Exit	Relative contribution[b]
Auckland	0.756	0.323	0.149	0.370	-0.086	1.969
Canterbury	0.132	-0.005	0.037	0.087	0.014	1.467
Wellington	0.079	0.198	-0.154	0.060	-0.026	0.560
Rest of South Island	0.079	0.014	0.024	0.042	0.000	1.317
Waikato	0.037	-0.027	0.011	-0.019	0.072	0.398
Otago	0.033	-0.020	0.036	0.016	0.000	1.179
Rest of Lower North Island	-0.006	-0.039	0.019	0.017	-0.004	-0.068
Rest of Upper North Island	-0.020	-0.026	-0.066	0.070	0.002	-0.172
New Zealand	1.089	0.419	0.054	0.644	-0.027	1.089

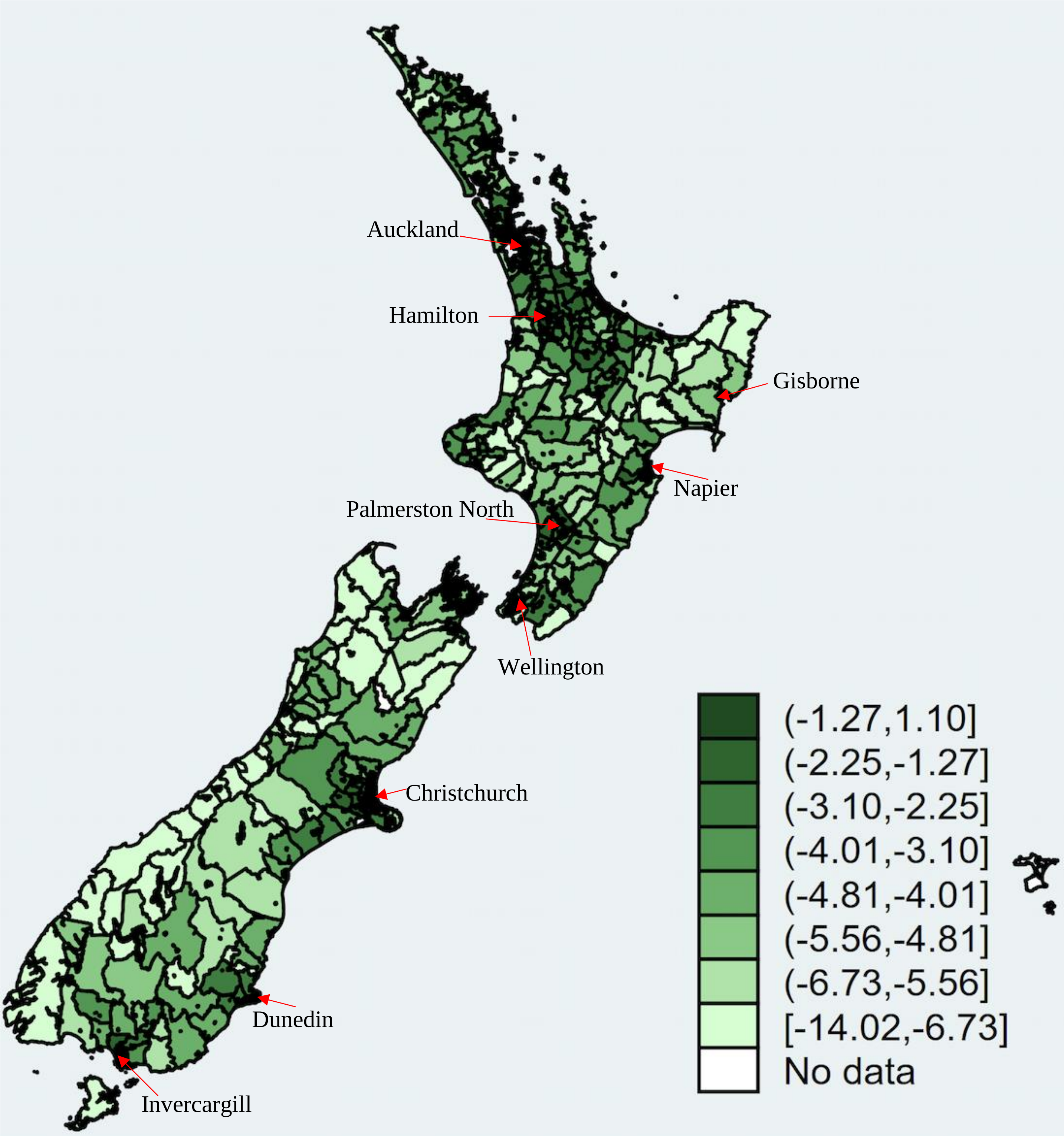
[a] Based on Haltiwanger-type approach – see equation A.3. Note, 'between-firm' contribution is the sum of such contributions in equation A.3, and the sign on 'Exit' contribution has been reversed
[b] Contribution in first column of data divided by 2001 output share

Figure 1: Labour productivity (in 2015 NZ$ constant prices) 1999-2016 (Territorial level 2)



Source: OECD (2018b)

Figure 2: Average *ln* Distance (medium decay, $e^{-0.05(d_{i,j})}$) by area unit code (2013 boundaries), 2016 all 64 NZSIOC industries (2,020 area units are covered including small islands)



Source: based on equation (3)

Unpublished appendix

Table U.1: Long-run (weighted) parameter estimates from estimation production function (equation 1), New Zealand, 2001-16

Industry	AA11	AA12	AA14	AA21	AA32	BB11	CC1	CC21	CC3	CC41
ln intermediate inputs	0.413***	0.777***	0.627***	0.727***	0.628***	0.696***	0.717***	0.688***	0.674***	0.649***
ln employment	0.535**	0.509**	0.252***	0.417***	0.279***	0.396***	0.145**	0.262***	0.348***	0.327***
ln capital	0.203*	0.106*	0.167***	0.293***	0.181***	0.223***	0.077**	0.168*	0.092**	0.104***
$\hat{\theta}_n$	1.098**	0.243*	0.156	0.420	0.180*	0.749	0.146	-0.041	0.131	0.115
$X_{it}'\hat{\beta}$	-0.399	0.238*	0.590***	0.533	0.608***	2.206***	0.258*	-0.092	0.111	0.594***
Time trend	0.021***	-0.006***	0.015***	-0.007	-0.007**	0.002	-0.004***	0.015***	0.005***	-0.003**
foreign	0.055	-0.157***	-0.172***	-1.073***	0.028	-0.482***	0.064	0.006	-0.049	-0.022
ln age	-0.001	-0.023*	-0.025	-0.126***	-0.032	-0.150***	0.033*	-0.055*	-0.001	-0.010
diversity	0.034	0.075**	0.208	-1.065	-0.076	0.073	-0.048	-1.639**	-0.137	-0.393
Herfindahl	0.987	-2.857	-0.043	-0.172	-1.254**	-0.776***	0.043	-3.623***	-0.087	1.587***
ln distance	-0.011	-0.045	-0.026	-0.140***	0.005	-0.113***	0.006	-0.005	-0.023*	-0.015*
ln distance × *ln* employment	0.023	0.088*	0.016	0.062***	0.004	0.034**	-0.003	0.000	0.013*	0.010***
Waikato	0.116**	0.157**	0.020	0.086	0.252***	-0.113	0.001	-0.083	0.030	-0.015
rest upper North Island	0.071	0.232***	0.027	0.046	0.172***	-0.033	-0.019	-0.086	-0.013	-0.048**
Wellington	-0.100	0.236***	-0.159**	0.054	0.148*	-0.194	0.018	-0.073	-0.011	-0.015
rest lower North Island	0.071	0.215***	-0.013	-0.065	0.015	0.183	-0.017	-0.040	-0.043*	-0.024
Canterbury	0.06	0.133*	-0.101**	0.136	0.089	-0.099	0.006	-0.066	0.006	-0.001
Otago	-0.07	0.183***	-0.115*	-0.177	0.077	-0.091	0.036	-0.164***	-0.019	-0.016
rest South Island	0.108	0.235***	-0.018	-0.066	0.165*	-0.088	0.027	-0.070	-0.038*	-0.011
1/σ	0.027	-0.044	-0.065***	-0.103**	0.002	-0.117**	-0.044**	0.020	0.038***	0.044
Observations	9,783	15,243	3,084	3,321	525	1,533	12,198	6,150	9,087	5,718
Number of firms	2,001	2,994	630	696	192	300	2,403	1,107	1,524	1,035
distance χ^2	3.463	6.164**	2.478	10.46***	3.235	7.297**	0.267	0.0981	3.268	6.948**
Pseudo-R^2	0.997	0.999	0.997	0.996	0.998	0.985	0.996	0.994	0.996	0.996
AR(2) z-statistics	1.518	2.257	-2.373	-1.638	-0.837	-1.158	1.420	-0.0580	-1.235	-0.174
AR(2) z-statistic p-value	0.129	0.240	0.176	0.102	0.403	0.247	0.156	0.954	0.217	0.862
Hansen test	25.04	26.42	45.78	51.11	53.50	20.36	46.26	22.46	17.89	55.40
Hansen test p-value	0.460	0.191	0.564	0.694	0.607	0.676	0.301	0.149	0.656	0.138
RTS	0.122	0.431*	0.132	0.585***	0.086*	0.456**	-0.025	0.102	0.075*	0.042

Table U.1 (cont.)

Industry	CC5	CC61	CC7	CC81	CC82	CC91	DD1	EE11	EE12	EE13
ln intermediate inputs	0.723***	0.647***	0.766***	0.655***	0.730***	0.671***	0.553***	0.625***	0.438***	0.711***
ln employment	0.210***	0.283***	0.274***	0.564***	0.305***	0.243***	0.299***	0.328***	0.611***	0.246***
ln capital	0.198**	0.156***	0.125*	0.142*	0.093**	0.097**	0.178***	0.079***	0.166*	0.056*
$\hat{\theta}_n$	-0.208	0.022	-0.187	0.037	-0.013	0.041	0.567***	0.154	0.168	0.132***
$X'_{it}\hat{\beta}$	-0.986	-0.080	-0.104	0.067	0.110	-0.129	0.526***	-0.425***	0.033	0.076
Time trend	0.001	0.001	-0.015***	-0.011***	0.009***	-0.001	-0.015***	-0.001	-0.011***	0.008***
foreign	0.086	0.065	0.013	-0.118	-0.053	-0.027	0.009	0.007	-0.311***	0.025
ln age	0.042*	-0.015	-0.000	-0.016	0.006	0.012	-0.024	0.001	-0.031	-0.005
diversity	-0.152	-0.706	0.656	1.334	0.223	-0.519	-0.515	-1.333**	0.100	0.478***
Herfindahl	0.519*	0.389*	-0.519***	0.639	-0.004	0.419	0.449*	0.776**	-0.588***	-0.362
ln distance	0.011	-0.006	-0.003	-0.053*	-0.014	0.007	0.006	0.011	-0.049***	-0.001
ln distance × *ln* employment	-0.001	0.001	0.002	0.027**	0.008	0.002	0.003	0.009	0.024***	0.003
Waikato	-0.036	-0.091***	-0.034*	-0.120***	-0.041*	-0.048**	0.033	-0.148***	-0.077	-0.017*
rest upper North Island	0.001	-0.068***	-0.008	-0.049	-0.038	-0.008	0.019	-0.074*	-0.082***	-0.021*
Wellington	0.041	-0.033	-0.025	0.024	-0.013	0.012	0.070*	-0.022	-0.064*	-0.009
rest lower North Island	0.043	-0.080***	-0.002	-0.074	-0.043	-0.018	0.020	-0.129***	-0.079*	-0.022*
Canterbury	-0.015	-0.009	-0.037***	-0.071***	-0.041**	-0.027*	0.007	-0.092***	-0.045	0.015
Otago	-0.060	-0.061*	-0.038	-0.151***	-0.047	0.011	0.126***	-0.103***	-0.06	-0.007
rest South Island	0.059	-0.054*	-0.042*	-0.047	-0.079***	0.005	-0.036	-0.084**	-0.073	-0.007
1/σ	0.110***	0.027	0.164***	0.175***	0.068***	-0.019	0.019	0.005	0.007	-0.001
Observations	5,943	2,991	14,661	5,529	13,911	7,713	2,427	4,878	5,589	75,921
Number of firms	978	543	2,328	1,005	2,301	1,353	528	1,053	1,020	15,774
distance χ^2	1.164	0.797	0.0554	3.958	1.716	0.749	3.337	17.78***	11.750***	3.689
Pseudo-R^2	0.994	0.997	0.997	0.994	0.994	0.997	0.997	0.999	0.992	0.995
AR(2) z-statistics	1.543	0.495	-0.366	-0.845	0.600	1.301	1.274	-0.0464	-0.978	-0.814
AR(2) z-statistic p-value	0.123	0.621	0.715	0.398	0.549	0.193	0.203	0.963	0.328	0.416
Hansen test	25.12	71.89	21.03	28.77	33.03	31.87	32.71	47.12	18.44	17.83
Hansen test p-value	0.456	0.188	0.172	0.581	0.196	0.620	0.712	0.701	0.141	0.106
RTS	0.008	0.060	0.018	0.149**	0.055	0.028	0.017	0.027	0.206***	0.014

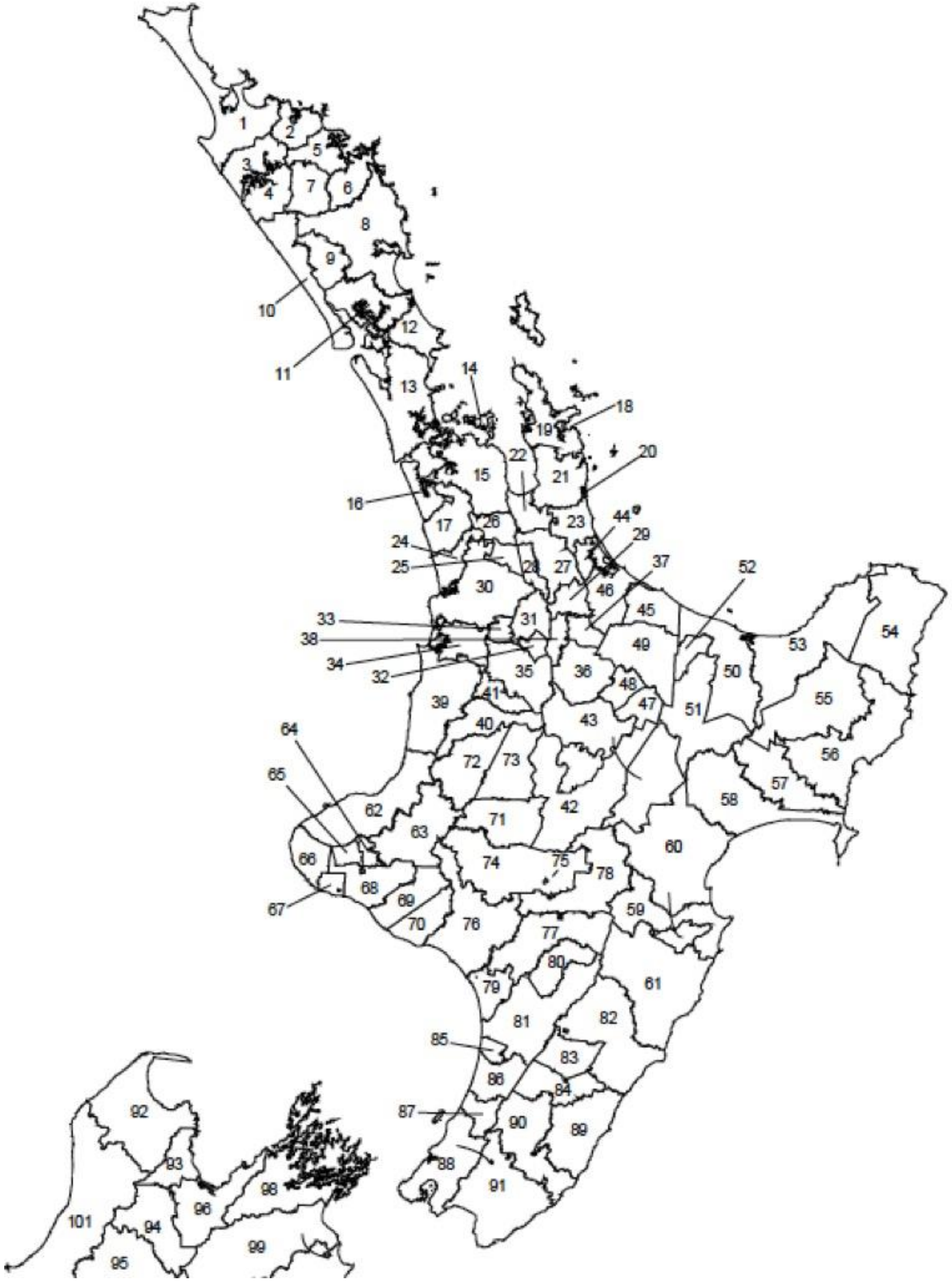
Table U.1 (cont.)

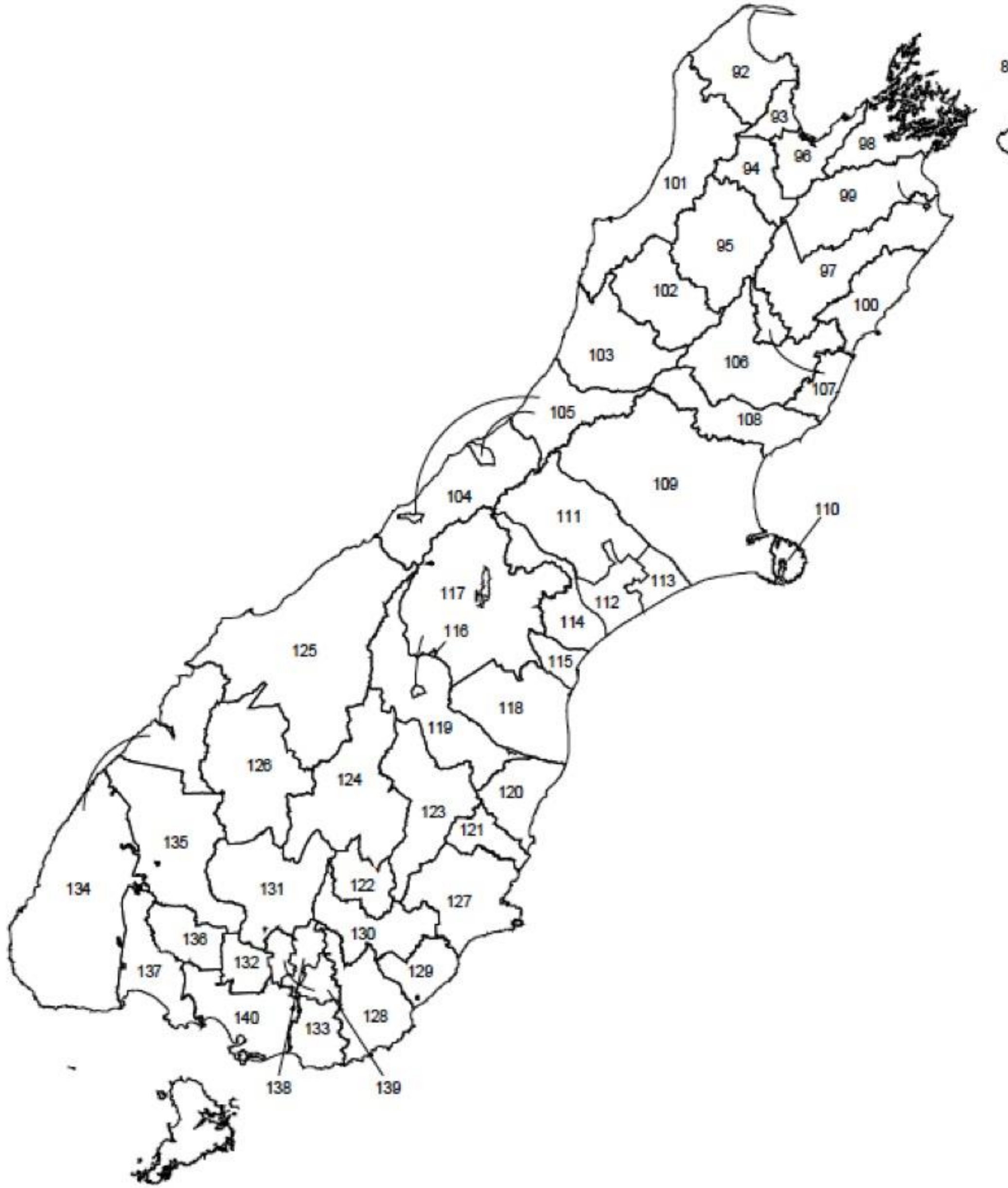
Industry	FF11	GH11	GH12	GH13	GH21	II11	II12	II13	JJ11	JJ12
ln intermediate inputs	0.364***	0.433***	0.584***	0.384***	0.548***	0.447***	0.508***	0.446***	0.600***	0.551***
ln employment	0.357***	0.514***	0.230***	0.310*	0.259***	0.311***	0.290***	0.428***	0.188***	0.292***
ln capital	0.347***	0.200***	0.211***	0.378*	0.155***	0.208***	0.192***	0.110**	0.121***	0.156***
$\hat{\theta}_n$	0.048	0.320**	0.256	0.512**	0.095*	0.161*	-0.137	0.189	-0.045	0.134
$X'_{it}\hat{\beta}$	-0.173	-0.082	0.242	0.237	0.104*	0.206*	-0.219	-0.114	-0.045	-0.428
Time trend	0.005*	0.005*	0.002	0.025***	0.003***	-0.005***	0.013***	-0.009***	0.001	0.036***
foreign	0.138**	-0.218**	-0.029	-0.110	-0.047*	0.069	0.195***	0.083	0.182**	0.173***
ln age	0.018	0.015	0.047**	0.026	0.021***	0.013	0.027	0.047	0.056**	0.049
diversity	-0.403	0.466	-0.027	-0.799	0.011	0.474*	-0.542	-0.670	3.032**	0.765
Herfindahl	1.078**	-0.470	0.071	-0.315	0.195	-0.124	-0.044	-1.673***	-0.106	0.104
ln distance	-0.016	-0.026*	0.007	-0.032*	-0.001	0.006	0.005	0.006	0.001	0.002
ln distance × *ln* employment	0.014	0.021***	-0.005	0.014	0.005*	0.002	-0.001	0.007	0.003	-0.002
Waikato	-0.032	-0.038	0.001	0.023	0.001	0.007	0.031	-0.086	-0.043	-0.038
rest upper North Island	-0.032	-0.021	-0.008	0.006	0.005	0.001	-0.013	-0.091**	-0.055	-0.148***
Wellington	-0.040	-0.005	0.015	0.015	0.013	0.016	0.034	-0.096*	-0.032	0.097
rest lower North Island	-0.052	-0.027	0.006	0.041	-0.002	0.005	0.170*	-0.104*	-0.065	-0.061
Canterbury	0.007	0.045	0.020	0.030	0.004	0.009	-0.019	-0.025	-0.060	0.046
Otago	-0.088*	-0.001	0.0042	-0.018	0.005	0.026	-0.025	-0.102	-0.019	-0.152**
rest South Island	-0.050	0.038	-0.003	0.018	-0.005	-0.003	0.036	-0.116**	-0.016	-0.018
1/σ	0.035***	0.058***	0.006	-0.092**	-0.095***	-0.015***	0.008	0.017	-0.040	0.018
Observations	57,840	16,086	18,726	61,743	60,831	16,623	2,691	7,281	5,250	1,785
Number of firms	11,106	2,883	4,290	12,399	15,654	3,441	645	1,614	1,233	483
distance χ^2	1.600	10.35**	0.193	5.084*	17.60***	14.92***	0.183	9.582***	0.585	0.466
Pseudo-R^2	0.987	0.990	0.992	0.989	0.994	0.997	0.987	0.995	0.997	0.988
AR(2) z-statistics	1.176	1.079	1.174	3.398	-0.673	-0.552	-2.903	-0.861	0.733	0.218
AR(2) z-statistic p-value	0.239	0.280	0.240	0.168	0.501	0.581	0.137	0.389	0.463	0.828
Hansen test	63.04	61.36	64.07	25.89	51.12	63.22	49.65	61.40	47.24	52.25
Hansen test p-value	0.187	0.111	0.243	0.116	0.099	0.266	0.713	0.321	0.731	0.654
RTS	0.049	0.092*	0.020	0.109	0.043***	-0.021	-0.020	-0.030	-0.060	-0.020

Table U.1 (cont.)

Industry	KK13	KK1_	LL11	MN11	MN21	RS11	RS21
ln intermediate inputs	0.540***	0.274***	0.371***	0.323***	0.279**	0.502***	0.418***
ln employment	0.375***	0.703***	0.534***	0.416***	0.390***	0.310***	0.345***
ln capital	0.263**	0.088	0.267*	0.344***	0.294**	0.164***	0.366***
$\hat{\theta}_n$	0.096	0.680***	0.153	0.263*	0.224	0.331*	0.202***
$X'_{it}\hat{\beta}$	0.112	0.362	-0.566	-0.082	-0.119	-0.022	0.113*
Time trend	-0.010***	-0.009	-0.006	-0.003*	-0.007**	0.007***	-0.007***
foreign	-0.077	0.251***	-0.052	0.076	0.048	0.003	0.012
ln age	0.046	0.169***	0.086	-0.001	0.050	0.010	0.027***
diversity	0.690	1.766	0.232	0.525	-1.746***	0.256	-0.339
Herfindahl	0.245	0.183	-1.711	0.561	-2.785***	0.471***	0.498
ln distance	-0.005	0.003	0.031	-0.005	0.031*	-0.004	-0.020***
ln distance × *ln* employment	0.011	0.020***	-0.018	0.008	0.005	0.013	0.006
Waikato	0.055	-0.035	-0.045	-0.034	0.018	-0.043	0.008
rest upper North Island	-0.057	-0.257*	-0.131	-0.046*	0.032	-0.045	0.021
Wellington	0.040	-0.090	-0.216	0.076***	0.001	0.024	0.022*
rest lower North Island	-0.001	-0.155	-0.583***	-0.023	0.113*	-0.069	0.028
Canterbury	0.073	0.032	-0.101	-0.020	0.025	-0.033	0.046***
Otago	0.039	-0.113	-0.237	-0.005	0.073*	-0.029	0.041**
rest South Island	0.021	0.180	0.422	-0.033	0.069	-0.025	0.036*
1/σ	0.117***	0.201***	0.085	0.075***	-0.017	-0.065	0.039
Observations	10,197	3,267	288	75,687	27,690	8,016	49,821
Number of firms	2,382	825	126	17,280	6,771	1,959	9,753
distance χ^2	1.542	33.44***	0.844	0.989	21.13***	2.944	10.85***
Pseudo-R^2	0.983	0.982	0.999	0.992	0.988	0.996	0.993
AR(2) z-statistics	0.400	1.175	-0.512	1.444	-0.0283	1.796	1.263
AR(2) z-statistic p-value	0.689	0.240	0.609	0.149	0.977	0.173	0.207
Hansen test	26.58	50.60	10.67	62.09	14.50	41.26	24.67
Hansen test p-value	0.147	0.110	0.908	0.184	0.206	0.127	0.116
RTS	0.055	-0.156***	0.013	0.037	-0.027	0.032	0.095***

Figure U.1 New Zealand's travel-to-work areas (TTWAs)





Source: Papps and Newell (2002), Figures 3 and 4

Legend to Figure U.1

TTWA	Name	TTWA	Name	TTWA	Name	TTWA	Name	TTWA	Name
1	Kaitaia	31	Cambridge	61	Central Hawke's Bay	91	Kahutara	121	Palmerston/Waihemo
2	Mangapa-Matauri Bay	32	Rotongata	62	New Plymouth	92	Golden Bay	122	Teviot
3	Hokianga North	33	Te Awamutu	63	Douglas	93	Motueka	123	Maniototo
4	Hokianga South	34	Ngutunui	64	Toko	94	Golden Downs	124	Alexandra
5	Kerikeri	35	Maihiihi	65	Stratford	95	Murchison/Lake Rotoroa	125	Wanaka
6	Moerewa	36	Tokoroa	66	Kahui	96	Nelson	126	Queenstown
7	Kaikohe	37	Tapapa	67	Kapuni	97	Ward	127	Dunedin
8	Whangarei	38	Arapuni	68	Hawera	98	Picton	128	Clutha
9	Maungaru	39	Marokopa	69	Patea/Whenuakura	99	Blenheim	129	Balclutha
10	Dargaville	40	Mokauiti	70	Waverley/Makakaho	100	Kaikoura	130	Tuapeka
11	Rehia-Oneriri	41	Te Kuiti	71	Raurimu	101	Westport	131	Waikaia
12	Warkworth	42	Turangi	72	Otangiwai-Heao	102	Reefton/Inangahua	132	Hokonui
13	Central & North Auckland	43	Taupo	73	Taumarunui	103	Grey/Greymouh	133	Toetoes
14	Waiheke Island	44	Katikati	74	Tangiwai	104	Whataroa	134	Te Anau
15	Southern Auckland	45	Te Puke	75	Waiouru	105	Hokitika	135	Mararoa River
16	Waiuku/Glenbrook	46	Tauranga	76	Wanganui	106	Amuri	136	Wairio
17	Pukekohe	47	Golden Springs	77	Pohonui-Porewa	107	Parnassus	137	Te Waewae
18	Whitianga	48	Ngakuru	78	Taihape	108	Hurunui	138	Chatton
19	Te Rerenga	49	Rotorua	79	Marton	109	Christchurch	139	Gore
20	Whangamata	50	Whakatane	80	Kiwitea	110	Okains Bay	140	Invercargill
21	Thames	51	Murupara/Matahina-Minginui	81	Palmerston North	111	Mt Somers	141	Great Barrier Island
22	Hauraki Plains	52	Kawerau	82	Dannevirke	112	Hinds		
23	Waihi	53	Opotiki	83	Pahiatua/Mangatainoka	113	Ashburton		
24	Te Akau	54	East Cape	84	Nireaha-Tiraumea	114	Temuka/Orari		
25	Whitikahu	55	Tarndale-Rakauroa	85	Foxton	115	Timaru		
26	Waerenga	56	Gisborne	86	Levin	116	Twizel		
27	Ngarua	57	Ruakituri-Morere	87	Otaki	117	Mackenzie		
28	Morrinsville	58	Wairoa	88	Wellington	118	Waihao		
29	Matamata	59	Hastings	89	Whareama	119	Aviemore		
30	Hamilton	60	Napier	90	Masterton	120	Oamaru		

Figure U.2: Impact of different decay functions on distance index

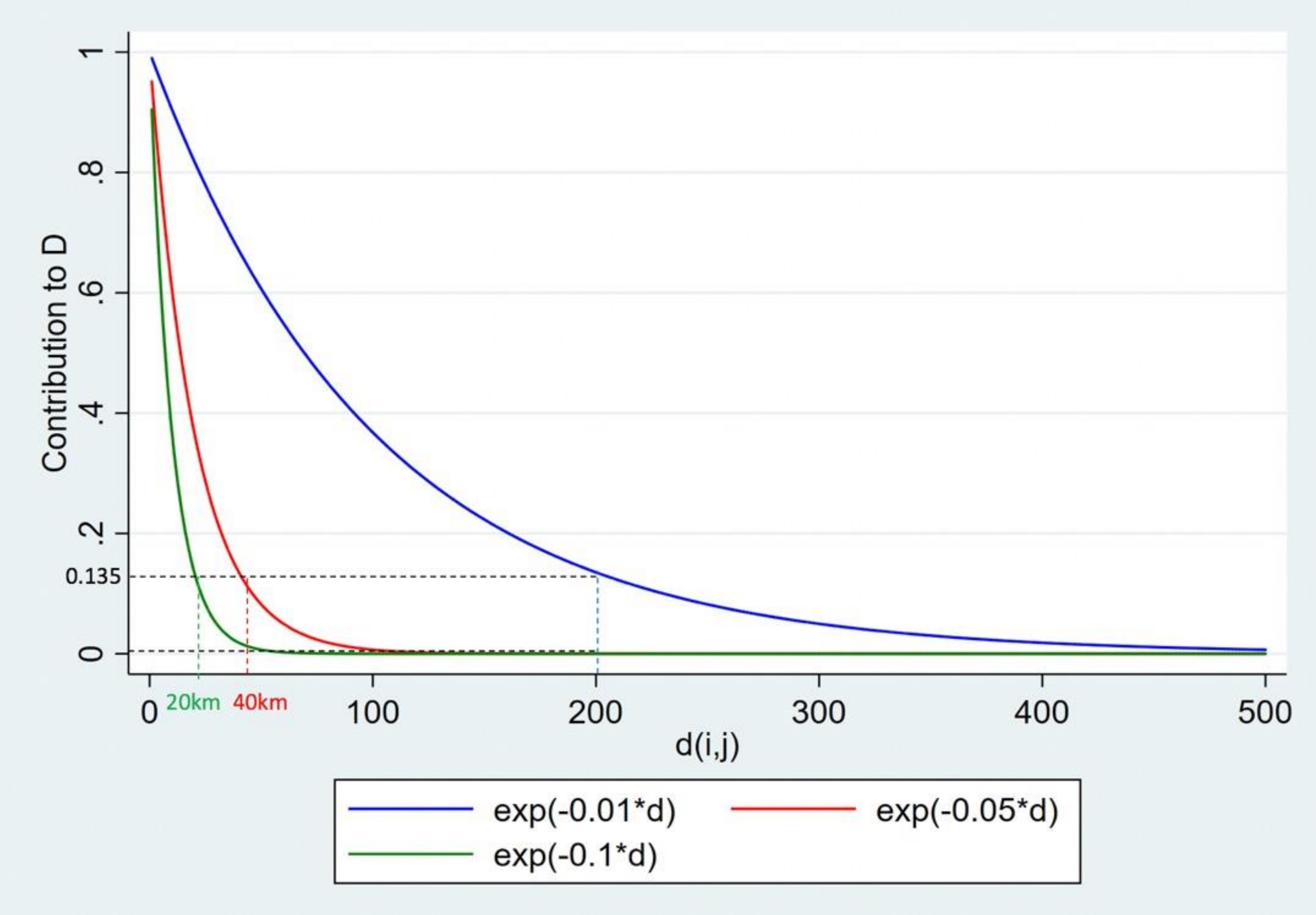
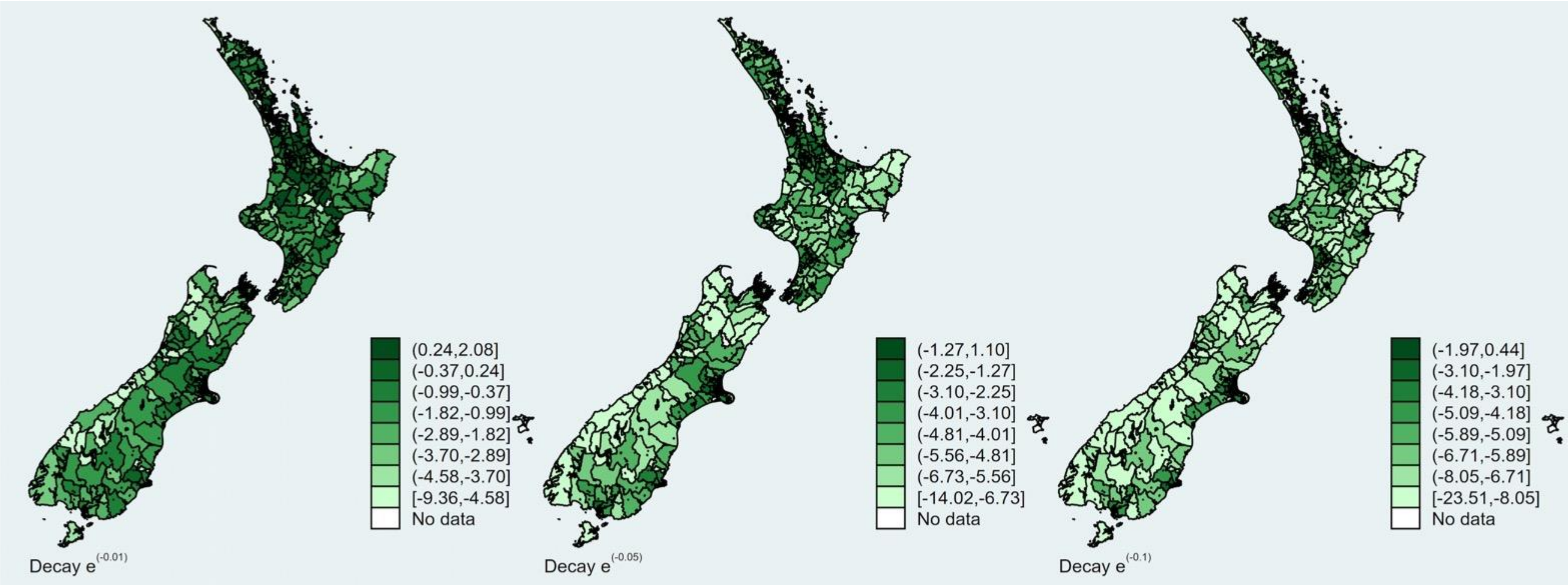


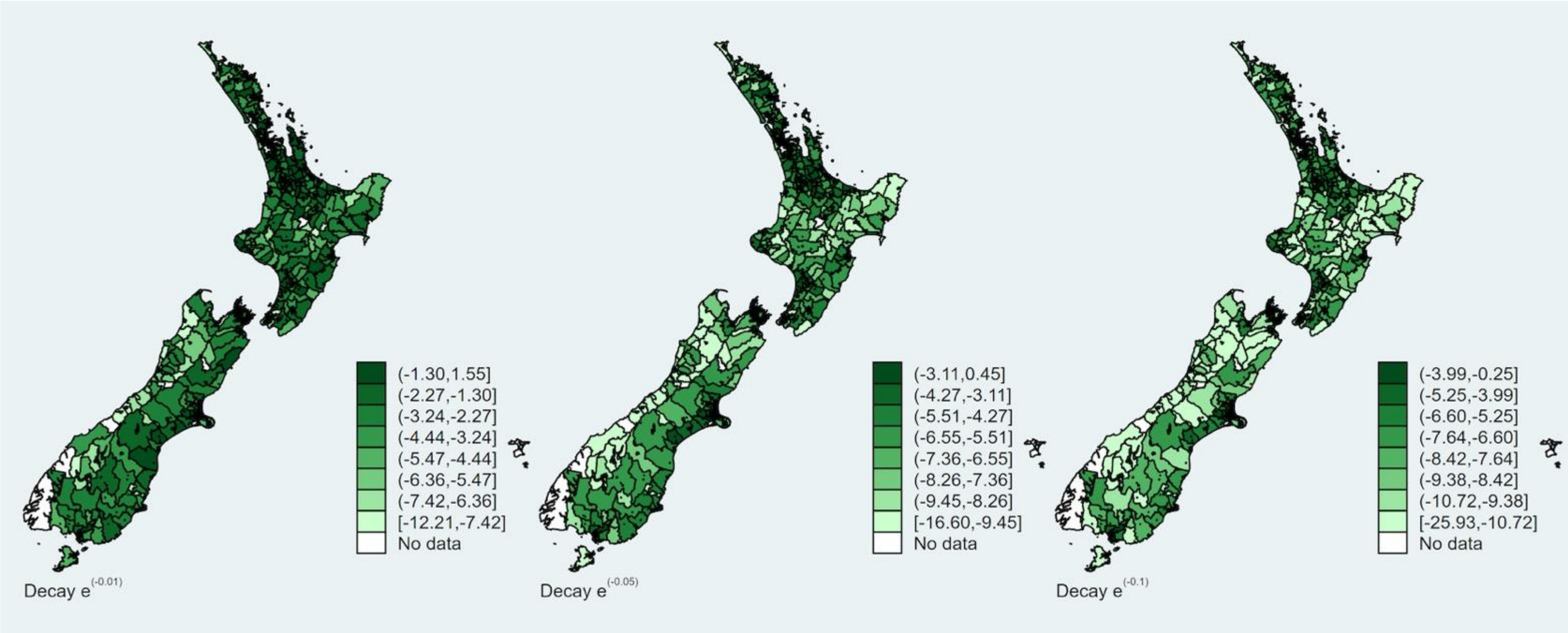
Figure U.3: Average *ln* Distance by area unit code (2013 boundaries), 2016 (2,020 area units are covered including small islands)

(a) based on 64 NZSIOC industries



Source: based on equation (3)

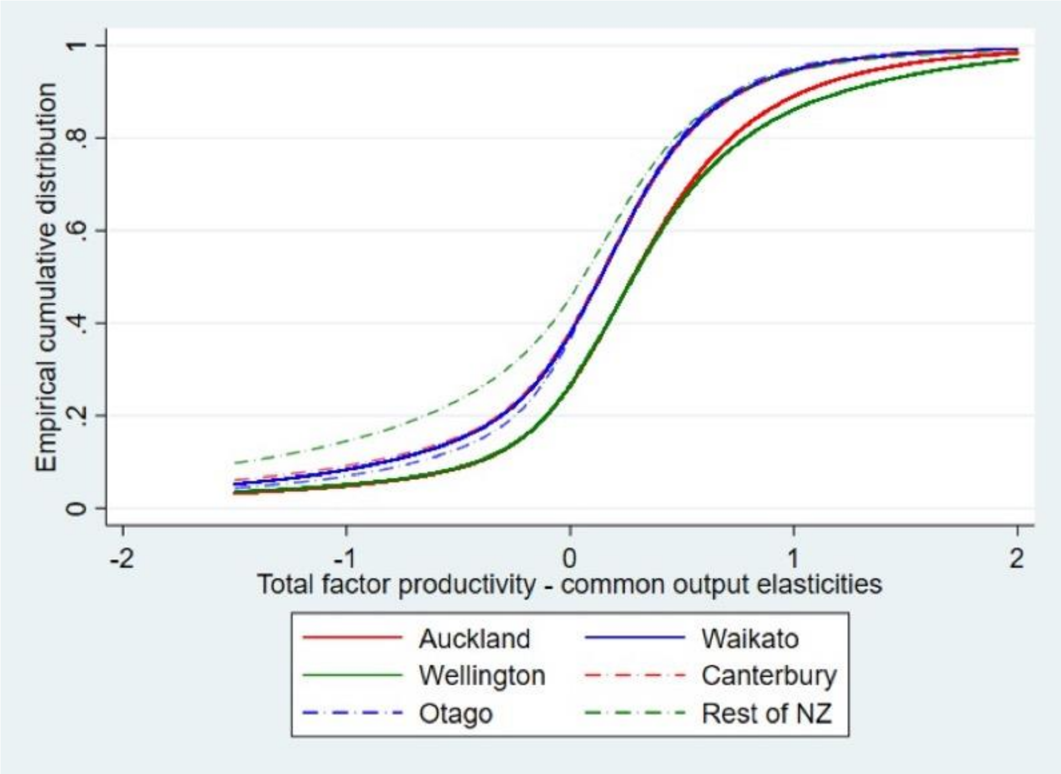
(b) based on industry 'clusters' as identified in Table U.3



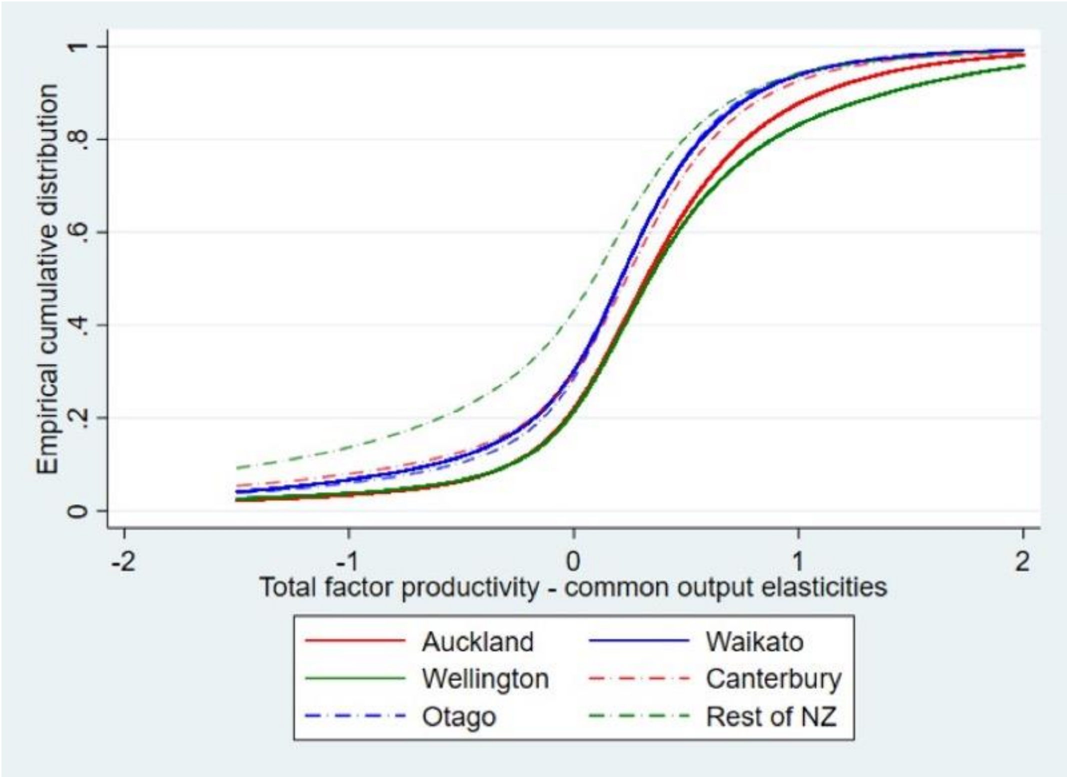
Source: based on equation (3)

Figure U.4: Cumulative *ln* TFP for firms by broad region, New Zealand

(a) 2001-07



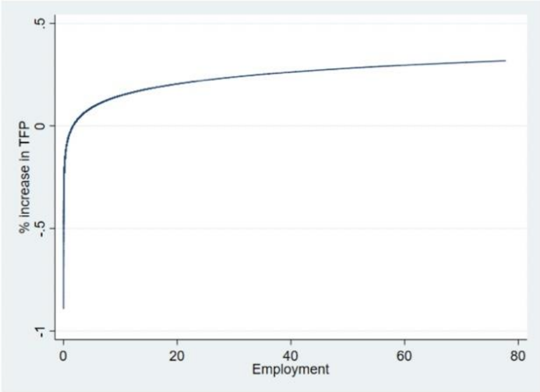
(b) 2008-16



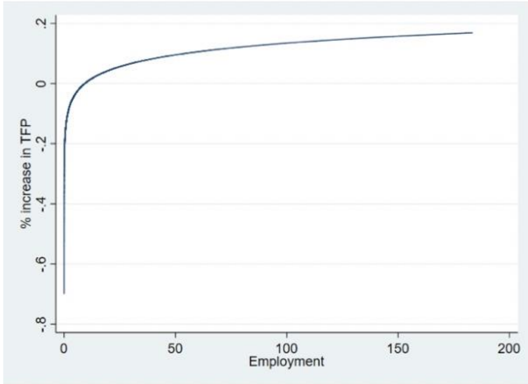
Source: based on equation (2a)

Figure U.5: Effect of a 1% increase in distance index on TFP for different sized firms, 2001-2016

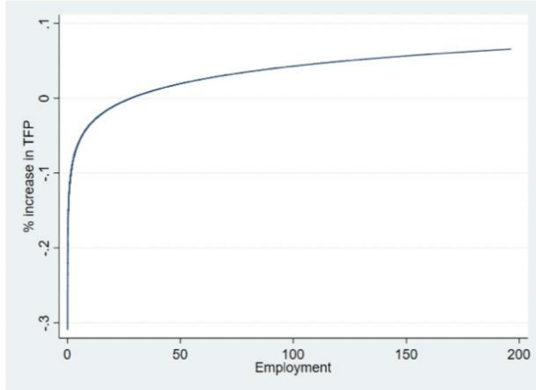
(a) Sheep, Beef cattle and grain farming (AA12)



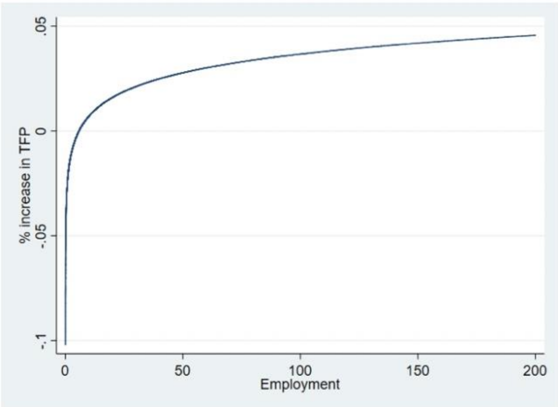
(b) Forestry & logging (AA21)



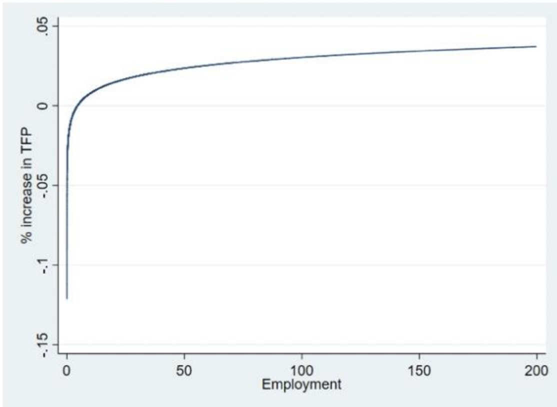
(c) Mining (BB11)



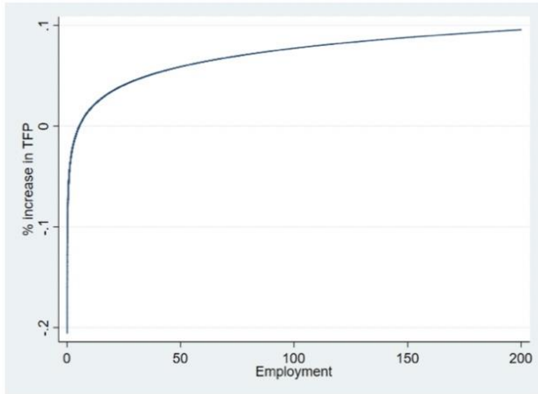
(d) Wood & paper products (CC3)



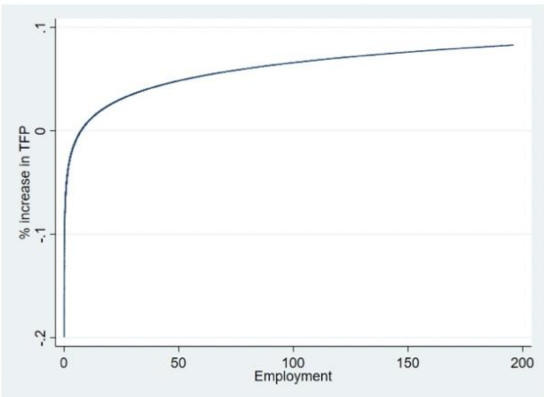
(e) Printing (CC41)



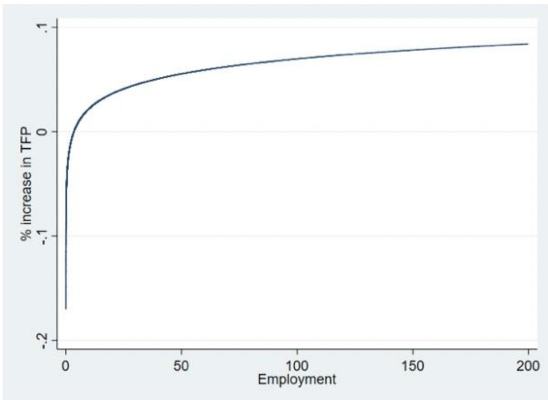
(f) Transport equipment (CC81)



(g) Heavy & civil engineering construction (EE12)



(h) Motor retailing (GH11)



(i) Finance & insurance (KK1)

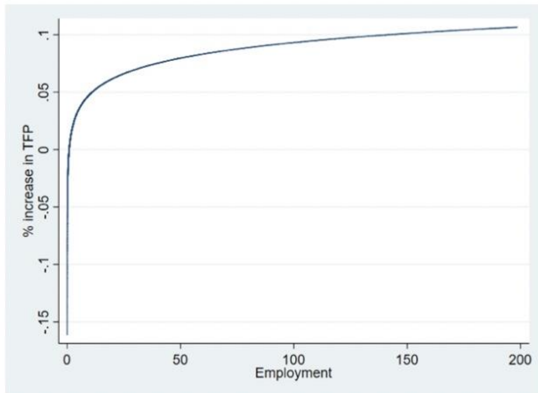


Figure U.6: Differences compared to Finance & insurance sector of mean *ln* TFP 2001-16: contribution of spatial and non-spatial factors (actual *ln* TFP difference is shown next to industry name)

Benchmark:	Non-spatial	Spatial	*ln* TFP
Finance & insurance	0.590	-0.054	0.536

Source: Table U.2

Table U.2: Differences compared to Finance & Insurance of mean *ln* TFP 2001-16 by sector: contribution of spatial and non-spatial factors

	Non-spatial[a]	Spatial[b]	*ln* TFP[c]
Professional, technical & scientific (MN11)	-0.082	0.075	-0.007
Auxiliary finance & insurance (KK13)	-0.412	0.253	-0.159
Metal products (CC7)	0.775	-1.009	-0.234
Utilities (DD1)	-0.303	0.059	-0.244
Building construction (EE11)	-0.306	0.045	-0.261
Heavy & civil construction (EE12)	-0.356	0.061	-0.295
Post, courier support & warehousing (II13)	-0.374	0.055	-0.319
Admin & support services (MN21)	-0.372	0.052	-0.320
Construction services (EE13)	-0.394	0.059	-0.335
Machinery & other equipment (CC82)	-0.427	0.073	-0.354
Transport equipment (CC81)	-0.456	0.077	-0.379
Other services (RS21)	-0.443	0.062	-0.381
Road transport (II11)	-0.484	0.055	-0.429
Petrol, chemical, polymer & rubber (CC5)	-0.505	0.053	-0.452
Printing (CC41)	-0.514	0.057	-0.457
Wholesale trade (FF11)	-0.572	0.106	-0.466
Motor retail (GH11)	-0.528	0.058	-0.470
Food beverage & tobacco (CC1)	-0.552	0.056	-0.496
Telecoms, internet & library services (JJ12)	-0.578	0.073	-0.505
Furniture & other manufacturing (CC91)	-0.595	0.054	-0.541
Rental & hiring (LL11)	-0.596	0.053	-0.543
Textile, leather & clothing (CC21)	-0.601	0.053	-0.548
Mining (BB11)	-0.601	0.050	-0.551
Wood & paper products (CC3)	-0.620	0.052	-0.568
Non-metallic minerals (CC61)	-0.641	0.042	-0.599
Support services to agriculture (AA32)	-0.662	0.045	-0.617
Supermarkets, specialised retailing (GH12)	-0.674	0.038	-0.636
Accommodation & food services (GH21)	-0.701	0.042	-0.659
Arts & recreational services (RS11)	-0.739	0.047	-0.692
Information media services (JJ11)	-0.770	0.048	-0.722
Rail, water, air & other transport (II12)	-0.434	-0.303	-0.737
Other retailing (GH13)	-0.892	0.022	-0.870
Sheep, Beef cattle and grain (AA12)	-1.011	-0.072	-1.083
Poultry, deer & other livestock (AA14)	-1.842	0.301	-1.541
Horticulture & fruit growing (AA11)	-1.839	0.167	-1.672
Forestry & logging (AA21)	-2.747	-0.955	-3.702
Finance & insurance (KK1_)[d]	0.590	-0.054	0.536

[a] $\sum_{it} \hat{\alpha}_X (\bar{X}_{it}^s - \bar{X}_{it}^F)$ where $X \in$ non-spatial determinants (e.g., *ln* age, foreign ownership, and labour-skills)) listed in Table A.1; s refers to sector and F to Finance & insurance.

[b] $\sum_{it} \hat{\alpha}_X (\bar{X}_{it}^s - \bar{X}_{it}^F)$ where $X \in$ spatial determinants (i.e.., diversity index, distance index, and region dummies) listed in Table A.1; s refers to sector and F to Finance & insurance

[c] (weighted) mean for sector minus Finance & insurance value.

[d] benchmark figures for sector with highest *ln* TFP

Table U.3: 'Clusters' associated with each of 31 NZSIOC primary and manufacturing industries

NZSIOC industry	Cluster of NZSIOC industries to which it belongs
AA11	AA11, AA32, CC522, CC53, MN213
AA12	AA12, AA32, CC522, AA14
AA13	AA13, AA12, AA32, CC522
AA14	AA14, AA12, AA14, AA32, CC11
AA21	AA21, AA32, II11
AA31	AA31, CC12, CC51, LL11, RS211
AA32	AA32, CC51
BB11	BB11, CC51, II12, LL11, MN111, DD113, DD1, II11
CC11	CC11, AA12, AA14, II13, II11
CC12	CC12, AA31, II123
CC13	CC13, AA13, AA12, II13, II11, II12
CC14	CC14, AA11, CC11, II11, MN113, CC13, AA14
CC15	CC15, AA11, CC15, CC32, CC53, MN113
CC211	CC211, AA12, CC11, CC212
CC212	CC212, CC211, FF11
CC31	CC31, AA21, II11
CC32	CC32, AA21, CC31
CC41	CC41, CC32, CC53, II13, LL11, LL12
CC51	CC51, BB11, CC71, FF11, II11
CC521	CC521, B11, DD113
CC522	CC522, FF11, II11
CC523	CC523, CC13, CC32, CC53, FF11, II11
CC53	CC53, CC521, FF11, II11
CC61	CC61, BB11, CC72, II11
CC71	CC71, DD1, FF11, BB11
CC72	CC72, CC71
CC81	CC81, CC71, RS211, GH11
CC821	CC821, CC71, FF11, CC521, MN113
CC822	CC822, CC71, CC72, CC822, MN111
CC911	CC911, CC31, CC72, II11, LL12, MN113
CC912	CC912, CC31, CC51, CC53, FF11