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

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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

New Zealand has a longstanding productivity problem, especially in terms of underperformance when compared to its nearest neighbour Australia. As illustrated more fully in the next section, OECD data shows a continuing decline (relative to other leading OECD countries) in labour productivity: in 1970, New Zealand was over 94% of the G7 average for GVA per worker, falling to 67% by 2018, while Australia declined from 112% to 88% and the USA from 136% of the G7 average in 1970 to 114% in 2018. As to the contribution of total factor productivity (TFP) growth – through improvements in efficiency and/or greater technological progress – to labour productivity growth (versus the contribution of capital deepening), the OECD (2019) show that between 1991 and 2017 New Zealand was ranked 17 out of 24 OECD countries at 67% of the average, while the contribution of TFP growth in Australia was 113% of the OECD average (the comparable US figure was 144%).

As to the main reasons for such underperformance, in recent years there seems to be a clear consensus emerging that a major cause relates to the size and geographic location of the country. Despite New Zealand's high global ranking in terms of its institutions and policies, 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. This includes 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).[1] 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]

More recently, this generally accepted view has been extended to cover (i) the importance of firms that operate at the (national and international) 'frontier' of technology (i.e., those with the highest levels of productivity) – in terms of how well do they perform within New Zealand; together with (ii) whether diffusion and/or reallocation of output shares across firms is optimal, and if not whether this in part explains the productivity problem. The main purpose of the current paper is to consider these issues of 'frontier versus laggard' firms. As Nolan et. al. (2018, p.7) state while summarising recent research:

> "A key theme … is that the processes of diffusion and reallocation generally do not work as well as they could in New Zealand. Many domestic frontier firms are disconnected from the international frontier, laggard firms tend not to catch up to the domestic frontier, and resources are stuck in a tail of small and unproductive firms … (hence) a large share of employment and capital is concentrated in firms with low productivity. There are too many small, old and relatively unproductive firms that neither grow rapidly nor exit the market."

[1] Rosenberg (2016) provides more recent evidence of the excessive dependence of New Zealand's exports on a narrow range of lower valued-added land-based commodities and tourism, adding that they produce a 'Dutch-disease' effect as they raise exchange rates when export values are high, pricing out other higher valued exports such as manufacturing goods.

[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).

The present study only has access to data for New Zealand firms (via the Longitudinal Business Database of Statistics NZ – see Fabling and Mare, 2015, 2019) and therefore does not consider whether frontier firms are amongst the global leaders in their industry[3]. Thus, it is only possible to consider how productivity has evolved in aggregate over 2001-16 in New Zealand's frontier vis-a-vis frontier firms in certain OECD countries as reported in Andrews et al. (2016). Instead, the main evidence presented in this paper is on whether there is a lack of diffusion from national 'best practice' frontier firms to the non-frontier. This is achieved through estimating a 'catching-up' model, as well as using the familiar Haltiwanger-type approach (Foster et. al., 2001) to consider whether there has been insufficient reallocation of resources from less to more efficient firms through 'churn' (the opening of more efficient and the closure of less efficient firms) and through the reallocation of market shares from continuing low to higher productivity firms.

The rest of this paper is set out as follows: in the next section, after briefly reviewing OECD data on labour productivity differences, the current debate on the importance of 'frontier' versus 'laggard' firms is presented, together with the existing evidence for New Zealand. 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, and presents results showing how frontier and non-frontier cohorts have performed, including firm characteristics associated with belonging to the TFP frontier, whether Auckland and Wellington dominate the frontier, as well as how 'persistent' are TFP rankings in terms of frontier firms and other sub-groups. Section 4 then presents the results from estimating a 'catching-up' model together with a decomposition of productivity growth into the importance of continuing firms and firm entry and exit for firms belonging to frontier and non-frontier sub-groups. The summary and conclusion at the end of the paper also includes the role of policy in this area.

Figure 1 around here

2. EXISTING EVIDENCE OF PRODUCTIVITY PROBLEM AND ROLE OF FRONTIER FIRMS

Labour productivity differences at a national level are available from the OECD productivity statistics database (OECD, 2020). Figure 1 shows GDP per hour worked (in USD 2015 prices, PPP) from 1970-2018 for New Zealand, Australia, the G7 and certain leading economies. In 1970 New Zealand had relatively high productivity in line with the UK and at over 94% of the G7 average, but thereafter it has consistently fallen behind (even during the period of the 'opening up' of New Zealand markets during 1984-1988 under the then Minister of Finance Roger Douglas – see Kelsey, 1995; Gibson and Harris, 1996; and Harris and Daldy, 1994). By 2018 New Zealand's labour productivity was only 67% of the G7 average, and 76%, 80%, 71% and 59% of that of Australia, Canada, the UK, and the US, respectively.[4] Additionally, following the 2008 financial crisis, when the 1990-2007 trend rate of growth in productivity declined in most countries (the UK being the exemplar on this front), with 'lost' productivity by 2018 of nearly 16 percentage points in the UK, and just over 8% for the G7 average, the trend growth of productivity in New

[3] This is the topic for a recent inquiry initiated by the NZ Minister of Finance and conducted by the Productivity Commission – see https://www.productivity.govt.nz/news/inquiry-into-new-zealands-most-productive-firms-confirmed/.

[4] Although not shown in Figure 1, New Zealand was 77% and 78% of the EU and OECD average in 2018.

Zealand hardly changed (suggesting a lack of international integration, and a reliance on small, segmented domestic markets).

The OECD study by Andrews et. al. (2016) is one of the few studies that provides information on firms at the global frontier (defined as the top 5% of firms in terms of labour productivity or total factor productivity levels within each two-digit industry in each year since the early 2000s). They report an increasing productivity divergence between the global frontier and non-frontier 'laggard' firms, with average labour productivity at the global productivity frontier growing between 2001-13 "…at an average annual rate of 2.8% in the manufacturing sector and 3.6% in the market services sector, while the corresponding growth rate of all other firms was around 0.5% in both sectors" (p. 4). This divergence is taken as evidence of a failure of the diffusion of productivity-enhancing technologies. Figure 2 is taken from their study, covering 23 countries, showing the divergence in TFP as frontier firms became more productive and all others seeing little change after recovering from early dips in 2001-03.

Figure 2 around here

Andrews *et al.* (*op. cit.*) also showed that global frontier firms were : on average 3 to 4 times more productive than non-frontier firms (cf. Figure 2); were larger, more capital intensive and paid higher wages (although in services they did not employ a significantly larger number of employees compared to manufacturing where there where frontier firms had significantly higher employment size than laggards). They also found increasing persistence at the frontier or that churning increasingly came from firms close to the frontier (i.e. within the top 10% or 20% of the TFP distribution). For example, over 50% of firms at the global frontier during 2001-03 in the services sector "… where either classified two years earlier as frontier firms … or resided outside the frontier grouping but were in the top 10% … By 2011-2013… this figure had risen to 63% … implying that technological diffusion may have stalled" (p. 22).

The evidence for New Zealand is more circumspect, in that it assumes that poor productivity performance reflects the above OECD findings; e.g., Conway, 2018 (pp. 42-43) states:

> "From a firm perspective, New Zealand's poor long-run productivity performance *could* reflect a failure of productivity-enhancing technologies to diffuse from firms operating at the global productivity frontier to firms operating at the domestic frontier and then on to domestic laggards … market selection effects that impede the allocation of productive resources may also contribute to poor aggregate productivity" (emphasis added).

This assertion is based on results that showed the distribution of TFP across New Zealand firms had been remarkably stable between 2001-12 (see Conway, op. cit., Chart 3). In addition, Conway, Meehan and Zheng (2015) found evidence of productivity convergence across manufacturing firms, but very slow or no convergence in sectors that dominate aggregate productivity, such as parts of the services sector and in the construction industry.[5]

[5] Allan (2018) has reviewed the recent work involving the use of microdata from the Longitudinal Business database (LBD); to date little of which is concerned with the main topic covered here on 'frontier versus laggard' firms. The only major exception is Zheng (2016) which concentrates more on geographic spillovers and estimates a standard β-convergence model.

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)[6] using system-GMM (Blundell and Bond, 1998) to address the issues of endogeneity inherent to production function estimation.[7] The model is:

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

where $\tilde{r}_{it}$ is revenue, y_{it} is output, p_{it} is price, e_{it} is employment, m_{it} is intermediate inputs,[8] k_{it} is the capital in firm i at time t. 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), with σ being the elasticity of demand obtained from the firm's demand function.[9] 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:[10]

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[6] The inclusion of fixed effects is necessary as empirical evidence using plant- and firm-level panel data (Baily *et al.,* 1992; Bartelsman and Dhrymes, 1998; Haskel, 2000; Martin 2008) shows that the distribution of productivity is persistent. Such persistence suggests that firms have 'fixed' characteristics (associated with access to different path dependent resources, managerial and other capabilities) that change little through time.

[7] Estimators (such as Olley and Pakes, 1996; Levinsohn and Petrin, 2003) that purport to overcome these endogeneity issues are based on assumptions that are more restrictive than those implied by system-GMM (Ackerberg *et al.*, 2015). In particular, these estimators do not allow for fixed effects, which are important (see previous footnote). Del Gatto *et al.* (2011) and Van Beveren (2012) provide useful surveys on these different approaches to measuring TFP. Note, equation (1) is estimated in dynamic form (providing short-run estimates), and these are converted to long-run (equilibrium) values to obtain the long-run relationship between output and factor inputs.

[8] Intermediate inputs cover materials, fuels, semi- and finished-goods and (especially business) services used in the production of new goods and services. A gross valued-added function is not estimated to avoid the imposition of weak separability (capital and labour are separable from intermediate inputs in production) and thus homogeneity with respect to α_M - see Gandhi *et al.* (2012) for a discussion.

[9] That is, a Dixit and Stiglitz (1977) constant elasticity of substitution firm-level demand function is assumed:

$$y_{it}^d = -\sigma(p_{it} - p_{It}) + q_{It} + \varepsilon_{it}^d \qquad (2)$$

demand shocks faced by the firm. 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.

[10] TFP here comprises those factors contained in X_{it} that influence efficiency and technological progress. It also comprises an error term ($\hat{\varepsilon}_{it}^s$), which will pick up any unobserved inputs (e.g., intangibles, the use of outsourcing, etc.), and changes in the level of utilisation of factor inputs. Since the current approach estimates a reduced-form model (equation 1) it is not possible to separate $\hat{\varepsilon}_{it}$ into the separate components $\hat{\varepsilon}_{it}^d$ and $\hat{\varepsilon}_{it}^s$., Approaches used in the literature that exclude X_{it} from the right-hand-side of (1) treat X_{it} as part of the random error term ($\hat{\varepsilon}_{it}^s$), and it is to be expected that estimates of the coefficients on the factor inputs and thus $\widehat{lnTFP}_{it}$ from such an approach are biased because of an omitted variable(s) problem.

$$ln\widehat{TFP}_{it} = \tilde{r}_{it} - \frac{1}{\hat{\sigma}}(r_{It} - p_{It}) - \left(\frac{\hat{\sigma}-1}{\hat{\sigma}}\right)(\hat{\alpha}_E e_{it} + \hat{\alpha}_M m_{it} + \hat{\alpha}_K k_{it}) \quad (3)$$

Equation (1) was estimated separately for 37 industry sub-groups based on NZSIOC (level 3) 4-digit sectors.[11] 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 (along with the diagnostic tests associated with each of the 37 equations estimated).[12] Of particular note is that 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. Table 1 also includes estimates of mark-ups ($\left(\frac{\hat{\sigma}}{\hat{\sigma}-1}\right) > 1$) and mark-downs (<1). The former are more prevalent in manufacturing and certain service sector industries (e.g., wholesale trade, motor retail, finance & insurance and professional, technical & scientific services); mark-downs were more in evidence in agricultural sectors, other retailing, , accommodation & food services, and road transport. 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.[13]

Table 1 around here

Estimates of *ln* TFP were calculated for each firm for 2001-16 using equation (3); when these are combined across industries, annual output-weighted averages of the elasticities reported in Table 1 are used. 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).[14] Figure 3 shows the cumulative distribution of *ln* TFP for selected year across all sectors, demonstrating the expected pattern of both a 'long-tail' of firms with low productivity and productivity increasing across time (although the distribution for 2006 and 2011 are very close indicating that the world financial crisis in 2008 stalled TFP growth in New Zealand as well).

Figures 3 and 4 around here

[11] see http://archive.stats.govt.nz/~/media/Statistics/browse-categories/industry-sectors/anzsic06-industry-classification/tables/nzsioc-classifications-tables.xls.

[12] Note, the pseudo-R^2 reported are 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.

[13] As a robustness test, all 37 industries were re-estimated using the Wooldridge (2009) approach – which is an extension of Olley and Pakes (1996) and Levinsohn and Petrin (2003). The results are similar except the estimates of $\hat{\alpha}_K$ tend to be much smaller (often 50% of the sys-GMM estimates) and less statistically significant. For this and other reasons (linked to similar arguments set out above about Olley and Pakes and Levinsohn and Petrin), the results in Table 1 are preferred.

[14] The author would like to thank Jonathan Haskel and Eric Bartelsman for their guidance on this issue. Note also, the results obtained using equation (3a) and a common technology were modified for presentational purposes by subtracting the mean value across all firms and years from each firm-level estimate.

Figure 4 presents estimates of (weighted) *ln* TFP for those 12 industries[15] with the greatest change 2001-16 (in terms of either the trend in the productivity of frontier firms, defined as the top 10%,[16] or a change in the gap between the frontier and firms in the lowest 10%); each diagram shows the lower bound value of the top 10%, the lower bound of the 75th percentile, the median 50th percentile, the lower bound of the 25th percentile, and the lower bound of the 10th percentile sub-groups. Table 2 summarises the results for all 37 industries covered; in terms of changes in productivity for the frontier sub-group, 30 out of 37 industries experienced only a small change (20 with small upward trends and 10 with small downward trends) over the 15 years covered. Only mining saw a substantive upward trend in the frontier, while metal products experienced the opposite with a significant decline. Overall, these results confirm those cited by Conway (2018) which was based on 2001-12 LBD data, that frontier productivity has been very stable in New Zealand. Given the evidence for the OECD (Figure 2 above), covering approximately the same period, it seems very likely that firms at the national frontier are not keeping pace with global frontier firms.

Table 2 around here

Table 2 also shows that in 13 of the 37 industries covered there is evidence of small decreases in the top-to-bottom gap in productivity, while in 8 industries the gap marginally increased between 2001 and 2016. The productivity gap between the frontier and the bottom 10% closed substantially in 5 service sector industries (other retailing, accommodation and food services, rail, water, air & other transport, and in telecoms, internet & library services), and increased significantly in mining. For 10 industries there is evidence of medium-sized changes in the gap, more than 2-to-1 in favour of closing the gap (widening was more prevalent in the agricultural and forestry sectors). There is little evidence that increases (decreases) in the frontier are associated with the closing (widening) of productivity gaps, except in other retailing and telecoms, internet & library services; i.e., no clear pattern emerges in Table 2.

Table 3 around here

As to which firms belong to the frontier sub-group (the top 10% in any year), Table 3 presents the results for 10 aggregated sectors from estimating a simple probit model of whether a firm belonged to the frontier (coded 1) as determined by a range of productivity shifters included in the vector X when estimating equation (1). Marginal effects are shown (denoting the change in the likelihood of belonging to the frontier from belonging to a discrete sub-group, such as foreign-owned, or from a unit change in a continuous variable, such as *ln* employment); being a frontier firm in the previous year is associated with a, *cet. par.,* 13-29% higher probability of being in the frontier in t (further information on transition rates across the productivity sub-groups is presented below), while smaller firms are more likely to belong to the frontier (especially in agriculture , fishing & forestry where a increase in employment of 2.7 decreases the probability of belonging to the frontier by over 18%[17]). Being an exporter is only associated with

[15] Figure U.1 in the unpublished appendix covers all 37 industries.

[16] Given the small numbers of firms in some industries (which also leads to potential disclosure issues with the data – Statistics NZ will only allow the publication of estimates based on at least 10 observations), the frontier was chosen here with respect to the top 10% rather than 5% as chosen by the OECD. Limiting the frontier to the top 5% does not change the results presented here in any substantive way.

[17] That is $e^1 \times -0.067 = -0.182$.

belonging to the frontier in 4 of the 10 sectors reported, and the effect is small (e.g., in transport, postal, telecoms and ICT, exporters are *cet. par.* only 2.8% more likely to belong to the frontier sub-group), and the association with foreign-ownership is also relatively weak (the largest positive effect is in finance & renting, where being foreign-owned leads to a 3.5% higher probability of being a frontier firm, while in agriculture, fishing & forestry being foreign-owned lowered the likelihood of being in the frontier by nearly 4%).

Older firms were more likely to belong to the frontier in 4 (service-based) sectors (the largest effect was a 2.7% increase from being one year older in the transport, postal, telecoms and ICT sector), while in the production sectors younger firms, *cet. par*., had a higher association with being part of the frontier. In the production sectors, belonging to an industry with a lower level of market competition (as denoted by the Herfindahl index) was associated with belonging to the frontier, while service sector firms were less likely to belong to the frontier if competition was lower. As to agglomeration effects, the 'distance' variable (see Table A.1 for an explanation of how this is defined) capturing localisation economies is positively associated with belonging to the frontier in half the sectors covered, and negatively associated in 4 other sectors; although no clear pattern emerges. Urbanisation economies (represented by the diversity index) are weaker.

The regional dummies take Auckland as the benchmark to compare against; in agriculture, fishing & forestry those areas where this sector generally is over-represented (e.g., the Waikato, the rest of the upper North Island and the rest of the South Island) are, *cet. par*., more likely to have firms belonging to the frontier than Auckland; but for most other sectors the opposite is found (although Wellington does only marginally worse than Auckland for most sectors, and has a higher probability of frontier firms in the professional, technical and scientific services sector). In mining, being located in the rest of the lower North Island provides a nearly 11% greater probability (cet. par.) of belonging to the frontier in this sector (reflecting the gas and oil sector that is predominantly located in the Taranaki region).

Table 4 around here

Table 4 presents a different (unconditional) approach to looking at whether firms in Auckland tend to dominate the frontier in New Zealand,[18] but provides a similar outcome with Auckland having fewer frontier firms in agriculture, fishing & forestry, but relatively more in other sectors (especially compared to firms located in the South Island).

Table 3 showed that there was a strong link between being a frontier firm in year t and $t - 1$; Table 5 considers the persistence of *ln* TFP across time for 10 sectors, showing that in all sectors the elasticity between productivity values in adjacent years ranged from 0.6 (in wholesale) to over 0.9 (manufacturing), indicating that firms tend to maintain their position in the productivity distribution on a year-by-year basis. However, including longer lagged values of productivity shows that over time there is a weakening in rankings as some firms change places. Table U.2, in the unpublished appendix, presents transition matrices for the 10 sectors in Table 5, with firms grouped into 6 cohorts covering frontier firms (in the top 10%), those in the 75-90th productivity sub-group, and those in the 50-75th, 25-50th and 0-10th sub-groups. Across all sectors, between 52-63% of firms remained in the frontier sub-group throughout the 2001-16 period, with 22-28% of those in the 50-

[18] If each location were equally represented with frontier firms, the cells in Table 4 would all have zero values (as the underlying percentage of firms in each area, including Auckland, would be 10%).

75th sub-group moving up to the frontier, leaving little transition from other sub-groups to the frontier. This is in line with the results reported by Andrews et. al. (2016) for OECD firms, of increasing persistence at the frontier or that churning increasingly came from firms close to the frontier.

Table 5 around here

4. CATCHING-UP WITH THE FRONTIER

The above results indicate that there was generally persistence in terms of the firms belonging to the frontier, that productivity at the frontier was largely stable and changed little between 2001-16, and that was only weak evidence of significant 'catching-up' of firms below the frontier suggesting that diffusion was likely truncated. In this section, the results from estimating a 'catching-up' model using fixed-effects OLS are presented to formally test whether 'best practice' technologies were diffusing to firms lower down the productivity distribution in New Zealand.

The model estimated is similar to that used by Griffiths *et. al.* (2009, equation 1):

$$ln\,TFP_{it}^{non-F} = \beta\; lnTFP_{it-1}^{non-F} + \sum_{g=1}^{5}\gamma_g(lnTFP_{t-1}^{F} - lnTFP_{it-1}^{g}) + \delta X_{it} + \alpha_i + \varepsilon_{it} \qquad (4)$$

where $ln\,TFP_{it}^{non-F}$ refers to firm i in year t in the non-frontier and $lnTFP_t^F$ is the lower boundary of the 90th percentile of each industry productivity distribution in year t; g denotes firms in the 75-90th, 50-75th, 25-50th, 10-25th and 0-10th percentile sub-groups, respectively;[19] X refers to covariates determining productivity included in this conditional catching-up model (see Table A.1); and $\alpha_i + \varepsilon_{it}$ comprises the random effects error term. In addition to equation (4), two other versions were estimated: a simpler version where the 5 percentile gaps were replaced by an overall gap, $\gamma(lnTFP_{t-1}^{F} - lnTFP_{it-1}^{g})$; and one where catching-up was allowed to vary during the post-2007 period, thus $\sum_{g=1}^{5}\gamma_g(lnTFP_{t-1}^{F} - lnTFP_{it-1}^{g}) \times t_{2008-16}$ was added to equation (4) in order to obtain $\hat{\gamma}_g$ for the post-2007 period. Unlike other versions of this type of model (e.g., the extended Griffith et. al., 2009 model; and Andrews et. al., 2015), $\beta = 1$ has not been imposed which would allow the model to be re-specified with $\Delta ln\,TFP_{it}^{non-F}$ as the dependent variable (as will be seen H_0: $\beta = 1$ is rejected when equation 4 is estimated); and the model does not have an additional regressor (e.g., $\Delta ln\,TFP_{it}^{F}$) indicating the impact on productivity in non-frontier firms of changes in the productivity of frontier firms.[20]

Table 6 around here

In terms of equation (4), positive estimates of $\hat{\gamma}_g$ indicate that firms further behind the technological frontier increased their productivity faster than firms near(er) the frontier,

[19] Note, when estimating (4) it is necessary to use the linear spline function in Stata ('mkspline') to ensure that there are not discrete jumps at the percentile boundaries.

[20] A version of equation (4) including $\Delta ln\,TFP_t^F$ and separately versions including $ln\,TFP_t^F$ and $ln\,TFP_{t-1}^F$ were tried but the parameter estimates obtained were never significant (and the estimates for the gap variables were very similar to those reported in Table 6). This is to be expected given the generally 'flat' profile of the 90th percentile for early all industries (see Figures 4 and U.1).

providing evidence of productivity catching-up to $lnTFP_t^F$.[21] Table 6 presents the results obtained;[22] for all sectors other than mining and arts & other services, there is evidence that catching-up overall (the first column of results for each sector) and catching-up across sub-groups (the second column of results) are mostly similar, suggesting that firms further from the frontier were catching-up faster than those closer to the frontier. Additionally, there is some evidence that the relationship was non-linear, as in nearly every sector $\hat{\gamma}_{0-10}$ (the sub-group furthest away from the frontier) was somewhat larger than the other sub-group catching-up parameter estimates. Thus, the expectation of the neoclassical growth model, that firms more distant from the frontier have more of an incentive and ability to catching-up[23] (as even small or basic changes in the adoption of technology can have a relatively large effect), was supported by the results presented here; in contrast, a cumulative causation approach – based on only some firms having sufficient knowledge (e.g., absorptive capacity associated with intangible knowledge assets) to catching-up, such that being too far from the frontier renders some firms incapable of adopting more advanced technologies – was not found in the New Zealand situation for the 2001-16 period.

As to the speed of (conditional) catching-up, this was fastest in agriculture, fishing & forestry, followed by wholesale distribution and then finance & renting and professional, technical & support services. For these sectors, an increase of 10% in the gap of a non-frontier firm with the frontier resulted in catching-up of between nearly 7-10%. Additionally, persistence for these sectors was strong ($\hat{\beta} > 0.79$), confirming that despite there being evidence of catching-up firms maintained their relative ranking in their industry productivity distribution for significant periods. At the other extreme, there is weaker persistence and little if any catching-up in arts & other services (except for firms in the bottom productivity sub-group), and a low rate in utilities & construction (on average for the latter, an increase of 10% in the gap of a non-frontier firm with the frontier resulted in catching-up of about 3%, implying that over time 'laggard' firms were slowly drifting away from the frontier).

It might be expected that catching-up was (negatively) affected by the 2007-08 world financial crisis; Table 6 (third column for each sector) provides the estimates of $\hat{\gamma}_g$ for 2008-16[24] indicating little change for most sectors (vis-à-vis column 2) except wholesale distribution and professional, technical & scientific services where there was a considerable reduction in catching-up, finance & renting where there was a sizeable reduction, and mining where catching-up actually increased. Persistence also decreased for these sectors (although less so in mining), suggesting overall a truncation in technology diffusion from the 'best practice' national frontier.[25]

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[21] Note, this is evidence of relative (rather than absolute) catching-up.

[22] Estimates of the gap variables were calculated for each of the 37 industries covered in Table 1, not the 10 sectors in Table 6.

[23] As Conway et. al. (2015) point out: "The theoretical idea underlying this convergence process is that knowledge spillovers between firms are to some extent non-rival and not fully appropriable. As such, firms below the domestic productivity frontier can potentially improve their productivity by learning from better-performing firms in their industry" (p. 29).

[24] I.e. $\sum_{g=1}^{5} \gamma_g (lnTFP_{t-1}^F - lnTFP_{it-1}^g) + \sum_{g=1}^{5} \gamma_g (lnTFP_{t-1}^F - lnTFP_{it-1}^g) \times t_{2008-16}$ for g = 1, .., 5.

[25] The only other 'catching-up' results that are known to the author are those available from Conway et. al. (2015, Table 5) covering 2001-11 using the same data source. However, little by way of comparison is possible as they did not use the percentile 'gap' sub-groups; they have $\Delta ln\, TFP_{it}^{non-F}$ as the dependent variable; and they cover primary, manufacturing and services rather than the 10 sectors (based on 37 separate industries) covered here.

Thus far, and referring back to the opening paragraph in this section, the results from the 'catching-up' model do show evidence that, *cet. par*., diffusion was occurring (although weakly in some sectors with additional weakening after 2007 for others) but this was generally alongside relatively strong persistence, suggesting that the speed of catching-up was insufficient to overturn the largely stable patterns between 2001-16 seen in Figures 4 and U.1.

Table 7 around here

Andrews *et. al.* (2015) noted that a lack of resource allocation from low- to high-productivity firms has a negative impact on productivity growth. Thus,, Table 7 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.[26] The first column of results headed 'contribution' shows that overall New Zealand's TFP growth in 2001-2012 was 1.1% p.a., to which all but the frontier plants made a positive contribution. This poor performance by the top 10% of firms in terms of their productivity[27] was mostly due to the closing down of relatively high productivity firms (-0.32), and *lower* productivity firms *increasing* their output shares relative to higher productivity firms in operation throughout 2001-16. While there was a significant positive contribution (0.44) from new start-ups, this was not enough to overcome the loss of relatively higher productivity firms that exited and the reallocation of market shares within the frontier towards firms with lower productivity.

The pattern of contribution for all but the frontier firms declines the further are firms from the frontier, with the largest share (0.56) being for those firms just below the frontier. The largest contribution to this was the improvement of productivity within the firms that were open throughout the period, followed by a sizeable positive impact though new firms starting-up. For those firms in the 50-75th percentile sub-group, entry dominates but not by much. For the other three sub-groups, new firms entering had lower productivity, and in the case of the sub-group furthest from the frontier there was also a small negative 'between-firm' contribution showing that lower productivity firms increased their output shares relative to higher productivity firms in operation throughout 2001-16.

The results presented here on productivity growth between 2001-16 provided little evidence overall of a 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) 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). Of more concern is the poor performance in terms of TFP growth of frontier firms; especially the closure of relatively more efficient firms (in section 3, Table 3, it was found that frontier firms tend to be *cet. par*. smaller, which is likely to make them more

[26] The decomposition approach is set out in the appendix.

[27] While TFP growth may have been negative for the frontier firms, their contribution to output growth was generally much stronger than the contributions from other sub-groups, especially those furthest from the frontier. Table U.3 in the unpublished appendix provides some evidence.

susceptible to higher closure rates due to their weaker financial resilience) and the loss of market share of higher productivity firms open throughout 2001-16. Clearly, more work needs to be undertaken with respect to this frontier sub-group, especially in the context of how they compare to the global frontier – which tends to comprise larger firms (cf. Andrews et. al., 2016). This will require a dataset comprising international firms that include a New Zealand cohort – and is presumably a core element of the current review being undertaken by the New Zealand Productivity Commission (see footnote 3).

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 when looking at industry-by-industry profiles of TFP for certain percentiles, overall there is little evidence of major changes in frontier TFP over 2001-16, and limited evidence of catching-up. Thus, these results confirm the work of others that frontier productivity has been very stable in New Zealand vis-a-vis the evidence for the OECD covering approximately the same period; that is, it seems very likely that New Zealand firms at the national frontier are not keeping pace with global frontier firms. With regard to which firms belong to the frontier sub-group (the top 10% in any year), there is strong evidence of significant persistence; smaller firms are more likely to belong to the frontier; and there is little relationship between exporting and/or being foreign-owned and belonging to the frontier sub-group. In OECD analysis, frontier firms have been found to be larger and more likely to have strong international connections. Other patterns are less clear-cut, such as older firms more likely to belong to frontier in services, but younger firms in production sectors. However, there is evidence that Auckland (and to a slightly lesser extent Wellington) do 'dominate' the frontier, except in agriculture, fishing & forestry.

Further econometric analysis of the firm-level TFP estimates found that both persistence (the likelihood that firms retain their relative TFP ranking over a period of time) and (conditional) catching-up were present such that, *cet. par*., diffusion was occurring (although weakly in some sectors with additional weakening after 2007 for others). Overall, the results suggest that the speed of catching-up was insufficient to overturn the largely stable patterns found between 2001-16. Regarding productivity growth between 2001-16, there was little evidence overall of a reallocation of market shares to firms with higher productivity, or the closure of the least productive firms; but the most important result was the poor performance in terms of TFP growth of frontier firms (i.e., the closure of relatively more efficient firms and the loss of market share of higher productivity firms open throughout 2001-16).

The most important conclusion from this study is that while there is some evidence of a failure of productivity-enhancing technologies to diffuse from firms operating at the national productivity frontier, the major problem is failure of productivity-enhancing technologies to diffuse from firms operating at the global productivity frontier. New Zealand's major problem is that frontier firms are underperforming because of their characteristics (e.g., small and lacking international connections) while productivity is overall adversely affected by a lack of competition, which generally creates barriers to exiting and insufficient reallocation of market shares from lower- to higher-productivity firms.

In terms of the policy response needed in New Zealand, Andrews et. al. (2015, p. 93) note that "innovations at the global frontier do not immediately or inevitably diffuse to all firms… frontier innovations often need to be adapted to national circumstances". However, to increase the likelihood of diffusion from the global frontier, there is a need for a sufficient level of global connections via trade, FDI, participation in global value chains and the international mobility of skilled labour. New Zealand does not do well on any of these factors. In addition to improving the trajectory of firms at the national frontier (towards the global frontier), there is also the need to ensure greater resource reallocation towards more productive firms. As Andrews et. al. (op. cit., p. 97) argue: "If small firms are (on average) old, this might reflect barriers to post-entry growth and weak market selection mechanisms… A key message is that creative destruction and up-or-out dynamics are central: entry matters but what happens next is crucial – all else equal, young firms should grow rapidly or exit (i.e. "up-or-out") but not linger and become small-old firms." With respect to New Zealand, there does appear to be clear evidence that there are higher exit barriers (except for frontier firms where the wrong firms, with higher productivity, were exiting 2001-16) due in part to a lack of competition associated with an over emphasis on producing for small domestic markets.

As stated at the end of the previous section, a priority for further research is more work needs to be undertaken with respect to this frontier sub-group, especially in the context of how they compare to the global frontier. But constructing the relevant, representative dataset comprising international firms that include a New Zealand cohort is not simple; national statistical agencies tend to operate stringent rules that does not allow the sharing of firm-level data that they possess, and yet this would be the most optimal way of proceeding when comparing New Zealand frontier with global frontier firms. A start might be possible if Statistics New Zealand and the Australian Bureau of Statistics were to agree to share data for such a project, as this might set the groundwork for convincing other agencies to share data as well. Building on the work of CompNet (ECB, 2020) is another possibility.

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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:

$$\ln \widehat{TFP}_t = \sum_j \sum_i G_j \times \theta_{ijt} \ln \widehat{TFP}_{ijt} \quad \text{(A.1)}$$

where G_j is a set of mutually exclusive dummy variables indicating whether a firm belongs to subgroup j[28] 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:

$$\Delta \ln \widehat{TFP}_t = \ln \widehat{TFP}_t - \ln \widehat{TFP}_{t-k} \quad \text{(A.2)}$$

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

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

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.

[28] 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[a]	-4.297	1.82	-4.047	2.42	-4.125	3.12
Foreign-owned	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 based on 64 NZSIOC industries	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

[a] As explained in Harris et. al. (2019), this index is based on Scholl and Brenner (2016) and is used to capture Marshall-Arrow-Romer localisation economies; it is defined as: $\sum_{j=1,j\neq i}^{J} e^{-x(d_{i,j})} \times \frac{E_j}{\sum_{k=1,k\neq i} E_k}$ where J is the number of observations; x is the rate of decay of the function; and $d_{i,j}$ is the distance between plant i and j; 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. 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.

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 $\sigma/(\sigma-1)$	N	N (firms)	Pseudo-$R^{2(a)}$	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

[a] calculated as the correlation squared between predicted and actual $\tilde{r}_{it}$ in equation (1)

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

Source: Table U.1

Table 2: Summary of frontier trend and 'catch-up' 2001-16 by industry

Industry (NZSIOC)	Frontier trend (+ upward trend)	Gap (– closing gap)
Horticulture & fruit growing (AA11)	+	– –
Sheep, Beef cattle and grain farming (AA12)	–	++
Poultry, deer & other livestock (AA14)	+	++
Forestry & logging (AA21)	+	++
Support services to agriculture, forestry, fishing & hunting (AA32)	–	– –
Mining (BB11)	+++	+++
Manufacturing		
Food beverage & tobacco (CC1)	–	– –
Textile, leather & clothing (CC21)	+	–
Wood & paper products (CC3)	+	–
Printing (CC41)	–	–
Petrol, chemical, polymer & rubber (CC5)	+	+
Non-metallic minerals (CC61)	+	– –
Metal products (CC7)	– – –	– –
Transport equipment (CC81)	+	+
Machinery & other equipment (CC82)	+	+
Furniture & other manufacturing (CC91)	+	+
Utilities (DD1)	– –	–
Building construction (EE11)	+	–
Heavy & civil engineering construction (EE12)	–	–
Construction services (EE13)	++	–
Wholesale trade (FF11)	+	– –
Motor retail (GH11)	–	+
Supermarkets, stores, specialised retailing (GH12)	++	0
Other retailing (GH13)	++	– – –
Accommodation & food services (GH21)	+	– – –
Road transport (II11)	–	+
Rail, water, air & other transport (II12)	+	– – –
Post, courier support & warehousing (II13)	+	+
Information media services (JJ11)	+	– – –
Telecoms, internet & library services (JJ12)	++	– – –
Finance & insurance (KK1_)	–	–
Auxiliary finance & insurance services (KK13)	–	–
Rental & hiring (LL11)	–	–
Professional, technical & scientific services (MN11)	+	–
Admin & support services (MN21)	+	– –
Arts & recreational services (RS11)	+	–
Other services (RS21)	+	–

– – –/– –/– large (>20%)/medium(10-20%/small (<10%) negative change 2001-2016 Source: Figures 3 and U.1

+++/++/+ large (>20%)/medium(10-20%/small (<10%) positive change 2001-2016

Table 3: (Weighted) marginal effects from a probit model of which firms belong to the frontier (coded 0/1) in New Zealand, 2001-16

Variables	Agriculture, Fish, Forestry	Mining	Manufacturing	Utilities & Construction	Wholesale	Retail & Accommodation	Transport, etc, ICT	Finance, Renting etc	Prof, Tech, Support	Arts, other services
$Frontier_{t-1}$	0.213***	0.134***	0.191***	0.189***	0.237***	0.225***	0.291***	0.221***	0.242***	0.217***
ln Employment	-0.067***	-0.018***	-0.010***	-0.017***	-0.010***	-0.015***	-0.013***	-0.012***	-0.005***	-0.016***
Exporter	0.020***	-0.005	-0.008***	-0.023***	0.022***	-0.003	0.028***	-0.009	-0.021***	0.022***
Foreign-owned	-0.039**	-0.021	0.015***	0.005	0.037***	-0.002	0.018***	0.035***	0.011***	0.013
ln age of firm	0.002	-0.015***	-0.001	-0.004***	-0.003**	0.008***	0.010***	0.002	0.003***	0.005***
ln Herfindahl index	0.004***	-0.003	0.006***	0.002***	0.015***	-0.002***	-0.009***	0.003*	-0.005***	-0.003***
ln Distance	0.002***	-0.000	-0.002***	0.001***	-0.002***	-0.002***	0.003***	0.001***	0.001***	-0.004***
ln Diversity	-0.001	0.003	0.001**	0.000	0.001	0.001	0.010***	0.006*	-0.002***	0.005***
Waikato	0.022***	-	-0.006**	-0.008***	-0.021***	-0.019***	-0.011**	-0.026***	-0.012***	-0.016***
Rest Upper North Island	0.025***	-0.029	-0.005**	-0.006***	-0.011***	-0.023***	-0.013***	-0.014**	-0.016***	-0.015***
Wellington	0.002	-	-0.007***	-0.007***	-0.005	-0.007***	-0.008*	-0.009*	0.018***	-0.006*
Rest Lower North Island	0.007	0.109***	-0.005*	-0.010***	-0.010**	-0.020***	-0.012**	-0.032***	0.002	-0.023***
Canterbury	0.001	-0.011	-0.007***	0.000	-0.002	-0.005**	0.003	-0.007	-0.008***	-0.007**
Otago	0.000	0.014	-0.010***	-0.012***	-0.026***	-0.015***	-0.019***	-0.017*	-0.007**	-0.012***
Rest South Island	0.034***	-0.046*	-0.006**	-0.009***	-0.016***	-0.017***	-0.008	-0.020*	-0.012***	-0.014***
Pseudo R^2	0.364	0.494	0.351	0.293	0.326	0.258	0.33	0.346	0.373	0.327
Observations	42,696	1,677	107,535	140,187	82,767	193,407	51,507	25,476	216,921	79,428

***/**/* significant at 1/5/10% level. The 10 sectors are based on aggregating across the 37 industries listed in Table 2.

Table 4: Percentage of New Zealand firms belonging to frontier top 10%, 2001-16 - other broad regions minus Auckland

	Wellington	Canterbury	Waikato	Otago	Rest of NZ
Agriculture, Fish, Forestry	2.5	3.1	0.5	3.8	3.2
Mining, Manufacturing, Utilities	-1.9	-1.2	-1.6	-3.0	-2.0
Wholesale, Retail & Accommodation	-1.4	-2.1	-3.8	-3.4	-3.2
Rest	5.1	-2.0	-3.3	-3.6	-3.6

Table 5: (weighted) OLS regression of *ln* TFP on lagged values

ln TFP_{t-1}	*ln* TFP_{t-2}	*ln* TFP_{t-3}	*ln* TFP_{t-4}	Constant	Observations	R^2
Agriculture, Fish, Forestry						
0.797***	–	–	–	-0.237***	386,991	0.653
0.512***	0.226***	0.089***	0.078***	-0.102***	183,531	0.732
Mining						
0.644***	–	–	–	-0.398***	3,105	0.431
0.445***	0.211***	0.109	0.064	-0.270***	1,515	0.562
Manufacturing						
0.907***	–	–	–	-0.157***	190,503	0.804
0.536***	0.240***	0.145***	0.066***	-0.039***	97,032	0.884
Utilities & Construction						
0.685***	–	–	–	-0.020***	389,553	0.456
0.529***	0.171***	0.105***	0.066***	-0.012***	179,418	0.549
Wholesale						
0.601***	–	–	–	0.000	120,585	0.330
0.436***	0.204***	0.144***	0.054***	-0.011**	60,069	0.415
Retail & Accommodation						
0.767***	–	–	–	0.283***	348,291	0.541
0.518***	0.199***	0.152***	0.079***	0.061***	156,363	0.657
Transport, etc, ICT						
0.728***	–	–	–	0.350***	126,612	0.521
0.569***	0.199***	0.063**	0.083***	0.099***	52,614	0.645
Finance, Renting etc						
0.802***	–	–	–	-0.120***	58,791	0.618
0.568***	0.206***	0.123***	0.049***	-0.051***	23,313	0.744
Prof, Tech, Support						
0.829***	–	–	–	0.086***	413,229	0.661
0.586***	0.182***	0.113***	0.081***	-0.013***	171,339	0.766
Arts, other services						
0.831***	–	–	–	-0.027***	174,156	0.684
0.511***	0.243***	0.116***	0.082***	-0.029***	81,549	0.788

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

Table 6: Parameter estimates from (weighted) fixed effects OLS catching-up model, New Zealand industries, 2001-16

Dependent variable: $lnTFP_{it}^{non-F}$	Agriculture, Fish, Forestry			Mining			Manufacturing		
	Baseline	2001-16	2008-16	Baseline	2001-16	2008-16	Baseline	2001-16	2008-16
$lnTFP_{it-1}^{non-F}$	0.801***	0.778***	0.699***	0.436***	0.413***	0.349***	0.630***	0.677***	0.662***
$(lnTFP^{F} - lnTFP^{non-F})_{it-1}$	0.989***	–	–	0.395***	–	–	0.553***	–	–
$(lnTFP^{F} - lnTFP^{75-90})_{it-1}$	–	0.983***	0.987***	–	0.261*	0.389***	–	0.543***	0.497***
$(lnTFP^{F} - lnTFP^{50-75})_{it-1}$	–	0.865***	0.875***	–	-0.281**	0.107*	–	0.405***	0.430***
$(lnTFP^{F} - lnTFP^{25-50})_{it-1}$	–	0.868***	0.918***	–	0.012	0.231*	–	0.469***	0.478***
$(lnTFP^{F} - lnTFP^{10-25})_{it-1}$	–	0.947***	0.986***	–	-0.224**	0.047	–	0.449***	0.438***
$(lnTFP^{F} - lnTFP^{0-10})_{it-1}$	–	1.036***	1.031***	–	0.037	0.244***	–	0.652***	0.635***
ln Distance	-0.050***	-0.048***	-0.048***	-0.096***	-0.092***	-0.093***	-0.002	-0.002	-0.002
ln Distance × *ln* Employment	0.043***	0.042***	0.042***	0.041***	0.039***	0.039***	0.002***	0.002***	0.002***
Foreign-owned	-0.056**	-0.053**	-0.053**	-0.219	-0.231	-0.224	-0.001	0.000	0.000
Time trend	-0.009***	-0.009***	-0.010***	0.003	0.004	-0.003	-0.002***	-0.001***	-0.000
ln age of firm	0.041***	0.045***	0.047***	0.015	0.029	0.029	0.009***	0.010***	0.009***
ln Herfindahl index	-0.004	-0.005	-0.005	-0.104***	-0.100***	-0.084***	0.005***	0.005***	0.005***
ln Diversity	0.017***	0.016***	0.017***	0.030	0.022	0.031	-0.007***	-0.006***	-0.006***
Auckland	-0.020	-0.012	-0.015	-0.189	-0.120	-0.073	0.002	0.003	0.002
Rest Upper NI	-0.010	0.003	-0.002	-0.680	-0.615	-0.527	-0.013	-0.007	-0.007
Wellington	0.004	0.021	0.015	-0.592	-0.613	-0.537	0.007	0.007	0.008
Rest Lower NI	0.015	0.010	-0.003	-0.239	-0.244	-0.144	-0.006	-0.007	-0.007
Canterbury	-0.014	-0.000	0.013	0.346	0.296	0.360	-0.007	0.002	0.003
Otago	0.001	0.015	0.029	1.100	1.264	1.289	0.019	0.031	0.035
Rest SI	0.011	0.028	0.042	0.035	0.065	0.083	-0.040	-0.038	-0.038
Constant	-0.599***	-0.597***	-0.596***	-1.359***	-1.646***	-1.742***	-0.913***	-0.813***	-0.845***
Observations	33,441	33,441	33,441	1,920	1,920	1,920	96,255	96,255	96,255
R^2	0.893	0.904	0.904	0.262	0.294	0.329	0.977	0.981	0.981
Number of firms	6,759	6,759	6,759	375	375	375	16,086	16,086	16,086

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

Table 6: (cont.)

	Utilities & Construction			Wholesale			Retail & Accommodation		
	Baseline	2001-16	2008-16	Baseline	2001-16	2008-16	Baseline	2001-16	2008-16
$lnTFP_{it-1}^{non-F}$	0.393***	0.426***	0.407***	0.916***	0.932***	0.592***	0.642***	0.701***	0.711***
$(lnTFP^{F} - lnTFP^{non-F})_{it-1}$	0.317***	–	–	0.851***	–	–	0.591***	–	–
$(lnTFP^{F} - lnTFP^{75-90})_{it-1}$	–	0.317***	0.276***	–	0.750***	0.347***	–	0.547***	0.501***
$(lnTFP^{F} - lnTFP^{50-75})_{it-1}$	–	0.244***	0.269**	–	0.634***	0.357**	–	0.404***	0.464***
$(lnTFP^{F} - lnTFP^{25-50})_{it-1}$	–	0.299***	0.302***	–	0.658***	0.324***	–	0.554***	0.569***
$(lnTFP^{F} - lnTFP^{10-25})_{it-1}$	–	0.259***	0.274***	–	0.702***	0.363***	–	0.535***	0.547***
$(lnTFP^{F} - lnTFP^{0-10})_{it-1}$	–	0.416***	0.397***	–	0.915***	0.578***	–	0.692***	0.702***
ln Distance	-0.001	-0.002	-0.001	-0.004**	-0.003**	-0.003**	-0.002*	-0.002*	-0.002*
ln Distance × *ln* Employment	0.002***	0.002***	0.002***	0.004***	0.005***	0.005***	-0.000	-0.000	-0.000
Foreign-owned	-0.029**	-0.028**	-0.027**	0.007	0.007	0.008	-0.003	-0.004	-0.004
Time trend	0.002***	0.002***	0.002***	-0.008***	-0.007***	-0.001	-0.001**	-0.001**	0.001**
ln age of firm	0.008***	0.010***	0.009***	0.021***	0.021***	0.020***	0.016***	0.014***	0.013***
ln Herfindahl index	-0.005**	-0.005**	-0.005**	0.003	0.002	0.002	0.009***	0.009***	0.008***
ln Diversity	0.012***	0.010***	0.010***	0.001	0.001	0.002	-0.001	0.000	0.000
Waikato	-0.006	-0.008	-0.009	0.006	0.016	0.015	0.004	0.004	0.003
Rest Upper North Island	-0.054***	-0.053***	-0.054***	-0.052	-0.040	-0.039	0.008	0.006	0.007
Wellington	-0.011	-0.014	-0.015	-0.012	0.003	0.001	-0.008	-0.007	-0.005
Rest Lower North Island	-0.056**	-0.054**	-0.054**	0.060	0.070	0.068	0.034	0.033	0.034
Canterbury	-0.000	-0.001	-0.002	-0.009	0.001	0.002	-0.009	-0.011	-0.008
Otago	0.006	0.004	0.004	-0.088	-0.065	-0.062	-0.007	-0.001	0.001
Rest South Island	0.017	0.012	0.012	-0.029	-0.021	-0.018	-0.046	-0.039	-0.038
Constant	-0.303***	-0.290***	-0.290***	-0.505***	-0.440***	-0.209***	0.409***	0.340***	0.295***
Observations	117,681	117,681	117,681	69,705	69,705	69,705	126,837	126,837	126,837
R-squared	0.449	0.516	0.506	0.097	0.314	0.315	0.247	0.443	0.444
Number of firms	22,236	22,236	22,236	12,921	12,921	12,921	28,443	28,443	28,443

Table 6: (cont.)

	Transport, etc, ICT			Finance, Renting etc			Prof, Tech, Support		
	Baseline	2001-16	2008-16	Baseline	2001-16	2008-16	Baseline	2001-16	2008-16
$lnTFP_{it-1}^{non-F}$	0.566***	0.619***	0.627***	0.770***	0.794***	0.679***	0.783***	0.798***	0.562***
$(lnTFP^{F} - lnTFP^{non-F})_{it-1}$	0.488***	–	–	0.694***	–	–	0.669***	–	–
$(lnTFP^{F} - lnTFP^{75-90})_{it-1}$	–	0.469***	0.470***	–	0.540***	0.365***	–	0.624***	0.348***
$(lnTFP^{F} - lnTFP^{50-75})_{it-1}$	–	0.389***	0.398***	–	0.547***	0.454***	–	0.524***	0.317***
$(lnTFP^{F} - lnTFP^{25-50})_{it-1}$	–	0.390***	0.383***	–	0.552***	0.437***	–	0.569***	0.333***
$(lnTFP^{F} - lnTFP^{10-25})_{it-1}$	–	0.504***	0.539***	–	0.432***	0.295***	–	0.567***	0.341***
$(lnTFP^{F} - lnTFP^{0-10})_{it-1}$	–	0.598***	0.604***	–	0.797***	0.663***	–	0.788***	0.561***
ln Distance	0.002	0.002	0.002	-0.000	-0.001	-0.001	-0.001	-0.001	-0.001
ln Distance × *ln* Employment	0.000	0.001	0.001	0.005***	0.005***	0.006***	0.004***	0.004***	0.004***
Foreign-owned	0.017	0.016	0.016	-0.029	-0.031	-0.031	0.019	0.020*	0.021*
Time trend	-0.004***	-0.004***	-0.003***	-0.004	-0.003	0.003	-0.010***	-0.010***	-0.004***
ln age of firm	0.022***	0.020***	0.020***	0.015	0.012	0.008	0.016***	0.021***	0.019***
ln Herfindahl index	-0.008*	-0.007*	-0.007*	0.038*	0.028	0.028	0.015***	0.014***	0.015***
ln Diversity	-0.015***	-0.013***	-0.013***	-0.036*	-0.027	-0.021	0.005	0.004	0.004
Waikato	0.018	0.016	0.016	0.120	0.072	0.089	-0.069**	-0.065**	-0.062**
Rest Upper North Island	0.033	0.034	0.033	0.084	0.089	0.100	-0.046	-0.042	-0.038
Wellington	0.067	0.064	0.063	-0.131*	-0.133**	-0.137**	-0.021	-0.024	-0.024
Rest Lower North Island	0.049	0.041	0.040	-0.021	-0.035	-0.029	-0.068	-0.067	-0.065
Canterbury	0.048	0.049	0.048	-0.172**	-0.177**	-0.174**	-0.036	-0.031	-0.029
Otago	0.106*	0.100*	0.098*	-0.587**	-0.562**	-0.557**	0.011	0.016	0.018
Rest South Island	0.023	0.024	0.024	-0.384	-0.400*	-0.404*	-0.037	-0.032	-0.029
Constant	0.279***	0.233***	0.212***	-0.807***	-0.654***	-0.681***	-0.386***	-0.352***	-0.141**
Observations	40,887	40,887	40,887	21,822	21,822	21,822	150,612	150,612	150,612
R-squared	0.794	0.799	0.799	0.852	0.88	0.879	0.196	0.34	0.34
Number of firms	9,084	9,084	9,084	5,067	5,067	5,067	32,718	32,718	32,718

Table 6: (cont.)

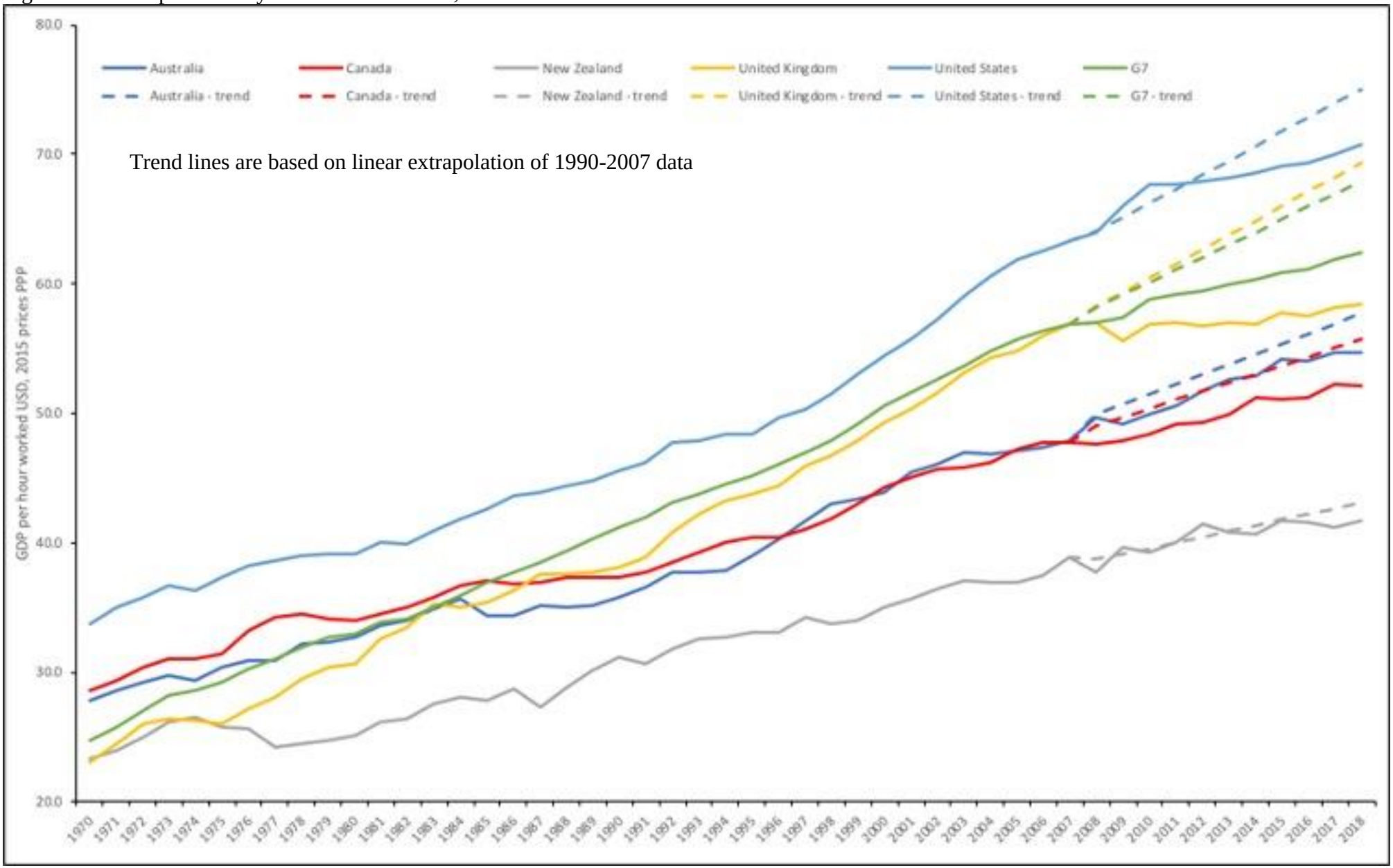
	Arts, other services		
	Baseline	2001-16	2008-16
$lnTFP_{it-1}^{non-F}$	0.290***	0.322***	0.284***
$(lnTFP^{F} - lnTFP^{non-F})_{it-1}$	0.140	–	–
$(lnTFP^{F} - lnTFP^{75-90})_{it-1}$	–	0.137	0.080
$(lnTFP^{F} - lnTFP^{50-75})_{it-1}$	–	-0.007	-0.009
$(lnTFP^{F} - lnTFP^{25-50})_{it-1}$	–	0.053	0.003
$(lnTFP^{F} - lnTFP^{10-25})_{it-1}$	–	0.050	0.057
$(lnTFP^{F} - lnTFP^{0-10})_{it-1}$	–	0.275***	0.244**
ln Distance	-0.004**	-0.004**	-0.004**
ln Distance × *ln* Employment	0.005***	0.005***	0.005***
Foreign-owned	-0.022	-0.022	-0.021
Time trend	-0.006***	-0.006***	-0.006***
ln age of firm	0.017***	0.018***	0.018***
ln Herfindahl index	-0.009**	-0.009**	-0.008**
ln Diversity	-0.002	-0.002	-0.002
Waikato	-0.057	-0.056	-0.056
Rest Upper North Island	-0.050	-0.043	-0.042
Wellington	0.046	0.053	0.052
Rest Lower North Island	0.018	0.036	0.034
Canterbury	0.024	0.030	0.031
Otago	-0.145*	-0.139*	-0.138*
Rest SI	-0.082	-0.087	-0.087
Constant	-0.530***	-0.501***	-0.507***
Observations	57,933	57,933	57,933
R-squared	0.104	0.198	0.197
Number of firms	10,914	10,914	10,914

Table 7: Productivity growth decomposition, New Zealand frontier sub-groups, 2001-16 (figures are average p.a. percentages)

	TFP growth[a]	Decomposition of TFP growth[b]			
Productivity sub-group	Contribution	Within-firm	Between-firm	Entry	Exit
ln TFP^{F}	-0.122	-0.065	-0.181	0.443	-0.320
ln TFP^{75-90}	0.560	0.294	0.086	0.173	0.007
ln TFP^{50-75}	0.269	0.036	0.074	0.109	0.051
ln TFP^{25-50}	0.192	0.060	0.060	-0.018	0.090
ln TFP^{10-25}	0.187	0.093	0.019	-0.050	0.126
ln TFP^{0-10}	0.003	0.000	-0.005	-0.012	0.020
New Zealand	1.089	0.419	0.054	0.644	-0.027

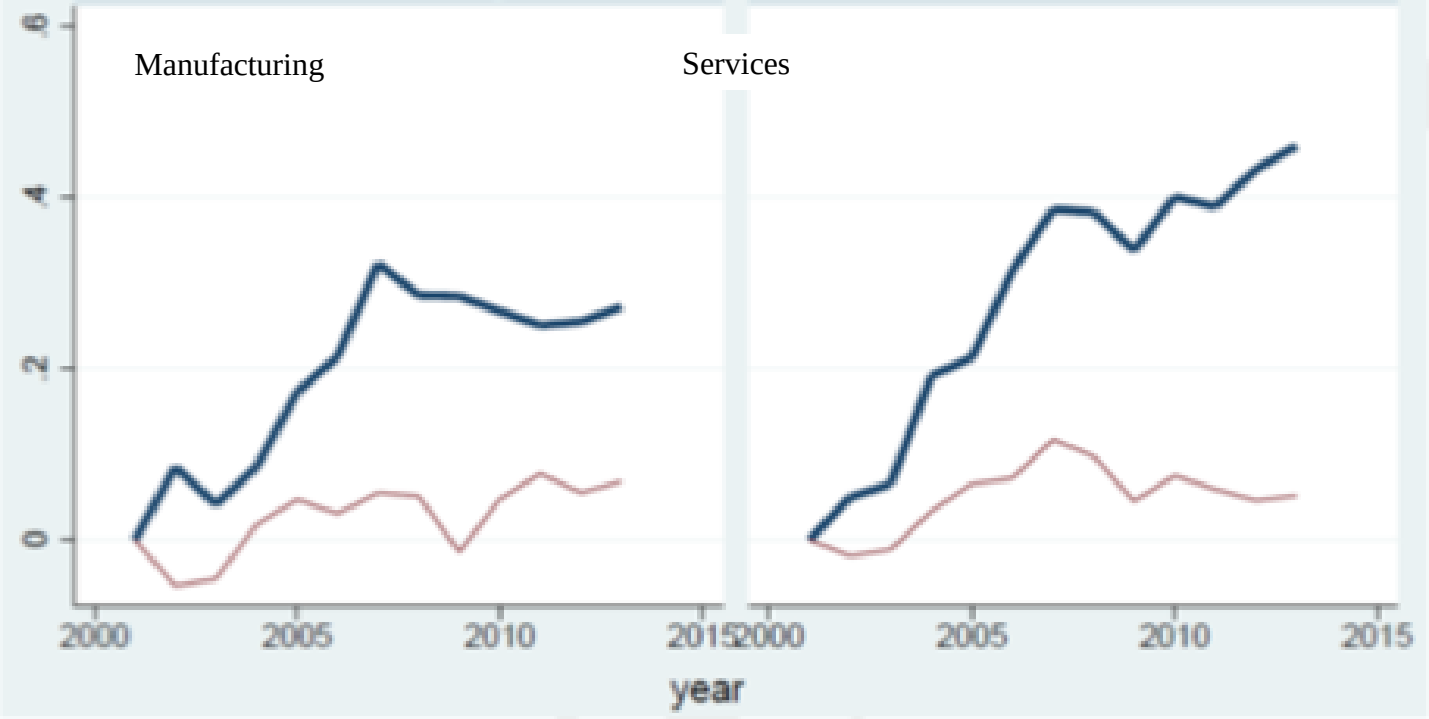
[a] *ln* TFP based on 'common elasticities' across industries, not individual industry output elasticities – see section 3 for a discussion
[b] Based on Haltiwanger-type approach – see equation A.3. Note, 'between-firm' contribution is the sum of such contributions in A.3, and the sign on 'Exit' contribution has been reversed

Figure 1: Labour productivity in selected countries, 1970-2018



Source: OECD statistics database

Figure 2: TFP in OECD frontier and laggard firms, 2001-13



Source: Andrews et. al. (2016, Figure 2b)

Figure 3: Cumulative *ln* TFP for firms (all sectors) by selected years, New Zealand, 2001-16

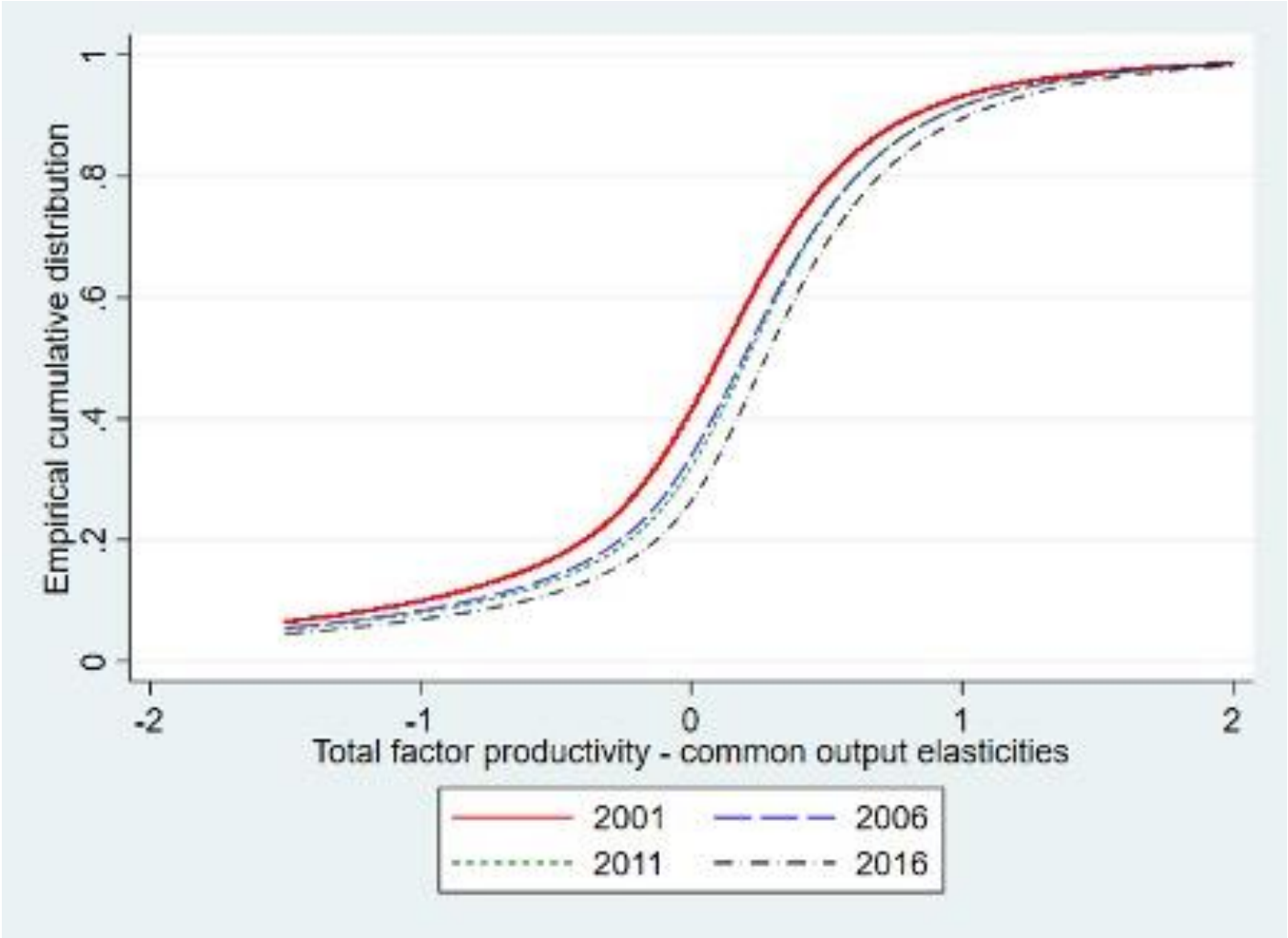
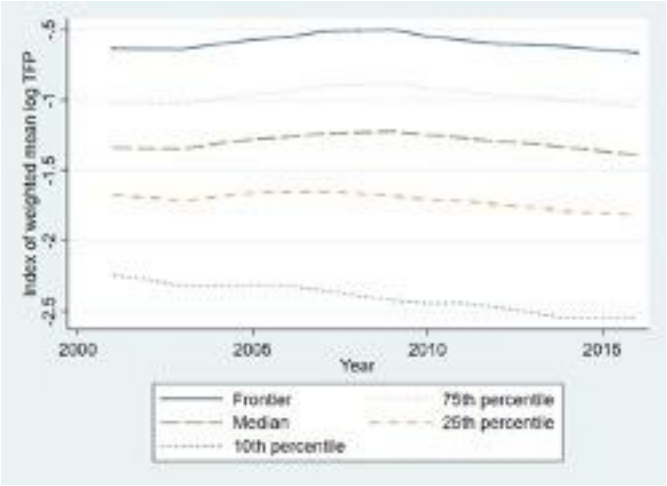
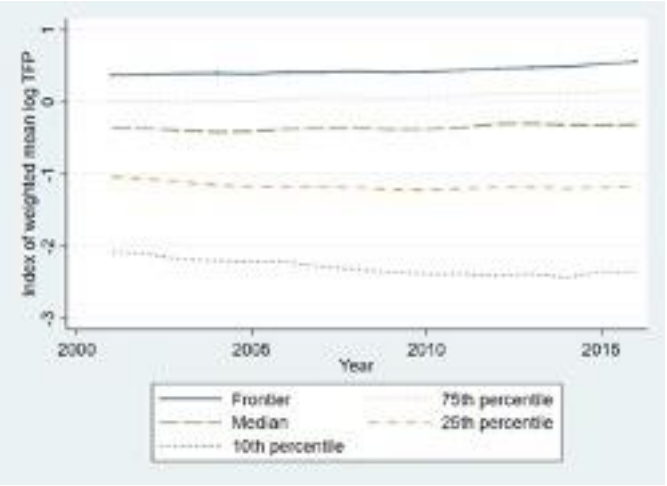


Figure 4: Weighted *ln* TFP for selected industries in New Zealand, 2001-16 (various percentiles)

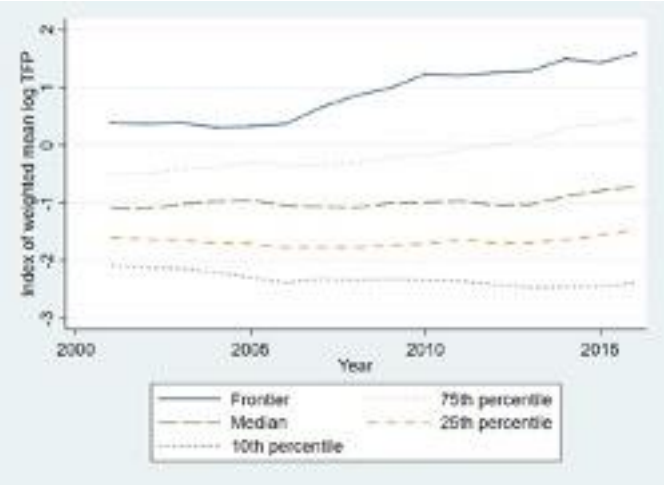
(a) Sheep, Beef cattle and grain farming (AA12)



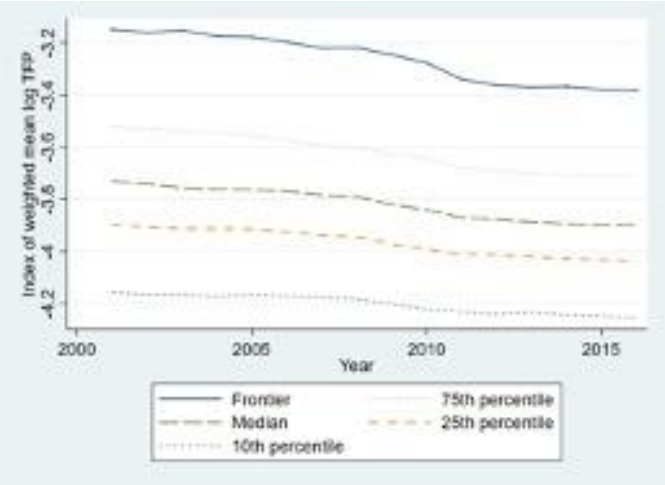
(b) Forestry & logging (AA21)



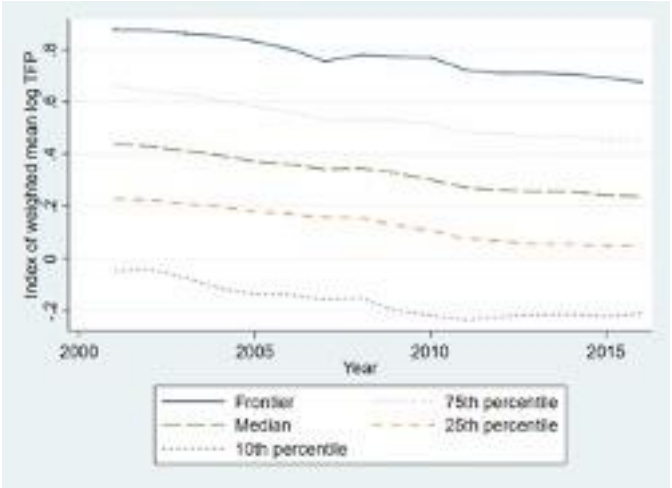
(c) Mining (BB11)



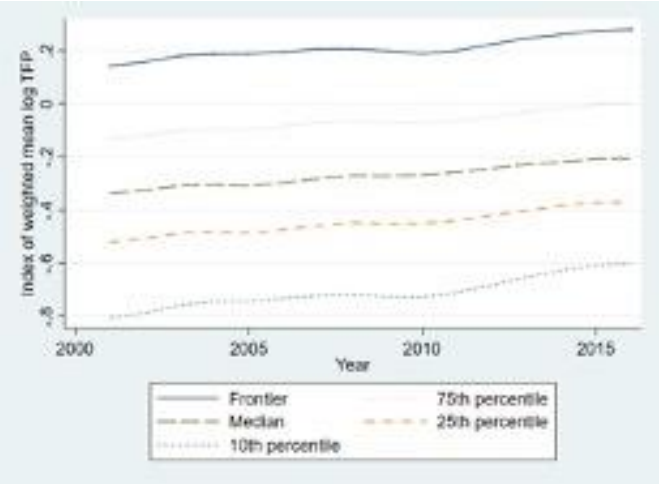
(d) Metal products (CC7)



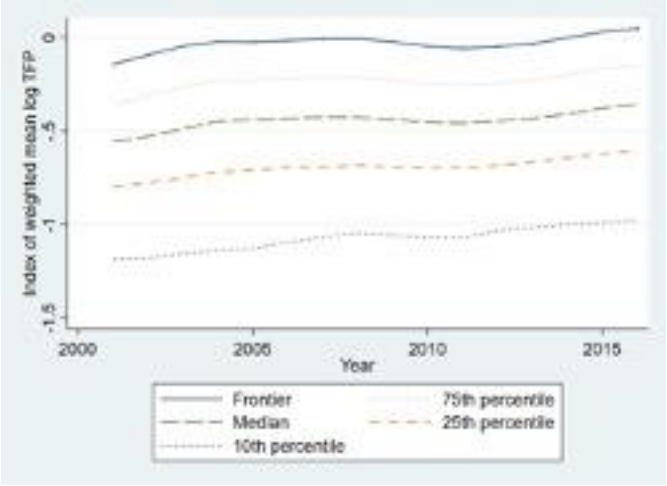
(e) Utilities (DD1)



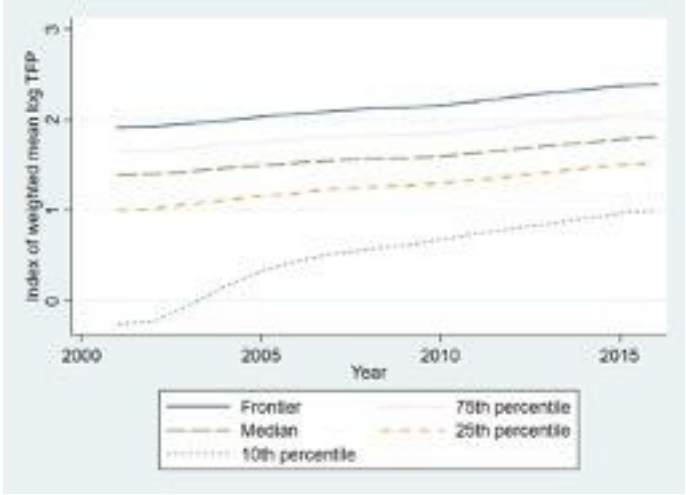
(f) Construction services (EE13)



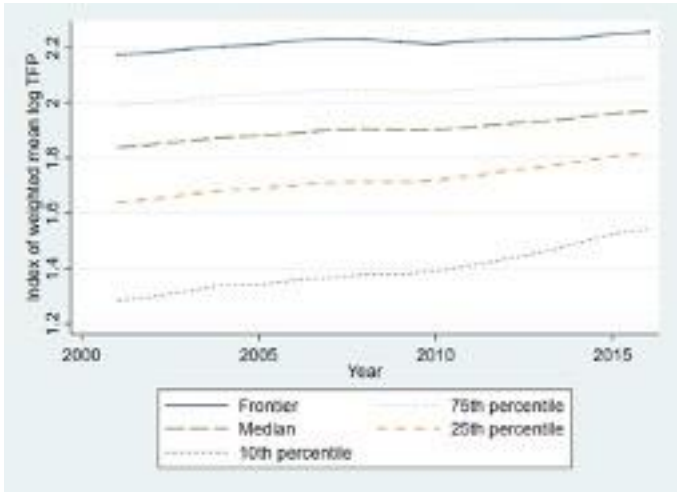
(g) Supermarkets, stores, specialised retailing (GH12)



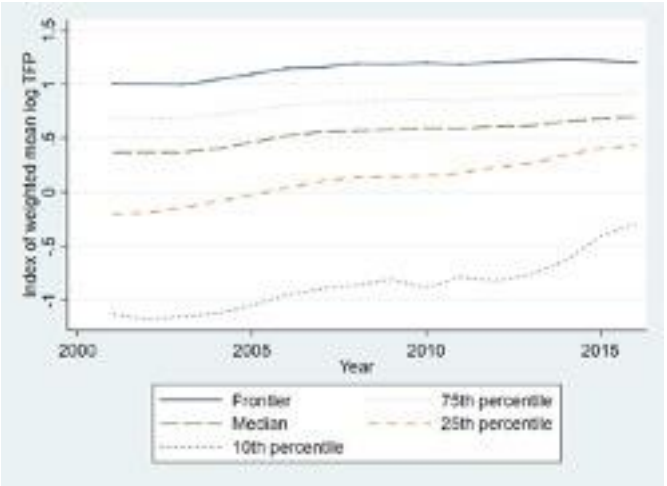
(h) Other retailing (GH13)



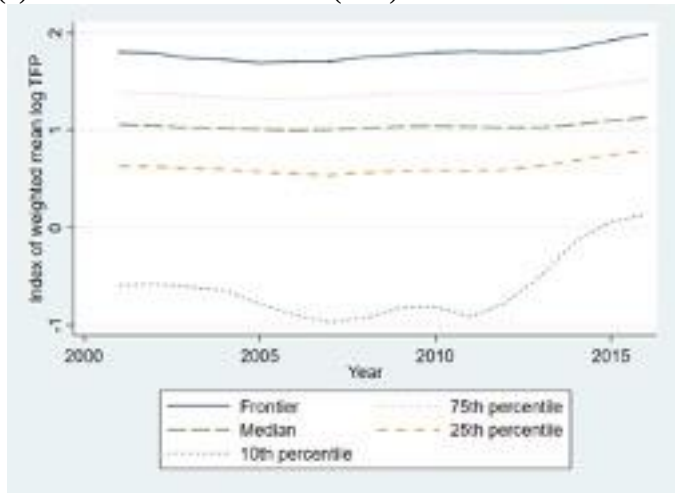
(i) Accommodation & food services (GH21)



(j) Rail, water, air & other transport (II12)



(k) Information media services (JJ11)



(l) Telecoms, internet & library services (JJ12)