NEW ZEALAND
PRODUCTIVITY COMMISSION
Te Kōmihana Whai Hua o Aotearoa

Geographic proximity and productivity convergence across New Zealand firms

Working paper 2016/04

December 2016

Author: Guanyu Zheng

The New Zealand Productivity Commission: Geographic proximity and productivity convergence across New Zealand firms

Date: December 2016

Authors: Guanyu Zheng

JEL classification:
ISBN: 978-0-478-44045-4

Acknowledgements: I would like to thank Dave Maré and Dean Hyslop from Motu and Paul Conway and Lisa Meehan from the Productivity Commission for excellent analytical support and comments on this paper. I would also like to thank Catherine Jeffcoat and Sally Aitken for editing and proof reading earlier drafts.

Information about the Productivity Commission can be found on www.productivity.govt.nz or by contacting +64 4 903 5150

Abstract

To examine the extent to which to new productivity-enhancing ideas and technologies diffuse within the New Zealand economy, this paper examines the speed with which lagging low-productivity firms converge towards leading high-productivity firms at both the local and national levels. Results show that New Zealand firms have faster productivity convergence towards the local frontier compared to the national frontier, suggesting that knowledge diffusion is geographically localised to some extent. In addition, this paper tentatively explores the relationship between the extent to which firms trade their output over geographic distance (domestic tradability) and productivity convergence. Results show a positive link between domestic tradability and productivity convergence to the national frontier, suggesting that firms that operate across larger markets have greater potential to learn from firms at the national productivity frontier within the New Zealand economy.

Contents

Tables

Figures

1 Introduction

Knowledge is an increasingly important factor of production in New Zealand and other economies. This is reflected in large and growing investment in research and development (R&D), higher employment in knowledge intensive industries and greater demand for highly-skilled labour. Therefore, fostering innovation and promoting the diffusion of new knowledge across firms is crucial in lifting future economic growth and the competitive advantage of firms, regions and nations.

Knowledge has some interesting properties, including non-rivalry in consumption and partial-only excludability. As a result, knowledge can diffuse across firms on the basis of a knowledge transaction (eg, purchasing a patent) or through learning by doing or labour flows. Knowledge diffusion results in a more efficient production technology in recipient firms, potentially leading to productivity convergence (eg, Caniëls (2000) and Corrado, Haskel, and Jona Lasinio (2014). Hence, knowledge diffusion is important for productivity growth.

However, knowledge diffusion is a "sticky" process that is influenced by a number of factors. One important factor that influences diffusion is proximity to the source of technological knowledge. There is a general claim that proximity promotes more interactive learning between economic actors. Boschma (2005) highlights five interconnected dimensions of proximity, including cognitive, organisational, social, institutional and geographic proximity. Cognitive proximity focuses on the capability to absorb knowledge. Organisational proximity highlights the capacity to control the exchange of complementary knowledge between firms. For social proximity, trust and embedded relationships are the key. Institutional proximity captures the impact of formal (such as laws and rules) and informal (such as culture norms and languages) institutions that can help coordinate learning. Lastly, geographic proximity is associated with the spatial distance to knowledge. In combination, these diverse and complementary proximity factors facilitate the process of knowledge diffusion.

This paper studies the impact of geographic proximity on the diffusion of knowledge across New Zealand firms. A larger literature supports the idea that knowledge is expensive to transmit over distance, resulting in knowledge diffusion being geographically localised. For example, Griffith, Redding, and Simpson (2009) find that knowledge diffusion is stronger across firms at the regional level than at the national level in the United Kingdom. For cross country studies, Andrews, Criscuolo, and Gal (2015) find that knowledge diffusion is stronger within countries than across countries. This evidence suggests that firms will be able to tap into tacit and non-codified knowledge by being located in close geographic proximity to frontier firms. In this scenario, geographic proximity facilitates knowledge exchanges between firms and enhances the capability of firms to absorb tacit knowledge.

This paper applies the framework developed by Griffith et al. (2009) to investigate knowledge diffusion at the regional and national levels in New Zealand. Figure 1 sketches out the broad knowledge flows that influence firm productivity growth within this framework. Firms are classified into one of three types depending on how relatively productive they are:

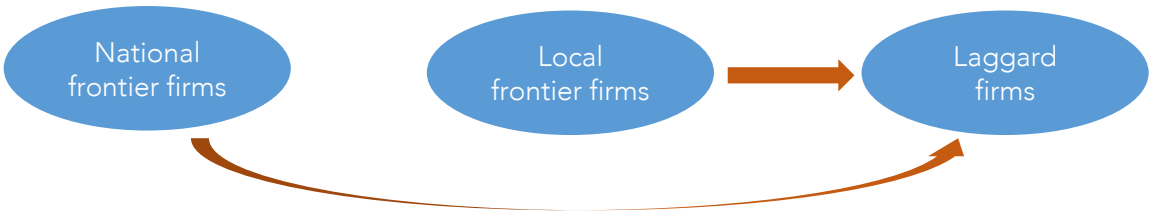
- The national frontier firms – these firms are the most productive firms in New Zealand in their industry. The evidence indicates that these high-productivity frontier firms tend to be young and open to international engagement through exports and FDI (Conway, Meehan, & Zheng, 2015).
- The local frontier firms – these firms are the most productive firms in their local market in their industry, but they are less productive than national frontier firms.
- Laggard firms – these firms are relatively less productive in their industry within New Zealand.

The framework illustrates that knowledge can simultaneously diffuse from the national and local frontiers to laggard firms. Firms at the national frontier often actively engage with high-productivity firms in international markets. These firms introduce new knowledge or technology that then spreads to the rest of the economy.

At the same, firms at the local frontier may create or adopt knowledge to fit with local conditions. It can then diffuse to laggard firms. Under this framework, the productivity of laggard firms improves towards that of frontier firms as they adopt productivity-enhancing knowledge and converge towards both frontiers.

This paper uses regression analysis which models multi-factor productivity (MFP) growth to examine the extent to which the framework depicted in Figure 1 is an accurate representation of technology transfer within the New Zealand economy. It captures the idea of technology transfer from high to low productivity firms, where a firm's distance from the frontier is a measure of the potential for productivity convergence.

Figure 1 Knowledge diffusion framework



The results show significant productivity convergence within New Zealand and its local markets. In general, the speed with which laggard firms converge towards higher-productivity firms in their local market is faster than convergence to firms at the national frontier. These results are broadly analogous to the findings from Griffith et al. (2009) and indicate that geographic proximity plays an important role in the process of knowledge diffusion. (Conway & Zheng, 2014)

The results also show that the speed of productivity convergence to the national and local frontiers is highly industry-specific. The paper goes on to explore the impact of domestic tradability – measured using an indicator of the extent to which firms trade their output in local versus national markets (Conway & Zheng, 2014) – on firm convergence to the local and national frontiers. The results show that technological adoption by firms is influenced by the extent to which they trade their output over distance within New Zealand. Specifically, firms that operate in national markets are more inclined to adopt technology developed by firms at the national productivity frontier whereas firms more focused on the local market in which they are situated tend to learn from the most productive firms in their local market.

The rest of the paper proceeds as follows. Section 2 outlines the measurement of MFP and national and local frontiers in New Zealand. Section 3 illustrates the productivity dynamics of frontier and non-frontier firms. Section 4 presents regression results, and section 5 discusses the impact of geographic proximity and tradability on productivity convergence. Conclusions are offered in section 6.

2 The New Zealand productivity frontier

2.1 Firm-level productivity estimation

For this paper, firm-level productivity is estimated using data from the Longitudinal Business Database (LBD) from Statistics New Zealand from 2000 to 2012.[1] The focus is on revenue based multi-factor productivity (MFP) which refers to the efficiency with which firms convert a range of inputs – predominantly labour, capital and intermediate inputs – into outputs.[2]

[1] LBD is a rich source of firm-level data with employment and financial information from the Inland Revenue Department, merchandise trades from Customs and various business surveys from Statistics New Zealand (Fabling & Sanderson, 2016).

[2] MFP is usually derived as a residual from a conventional production function. Based on work by Fabling and Maré (2015b), firm-level MFP is calculated using fixed-effects Trans-log gross output production function across industries, so MFP is the sum of firm's fixed-effects and idiosyncratic error. Trans-log production function has a more flexible general form compared with Cobb-Douglas production function and allows the partial elasticities of substitution

The population of the LBD is all economically-significant firms in the private sector. Also, working proprietor only firms are excluded from the analysis as their financial information is subject to a high degree of measurement error (Fabling & Sanderson, 2014).

Each firm is assigned to one industry over its lifetime based on its predominant employment share. There are 16 industries used in the study across the primary, goods-producing and service sectors[3]. The industry classification generally corresponds to the Australian and New Zealand Standard Industrial Classification (ANZSIC) 2006 1-digit industries.

As well as an industry, each firm is assigned to one geographic location over its lifetime based on the location of its predominant employment share. If a firm has a number of branches across regions or has relocated, the location with the largest share of employment is chosen as a predominant business location. There are two broad options for setting geographic locations – territorial local authorities (TLAs) and labour market regions (LMRs). TLAs are based on administrative boundaries which typically come about given historical circumstances. LMRs are derived from travel-to-work data from the 2006 Census based on Papps and Newell (2002). LMRs represent functional and relatively self-contained economic areas within which the majority of employed people reside and work. As such, LMRs are territorial units based on the organisation of social and economic activity and as shown by Stabler, Olfert, and Greuel (1996), provide a more appropriate geographic unit for use in regional studies.

In New Zealand, Papps and Newell (2002) identified 102 labour market catchments, which were aggregated to 13 broad LMRs for the purpose of the analysis. They are Central North Island, Gisborne-Napier-Wairarapa, Greater Auckland, Greater Christchurch, Greater Hamilton, Nelson-Marlborough, Northland, South Westland – Rural South Canterbury, Southland-Otago, Taranaki, Thames-Tauranga, Wanganui-Palmerston North, and Wellington urban.

2.2 Measuring the productivity frontier

Defining local and national productivity frontiers is a challenging task and subject to a number of measurement issues. First, the best approach to measuring the frontier will differ depending on the characteristics of the underlying datasets, such as data coverage and size of the firm sample. Secondly, year-on-year fluctuations in measured MFP may be partly due to measurement errors. Thirdly, regional price deflators are unavailable in New Zealand.

All of these reasons could potentially lead to mismeasurement of the national and local productivity frontiers. To mitigate measurement errors and short-run volatility, some adjustment procedures are needed. First, firms in the top and bottom 1% of the MFP distribution in their industry are removed from the sample due to extremely long tails of the productivity distribution. Second, weights based on the input-weight developed by Maré, Hyslop, and Fabling (2015) are applied to calculate frontier firm's productivity level. Productivity estimates for small firms tend to be noisier than larger firms due to higher measurement errors on production inputs and outputs.[4] Weight adjustments on productivity level potentially reduce the impact of noisy productivity measures for small firms on frontier productivity.

The level of the national productivity frontier is set at the weighted 90th percentile of firm-level MFP in each industry in the study. The level of the local productivity frontier is set at the weighted 90th percentile of firm-level MFP for each industry within a LMR. Firms with higher productivity than the national productivity frontier are identified as national frontier firms. Firms with productivity equal to or greater than the level of the local productivity frontier but less than the level of the national productivity frontier are assigned as local frontier firms. All remaining firms are laggard firms.

---

between inputs. Under the Trans-log production function, gross output is regressed against labour, capital and intermediate inputs as well as firm-specific fixed effects. Output and input components are deflated using available price deflators at 2011 constant prices. Gross output, capital and intermediate values are deflated separately using producer output price, capital goods price and producer input price deflators. Labour is measured as the head count of employee plus working proprietors. Full-time and part-time employees cannot be distinguished based on this method. Alternatively, Fabling and Maré (2015a) implement a set of methods to derive an approximate measure of full-time equivalent (FTE) labour input.

[3] The mining industry is excluded from the analysis as it has a very small sample of firms when broken down across regions.

[4] Standard deviations of MFP for small firms with 1 to 5 employees are almost twice larger than for firms with 20 or more employees.

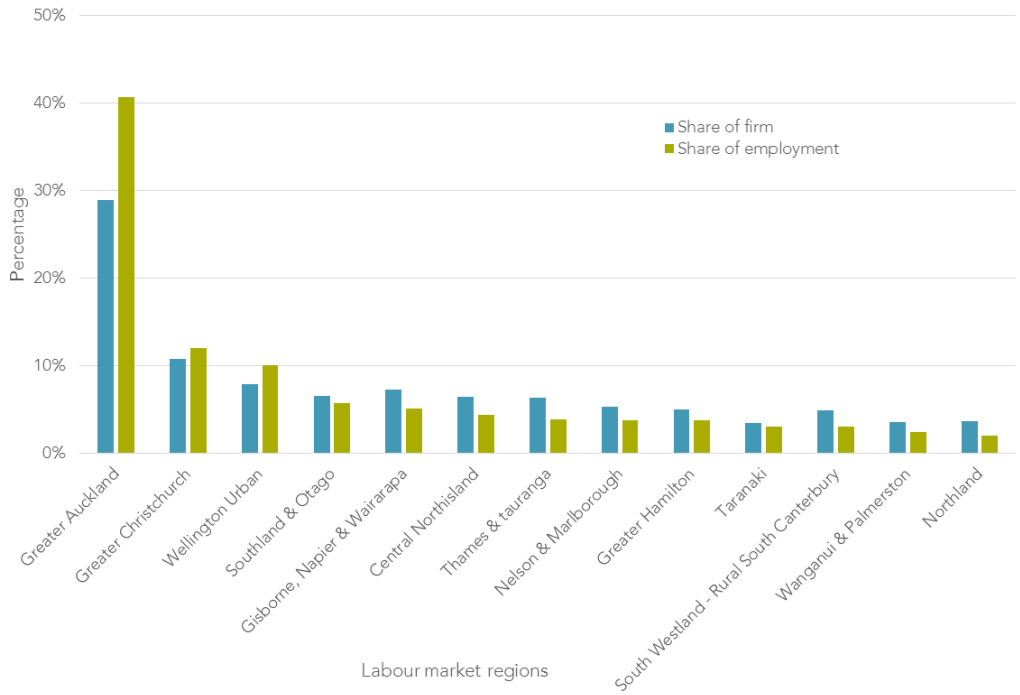
Some studies, including Griffith et al. (2009) and Andrews et al. (2015), use the top 10 or 100 firms in each industry as a basis for measuring the productivity frontier. In the New Zealand context, these different methods generate similar and correlated estimates of the productivity frontier.[5] However, in the case of New Zealand, frontier estimates based on the weighted 90th percentile show smaller volatility compared with the alternatives and thereby provide more accurate estimates for descriptive and regression analysis.

The national productivity frontier measured in this way is comprised of firms from different LMRs where the prices of outputs and inputs will vary. Given a lack of regional price deflators, the national productivity frontier is expected to be biased. It is not clear whether this bias will lead to an over-estimate or an under-estimate of the true national frontier.

In the productivity dataset used in this study, there are 909,033 firm-year observations and 12,901,500 employee-year observations over the 2000-2012 sample period. Looking at the locations of these firms shows that economic activity is spatially concentrated in urban areas. Specifically, the three major cities of Greater Auckland, Greater Christchurch and Wellington account for 48% of the total firm population and 63% of total employment years in the country (Figure 2). Consistent with agglomeration benefits, the spatial concentration of firms at the national frontier is even more marked with 52% of frontier firms and 73% of employment in firms at the national frontier clustered in these three cities (Figure 3).

Figure 4 shows a distinct spatial distribution of national frontier firms across sectors. For the primary sector, the national productivity frontier is predominately located in rural regions, such as Central North Island and Gisborne-Napier-Wairarapa. For the goods-producing sector, the national productivity frontier tends to be clustered in urban and semi-urban regions, including Greater Auckland, Southland-Otago and Taranaki areas. For the services sector, national frontier firms are disproportionally clustered in New Zealand's three major cities.

Figure 2 The spatial distribution of New Zealand firms and employment, 2000-2012



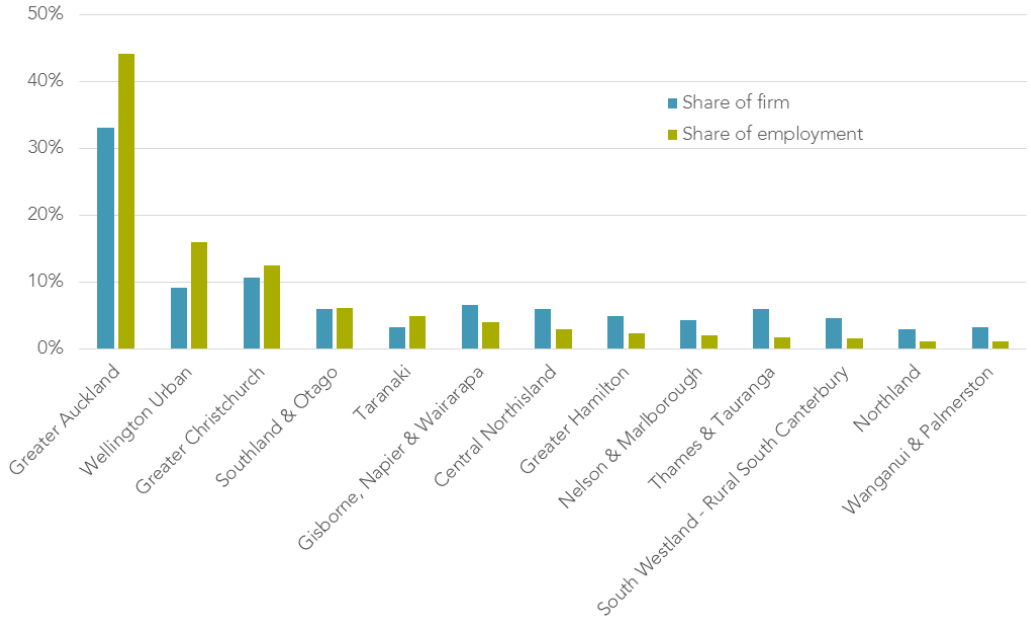
Source: Author's calculations using LBD

Notes:

1. Regions are defined as labour market regions using the methodology described in Papps and Newell (2002) and based on Census 2006 travel-to-work data

[5] Productivity frontiers measured on the basis of the top 10, top 100, weighted 90th percentile and unweighted 90th percentile generally show similar growth trends and are highly correlated, with a linear Pearson correlation coefficients of more than 0.9.

Figure 3 The spatial distribution of firms at the national frontier, 2000-2012

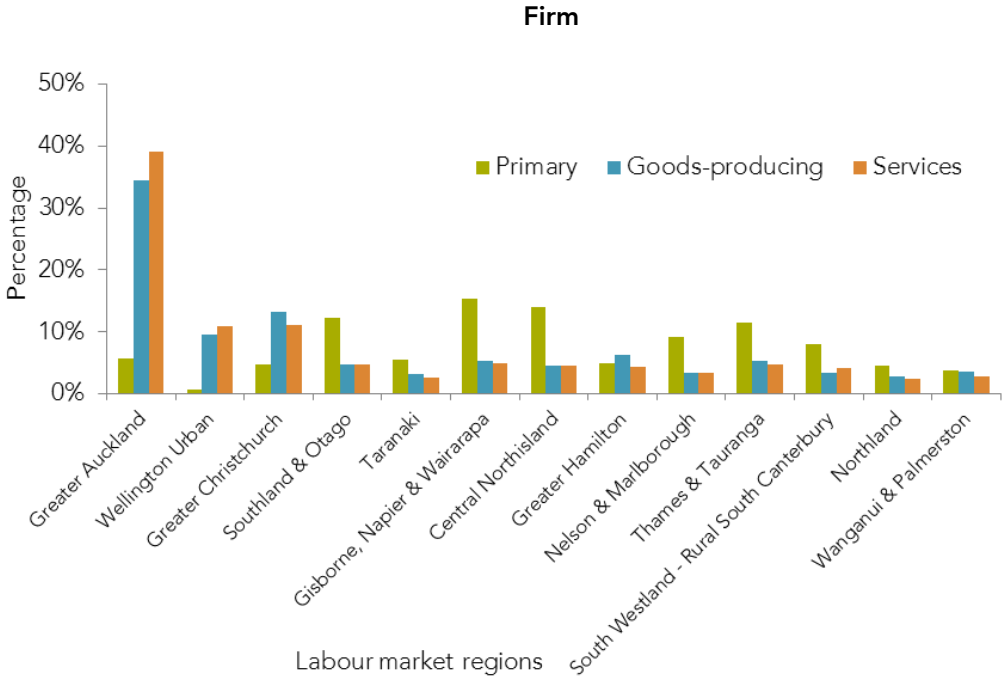


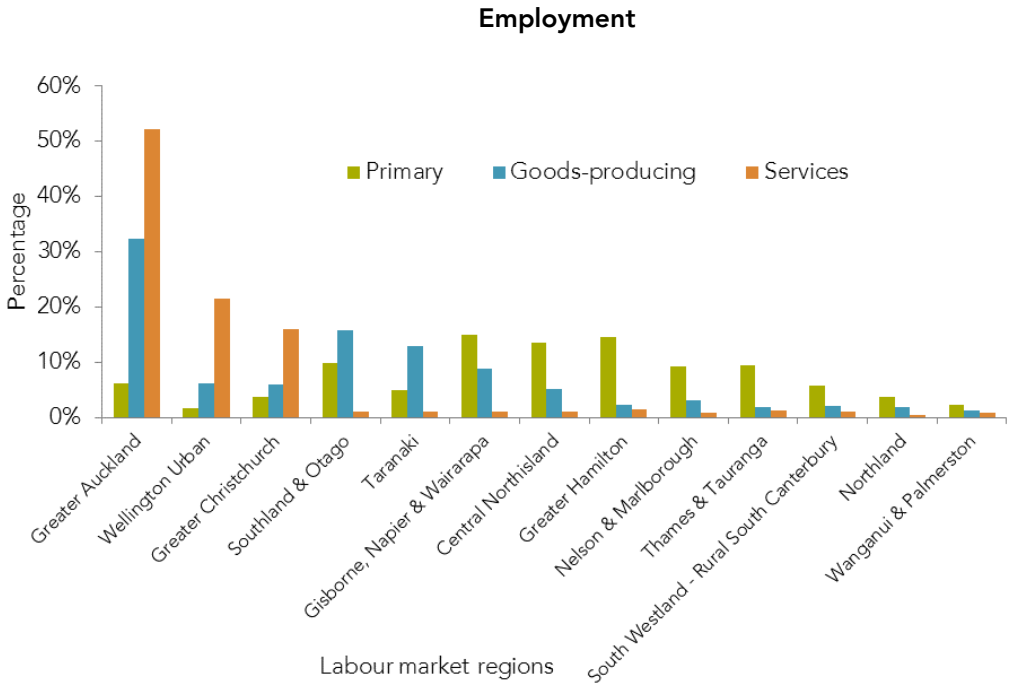
Source: Author's calculations using LBD

Notes:

1. Regions in New Zealand are labour market regions which are created by Papps and Newell (2002) based on Census 2006 travel-to-work data.
2. Firms with productivity levels higher than the weighted 90th percentile of firm-level MFP in each industry are classified as operating at the national frontier.

Figure 4 The spatial distribution of the national productivity frontier by sectors, 2000-2012





Source: Author's calculations using LBD

Notes:

1. Regions in New Zealand are labour market regions which are created by Papps and Newell (2002) based on Census 2006 travel-to-work data.
2. Firms with higher productivity than weighted 90th percentile of firm-level MFP in each industry are classified as national frontier.

3 New Zealand productivity dynamics

In New Zealand, national frontier firms, which are defined as firms in the top 10% of most productive firms, account for 21% of employment (Table 3-1). In comparison to less-productive laggards, these frontier firms tend to be relatively large, more capital intensive and more likely to be foreign owned or exporters. Firms at the local productivity frontier have broadly similar characteristics, but the differences with laggard firms are smaller. Most of New Zealand firms are laggard firms, which tend to be relatively small.

Table 3-1 Average firm characteristics by firm types

Firm types	Firm age (years)	Capital intensity	Gross-output per employee	Firm size (employee)	Exporter (% of total firms)	Foreign ownership (% of total firms)	Firm-year counts	Employment -year counts
Laggard firms	12.4	$20,827	$150,573	12.5	4.7%	3.1%	813,459	10,144,250
Local frontier	12.6	$30,013	$269,404	22.7	5.9%	4.0%	45,990	1,042,147
National frontier	11.6	$41,681	$416,184	34.6	8.4%	5.4%	49,587	1,716,457

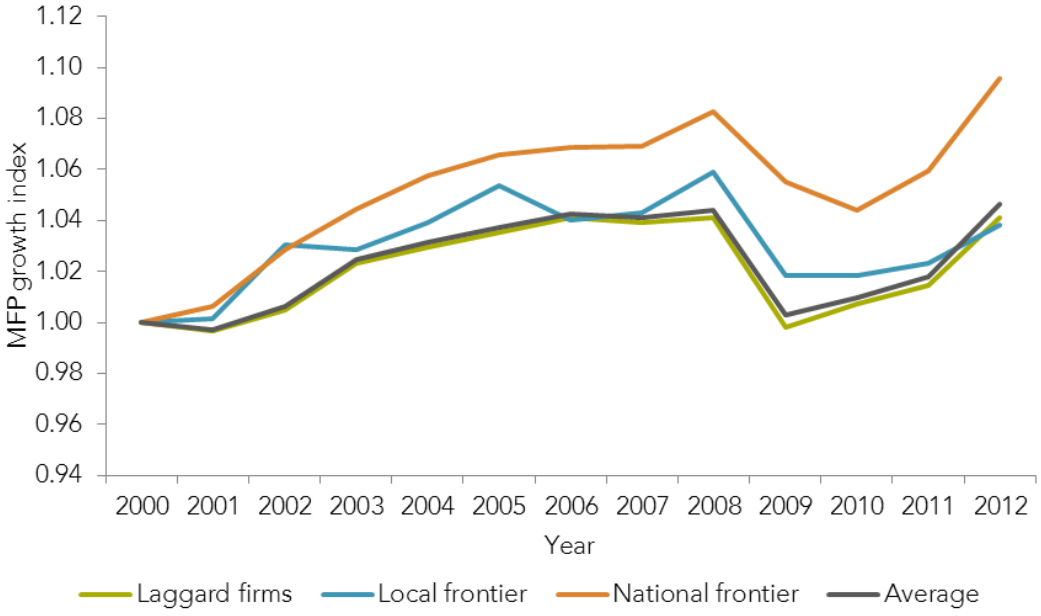
Source: Author's calculations using LBD

Notes:

1. Firm and employee counts are randomly rounded according to the confidentiality rules from Statistics New Zealand.

Figure 5 shows MFP growth for the three types of firms used in this study: national frontier firms; local frontier firms; and laggard firms over the 2000-2012 period. Productivity growth at the national frontier is stronger than the productivity growth of firms at the local frontier and laggard firms. Specifically, the productivity of firms at the national frontier expands at an average annual rate of 0.77%. This is almost 1.6 times faster than the productivity growth of firms at the local productivity frontier and 2.2 times faster than the productivity growth of laggards. Laggard firms have not kept pace with the productivity performance of firms at the national frontier. As a result, the productivity gap between lagging and national frontier firms has increased over time (Figure 6).

Figure 5 Annual MFP growth at laggards, local and national productivity frontier firms

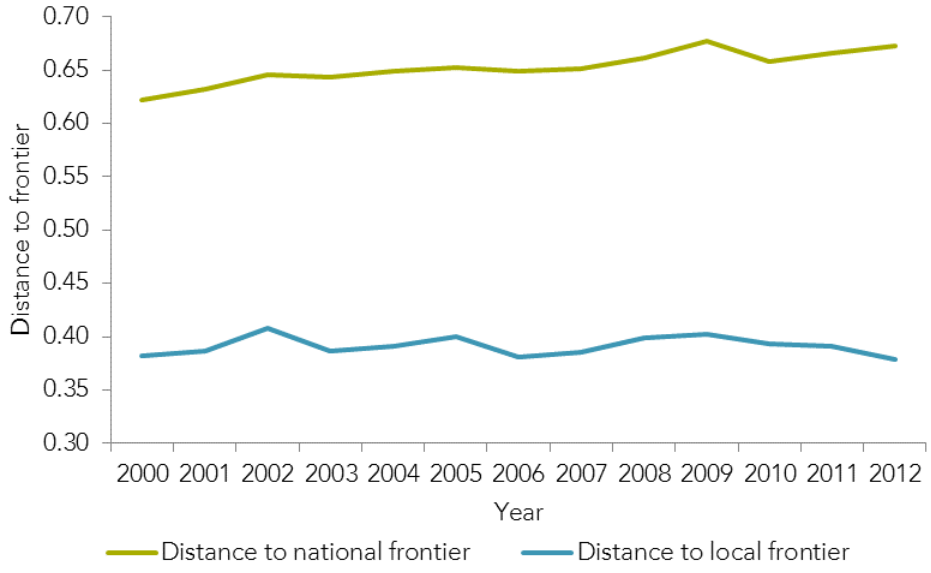


Source: Author's calculations using LBD

Notes:

1. Productivity index is set to 1 at the 2000 base year.
2. For each firm category, MFP is firstly aggregated to the industry level and then adjusted using industry weights to get to the aggregate measures.

Figure 6 Average productivity gaps between laggards and the national and local frontiers



Source: Author's calculations using LBD

Notes:

1. Distance to the productivity frontiers is measure as the log difference between average frontier (local or national) productivity and the average productivity of laggards.

4 Testing for productivity convergence

4.1 The productivity convergence model

The model used to test for convergence to the local and national frontiers is based on the co-integration framework used in Griffith et al. (2009). The MFP of a firm is assumed to be related to its lagged MFP and the MFP of national frontier and local frontier firms under a first order auto-regressive distributed lag co-integration relationship:

$$\ln A_{ijkt} = \alpha \ln A_{ijkt-1} + \beta_1 \ln A_{jt}^{NF} + \beta_2 \ln A_{jt-1}^{NF} + \theta_1 \ln A_{jkt}^{LF} + \theta_2 \ln A_{jkt-1}^{LF} + v_i + \varepsilon_{ijkt} \quad (1)$$

where i, j, k and t index firms, industries, regions and time respectively. All variables are expressed as natural logs. So the variable $lnA_{ijkt}$is the natural log of the MFP of firm i in industry j and region k at time t. $lnA_{jt}^{NF}$and lnA_{jkt}^{LF} are respectively MFP at the national frontier in industry j and MFP at the local frontier in industry j in a given labour market region k and time t. The variable v_i is an unobserved firm fixed-effect. The residual term ε_{ijkt} combine a full set of industry η_j and region-time η_{kt} dummies to control for unobserved industry and region-time specific effects, together with an idiosyncratic error μ_{ijkt}: $\varepsilon_{ijkt} = \eta_j + \eta_{kt} + \mu_{ijkt}$.

Equation (1) can be transformed into the base productivity convergence model:

$$\Delta \ln A_{ijkt} = \lambda_1 \Delta \ln A_{jt}^{NF} + \lambda_2 \Delta \ln A_{jkt}^{LF} + \delta_1 \ln \frac{A_{jt-1}^{NF}}{A_{ijkt-1}} + \delta_2 \ln \frac{A_{jkt-1}^{LF}}{A_{ijkt-1}} + \gamma \ln A_{ijkt-1} + v_i + \varepsilon_{ijkt} \quad (2)$$

where $\lambda_1 = \beta_1, \lambda_2 = \theta_1, \delta_1 = \beta_1 + \beta_2, \delta_2 = \theta_1 + \theta_2 \; and \; \gamma = \beta_1 + \beta_2 + \theta_1 + \theta_2 + \alpha - 1$

In equation(2), the annual MFP growth of a firm is modelled as a function of productivity growth at the national and local frontiers, distance to the national frontier, distance to the local productivity frontier, the firm's lagged productivity level and firm's fixed-effect. This fixed-effect model assumes conditional productivity convergence in the long run. It implies that firms operate with various technologies and have different long-run growth paths. As such, an important feature of this model is that a firm's productivity does not necessarily narrow the gap to the productivity frontiers over the long run.

Distance to the national frontier and distance to the local frontier are key variables of interest. Their corresponding coefficients, δ_1 and δ_2, capture the speeds of productivity convergence towards the national and local frontiers respectively. However, high collinearity between distance to national frontier and distance to local frontier causes unstable regression estimates in the base productivity convergence model. Accordingly, a modified model is used instead:

$$\Delta \ln A_{ijkt} = \lambda_1 \Delta \ln A_{jt}^{NF} + \lambda_2 \Delta \ln A_{jkt}^{LF} + \pi_1 \ln \frac{A_{jt-1}^{NF}}{A_{jkt-1}^{LF}} + \pi_2 \ln \frac{A_{jkt-1}^{LF}}{A_{ijkt-1}} + \gamma \ln A_{ijkt-1} + v_i + \varepsilon_{ijkt} \quad (3)$$

where $\lambda_1 = \beta_1, \lambda_2 = \theta_1, \pi_1 = \beta_1 + \beta_2, \pi_2 = \theta_1 + \theta_2 + \beta_1 + \beta_2 \; and \; \gamma = \beta_1 + \beta_2 + \theta_1 + \theta_2 + \alpha - 1$

To avoid collinearity, the term measuring the distance to national frontier is replaced by the productivity gap between the national and local frontier in equation (3). Therefore, annual MFP growth of a firm is modelled as a function of productivity growth at the national and local frontiers, the productivity gap between the national and local frontier, distance to the local productivity frontier and the firm's lagged productivity level.

The coefficients on the first and second terms in the equation capture the direct effects of MFP growth at the national and local frontiers on the MFP growth of firms. The third term – the productivity gap between the national and local frontier – is the size of productivity difference between the national and local productivity frontiers in the same industry. The coefficient, π_1, captures the long-run speed of productivity convergence to the national productivity frontier, $\pi_1 = \delta_1$. The fourth term, distance to the local frontier, is the size of the productivity gap between a firm's productivity and the local frontier for its industry within a LMR. Its corresponding coefficient, π_2, capture speeds of productivity convergence to both productivity frontiers, $\pi_2 = \delta_1 + \delta_2 = \theta_1 + \theta_2 + \beta_1 + \beta_2$. The difference between π_1 and π_2 is the estimated speed of productivity convergence to the local frontier, so $\delta_2 = \pi_2 - \pi_1$. The last term serves to control for serial correlation and to relax the assumption of the long-run homogeneity relationship.

Under the long-run homogeneity assumption, the rate of productivity growth for non-frontier firms equals the rate of growth at the frontier in a long run so that the lagged productivity variable can be ignored in regression analysis. However, Figure 5 in the previous section shows sustainable differences in growth rates between frontier and non-frontier firms such that the long-run homogeneity assumption is unlikely to be valid.

This base productivity convergence model is extended in equation (3) to assess the impact of a number of firm characteristics on firm-level MFP. Firm characters include firm age and firm size

$$\Delta \ln A_{ijkt} = \lambda_1 \Delta \ln A_{jt}^{NF} + \lambda_2 \Delta \ln A_{jkt}^{LF} + \pi_1 \ln \frac{A_{jt-1}^{NF}}{A_{jkt-1}^{LF}} + \pi_2 \ln \frac{A_{jkt-1}^{LF}}{A_{ijkt-1}} + \gamma \ln A_{ijkt-1} + \sum_n \omega_n x_{ijkt} + v_i + \varepsilon_{ijkt} \quad (4)$$

Firm size is the natural log of the sum of working proprietors and employee count. Firm age is the current year minus the firm's year of birth.

To estimate the productivity convergence regression, Instrumental Variables (IV) based on Anderson and Hsiao (1981) is the preferred method. This method controls for unobserved firm fixed-effects and endogenous bias on lagged productivity and distance to local frontier variables[6]. As a robustness check Ordinary Least Square (OLS) and Fixed-Effects estimation are also used.

4.2 Results

The results from different model specifications are shown in

[6] The Anderson-Hsiao method takes first-differencing to remove fixed-effects and uses lagged variables to correct endogenous variables. In this method, observations in the first two years of the data, 2000 and 2001, are excluded from regression analysis. There is an alternative IV method. It does not take first-differencing and uses lagged change variables to instrument endogenous variables.

Table 4-1. Columns 1 – 4 are derived using the specification in equation (4). The results in column 5 are based on the assumption of a long-run homogeneity relationship between frontier firms and laggard firms by omitting the lagged productivity level variable. Estimates shown in column 1 and 2 are based on OLS and fixed-effects respectively. Columns 3 – 5 are derived using the Instrumental Variables approach with the Anderson-Hsiao specification. Input weights are also applied to control for the impact of measurement errors from small firms. [7]

In all specifications the coefficients on the lagged productivity level are all statistically significant. This indicates that the long-run homogeneity assumption does not hold and should not be imposed on the productivity convergence model. In the case of assuming the long-run homogeneity relationship (column 5 in Table 2), coefficient estimates tend to be overestimated.

Coefficients on the distance to the local frontier and the distance between the local and national frontiers are always positive and statistically significant. This indicates that all else equal, firms that are further behind the local or national productivity frontier have faster rates of productivity growth.

In the preferred model specification (column 3), the speed of productivity convergence to the national and local frontiers are 0.1462 and 0.211 respectively.[8] Furthermore, coefficients on the distance to the local frontier are larger than coefficients for the distance between the local and national frontiers, indicating the productivity convergence to the local frontier is stronger than productivity convergence to the national frontier. These results are analogous to the U.K. study that find stronger convergence to the local productivity frontier than the national productivity frontier (Griffith et al., 2009). One possible mechanism underlying these results is that technology is relatively expensive to transmit over distance.

The coefficients on both the national and local frontier growth terms are also positive and significant in all specifications. That is, laggard firms in industries where the productivity growth of frontier firms is faster, experience faster productivity growth. In addition, firms with larger number of employees have faster productivity growth in the preferred model.

The estimation results in

[7] In Fabling and Maré (2015a) the input weights are equal to predicted values from the Trans-log production function.

[8] The speed of productivity convergence to the local frontier is equal to 0.3572 – 0.1462 =0.211, see column 3 in table 2.

Table 4-1 impose common coefficients across all firms. However, productivity convergence is likely to be industry specific, given that knowledge transfer may be easier in some parts of New Zealand's economy compared to others. To shed some light on any heterogeneity in productivity convergence across industries, equation (4) is estimated separately across 1-digit ANZSIC 2006 industries.

Table 4-1 Productivity convergence estimations

Variables	(1) OLS	(2) FE	(3) IV1	(4) IV2	(5) IV3
Productivity gap between NF and LF	0.0670***	0.2517***	0.1462***	0.1558***	0.3943***
	0.0109	0.0214	0.0213	0.0236	0.0175
Distance to local frontier	0.2191***	0.6615***	0.3572***	0.3591***	0.7602***
	0.0092	0.0241	0.0207	0.0233	0.0048
Lagged productivity level	-0.0847***	-0.6435***	-0.4012***	-0.4441***	
	0.0091	0.0214	0.0207	0.0234	
Changes in NF	0.1609***	0.1967***	0.1773***	0.1748***	0.3085***
	0.0127	0.0136	0.0150	0.0164	0.0132
Changes in LF	0.3748***	0.3310***	0.3248***	0.3056***	0.3989***
	0.0103	0.0113	0.0129	0.0143	0.0124
Age	0.0002***				
	0				
Firm size	0.0061***	-0.0092***	0.0201***	0.0251***	0.0200***
	0.0004	0.0011	0.0012	0.0020	0.0012
Speed of productivity convergence to the national frontier	0.0670	0.2517	0.1462	0.1558	0.3943
Speed of productivity convergence to the local frontier	0.1521	0.4098	0.2110	0.2033	0.3659
Observations	681,648	522,729	522,729	399,476	522,729
Adjusted R-square	0.1573	0.6527	0.5406	0.5441	0.5402
Weak instrument statistics			16500***	5468.07***	8253.2***
Over-identification statistics			0	463.25***	0

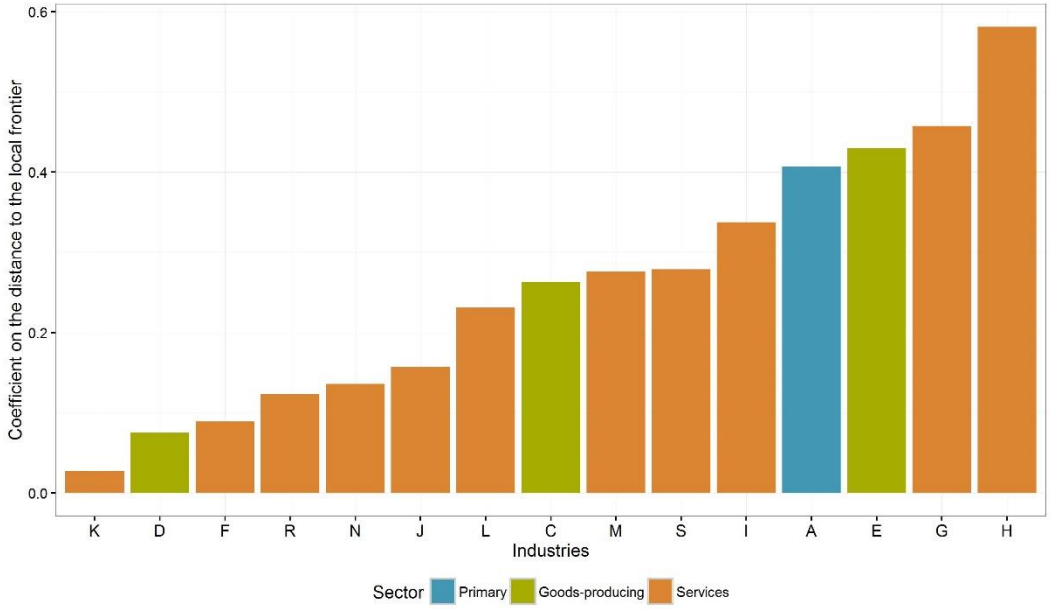
Source: Author's calculations using LBD

Notes:

1. Column 1 is OLS estimate and column 2 is fixed-effects with the differencing transformation. Column 3 - 5 are Instrumental Variable estimates. Instruments in column 3 are 2nd lagged productivity level and 1st lagged change of LF productivity. Instruments in column 4 are 2nd and 3rd lagged productivity level, 1st and 2nd lagged change of LF productivity. Instrument in column 5 is 2nd lagged productivity level.
2. Column 1 – 4 include lagged productivity level as a part of regressors to relax the assumption of the long-run homogeneity. Column 5 assumes the long-run homogeneity relationship.
3. Age variable is omitted from FE and IV due to collinearity.
4. Figures on the speed of productivity convergence to the national frontier equal to coefficients on productivity gap between NF and LF. Figures on the speed of productivity convergence to the local frontier equal to coefficients on distance to LF subtracted by coefficients on productivity gap between NF and LF.
5. Instrumental variable regressions are calculated under the ivreg2 procedure in Stata version 14 with general moment of methods.
6. Weak instrument statistics are F-statistics from Cragg-Donald based weak instrument tests. F statistics are greater than 5% of the significant level, suggesting instruments used IV are strong instruments
7. Over-identification statistics are J statistics from Sargan-Hansen tests. J statistics are greater than 5% of the significant level, suggesting instruments are correlated with the error term.

Figure 7 and Figure 8 show that productivity convergence to the local and national frontiers is indeed heterogeneous across industries.[9] In terms of productivity convergence to the local frontier, all 15 industries show positive signs of productivity catch-up over time. On the other hand, there are only nine industries that show positive signs of productivity convergence to the national frontier.

Figure 7 Speeds of productivity convergence to the local frontier

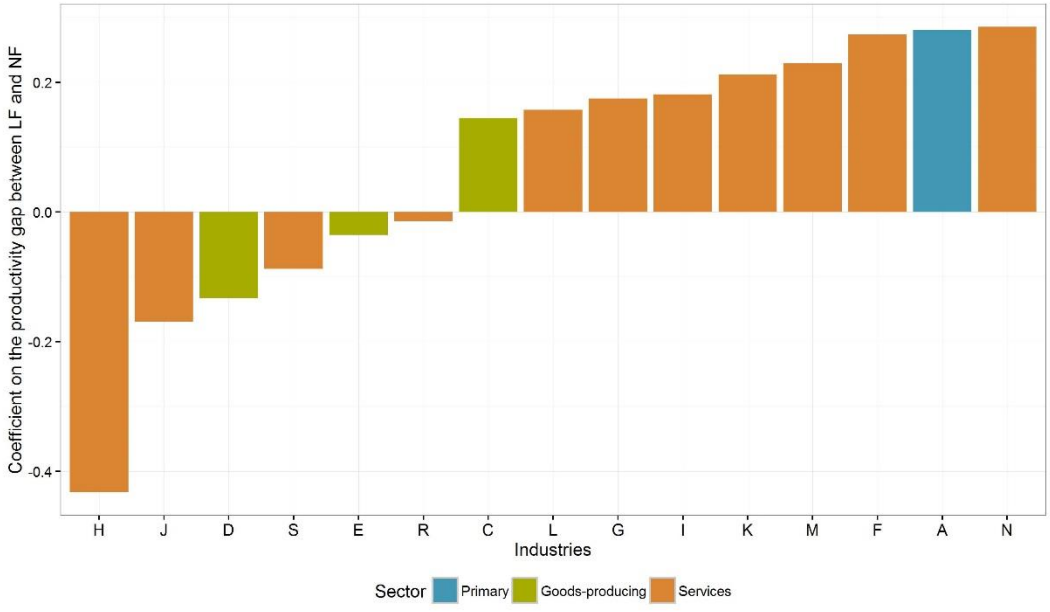


Source: Author's calculations using LBD

Notes:

1. Primary, goods-producing and service industries are colour-coded in blue, green and orange respectively.
2. Industry code A="Agriculture", C="Manufacturing", D="Electricity, gas and water supply", E="Construction", F="Wholesale trade", G="Retail trade", H="Accommodation and restaurants", I="Transport, postal and warehouse services", J="Media and Telecommunications", K="Finance and insurance", L="Real estate and rental services", M="Professional, scientific and technical services", N="Administrative and support services", R="Arts and recreation services", S="Other services"

Figure 8 Speeds of productivity convergence to the national frontier



Source: Author's calculations using LBD

[9] Detailed regression estimates are shown in Appendix A.

Notes:

1. Primary, goods-producing and service industries are colour-coded in blue, green and orange respectively
2. Industry code A="Agriculture", C="Manufacturing", D="Electricity, gas and water supply", E="Construction", F="Wholesale trade", G="Retail trade", H="Accommodation and restaurants", I="Transport, postal and warehouse services", J="Media and Telecommunications", K="Finance and insurance", L="Real estate and rental services", M="Professional, scientific and technical services", N="Administrative and support services", R="Arts and recreation services", S="Other services"

Among these 15 industries, eight industries show relatively strong productivity convergence to the local frontier but weak productivity convergence to the national frontier.[10] They include manufacturing; construction; retail trade; accommodation and restaurant; transport, postal and warehousing; information median and telecommunications; rental, hiring and real estate; and other services. These industries contribute 54 percent of total employment and 69 percent of total gross output in the private sector. In addition, firms in utility and recreation industries have very weak or no productivity catch-ups to any productivity frontiers. For the remaining industries, the national productivity frontier plays a big role for firm's productivity growth.

Table 4.2 Industry groups for productivity convergence

Classifications	Industries
Relatively weak productivity convergence to local and national frontiers	Utility (electricity, gas and water supply and waste management); Recreational services
Relatively strong productivity convergence to the national frontier, but weak or no productivity convergence to the local frontier	Wholesale trade; Finance and insurance; Administrative and support services
Relatively strong productivity convergence to the local frontier, but weak or no productivity convergence to the national frontier	Manufacturing; Construction; Retail trade; Accommodation and restaurant; Transport, postal and warehousing; Information median and telecommunications Rental, hiring and real estate; Other services
Relatively strong productivity convergence to national and local frontiers	Agriculture, forestry and fishing; Professional, scientific and technical services

Source: Author's calculations using LBD

Notes:

1. Relatively strong (weak) productivity convergence means the speed of productivity convergence for a particular industry is higher (lower) than the economy-wide productivity convergence. The economy-wide productivity convergence is based on results shown in column 3 in table 2.

5 Discussion

5.1 Productivity convergence and geographic proximity

In the previous section, the speed of productivity convergence to the local frontier is stronger than the speed of productivity convergence to the national frontier. This is consistent with findings in the UK study by Griffith et al. (2009). Also, the analysis in this paper is broadly analogous to cross country studies which examine speeds of productivity convergence to the global and domestic frontier.

[10] Relatively strong (weak) productivity convergence means the speed of productivity convergence for a particular industry is higher (lower) than the economy-wide productivity convergence. The economy-wide productivity convergence is based on results shown in column 3 in table 2

Bartelsman, Haskel, and Martin (2008) and Andrews et al. (2015) use firm-level data from selected OECD countries and find that domestic firms are more attracted towards their national productivity frontiers as opposed to the international frontier in their industry. All this evidence points to an important feature of knowledge diffusion - knowledge diffusion tends to be geographically localised to an important extent.

Knowledge is an intangible asset which creates a substantial part of the value added of business. Accordingly, learning is important in determining the success of firms. Knowledge is often embodied in workers and capital and is often tacit and non-codified. Unlike codified knowledge that can be easily transmitted over distance, tacit knowledge can only be transferred through direct interactions (Foray & Lundvall, 1997). Because learning and knowledge adoption often involves interactions between individuals, geographic distance can matter in the sense that the cost of setting up and maintaining interactions is likely to rise with the distance between the source and recipient of knowledge.

5.2 Productivity convergence and domestic tradability

The extent of knowledge diffusion differs by industries. Among a number of other factors, this may reflect differences in the extent to which firms in different industries trade their output over distance within the domestic economy.

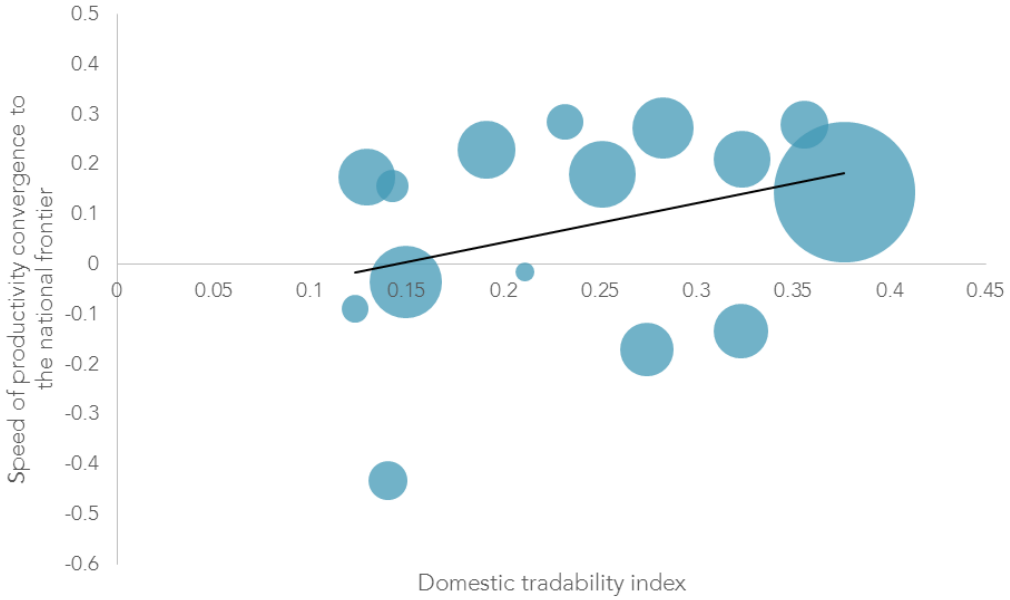
Conway and Zheng (2014) applied the methodology developed by Jensen, Kletzer, Bernstein, and Feenstra (2005) to New Zealand and measured the extent to which industries trade their output outside of the local labour market in which they are located. They used regional employment and population data in conjunction with the input-output table and compared the geographic concentration of firms with the spatial distribution of demand for their output from downstream customers. The general idea is that if an industry is geographically concentrated in one location and sells its output to a downstream customers that are largely located in other locations, then the output of that industry is assessed as being relatively tradable.

Industries selling output that is relatively more tradable have very different characteristics compared to industries that trade their output locally. Firms in industries that trade their output across regions within New Zealand are likely to be bigger, more productive, geographically agglomerated and more likely to export (Conway & Zheng, 2014). In contrast, firms in industries that sell non-tradable output tend to be smaller, less productive and geographically dispersed reflecting the distribution of their customers.

The extent to which output is traded over distance may also influence a firm's incentives to adopt new knowledge and technology. Indeed, Figure 9 shows a positive relationship between the speed of convergence to the national frontier and domestic tradability across industries. Figure 10 shows a negative relationship between the speed of productivity convergence to the local frontier and domestic tradability. On the face of it, these indicative relationships tentatively suggest that the national frontier exerts a greater pull on firm's performance in domestically tradable industries, while firms in non-tradable industries are more attracted to the local frontier.[11]

[11] Domestic tradability is static over time and cannot be used for convergence regression models as it is treated as firm's fixed-effects.

Figure 9 Convergence to the national frontier and domestic tradability

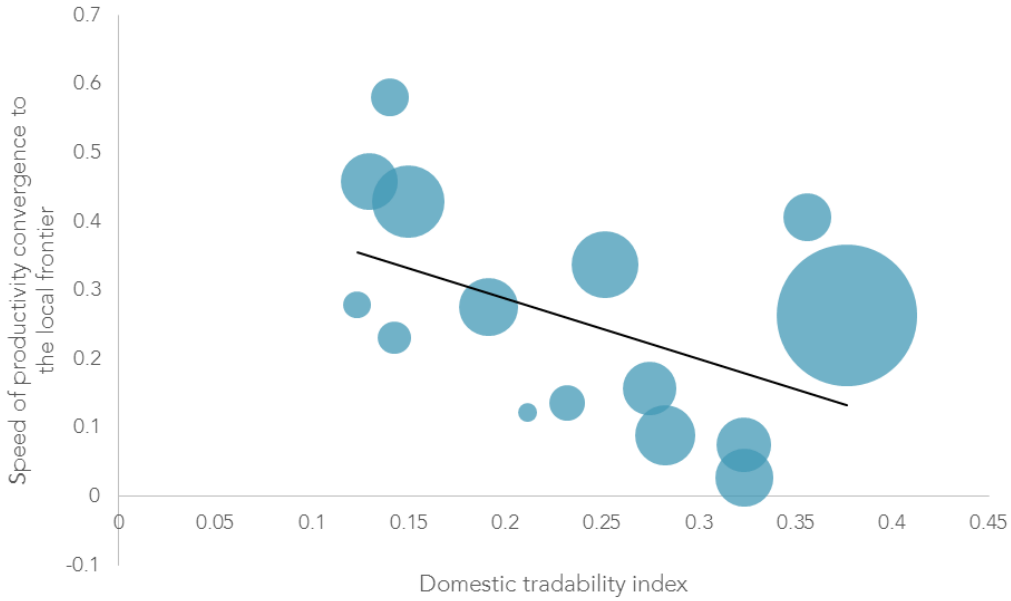


Source: Author's calculations using LBD

Notes:

1. Size of dot represents industry contribution to New Zealand's gross output.
2. The black solid line represents the best fitted line from a weighted linear regression.

Figure 10 Convergence to the local frontier and domestic tradability



Source: Author's calculations using LBD

Notes:

1. Size of dot represents industry contribution to New Zealand's gross output
2. The black solid line represents the best fitted line from a weighted linear regression.

6 Conclusion

In this paper, the extent of knowledge diffusion within the New Zealand economy has been estimated across broad industries using the Longitudinal Business Database. The main finding shows that productivity convergence to both the national and local productivity frontiers are statistically and economically significant, indicating that knowledge diffuses within and across regions.

The speed of convergence to the local frontier is greater than the speed of convergence to the national frontier. This indicates that geographic proximity is important in the diffusion of technology. One possible reason is that much information and technical know-how is tacit and non-codifiable. Geographic proximity facilitates information exchange between firms and enhances the capability of firms to absorb tacit technology.

Results also show that the speed of productivity convergence towards the national and local frontiers differs across industries. One possible explanation for this is that firms that trade their output over different sized markets will have different levels of exposure to technology and different incentives to adopt technology. On the face of it, results tentatively suggest that firms in domestically tradable industries have greater motivation to adopt advanced technology from the national productivity frontier, but firms in domestically non-tradable industries tend to learn from the best local firms.

References

Anderson, T. W., & Hsiao, C. (1981). Estimation of dynamic models with error components. *Journal of the American statistical Association, 76*(375), 598-606.

Andrews, D., Criscuolo, C., & Gal, P. (2015). Frontier Firms, Technology Diffusion and Public Policy: Micro Evidence from OECD Countries: OECD Mimeo.

Bartelsman, E., Haskel, J., & Martin, R. (2008). Distance to Which Frontier? *Evidence on productivity convergence from international firm-level data. Centre for Economic Policy Research Discussion Paper Series*(7032).

Boschma, R. (2005). Proximity and innovation: a critical assessment. *Regional studies, 39*(1), 61-74.

Caniëls, M. C. (2000). Knowledge spillovers and economic growth. *Books*.

Conway, P., Meehan, L., & Zheng, G. (2015). Do New Zealand firms catch up to the domestic productivity frontier?

Conway, P., & Zheng, G. (2014). Trade over distance for New Zealand firms: measurement and implications.

Corrado, C. A., Haskel, J., & Jona Lasinio, C. (2014). Knowledge spillovers, ICT and productivity growth.

Fabling, R., & Maré, D. (2015a). Addressing the absence of hours information in linked employer-employee data. *2015-17*.

Fabling, R., & Maré, D. (2015b). Production function estimation using New Zealand's longitudinal business database.

Fabling, R., & Sanderson, L. (2014). Productivity distributions in New Zealand: The dangers of international comparisons *Motu research*.

Fabling, R., & Sanderson, L. (2016). A Rough Guide to New Zealand's Longitudinal Business Database. *Available at SSRN*.

Foray, D., & Lundvall, B. (1997). The knowledge based economy. *OCDE, Paris*.

Griffith, R., Redding, S., & Simpson, H. (2009). Technological catch-up and geographic proximity. *Journal of Regional Science, 49*(4), 689-720. doi: 10.1111/j.1467-9787.2009.00630.x

Jensen, J. B., Kletzer, L. G., Bernstein, J., & Feenstra, R. C. (2005). *Tradable services: Understanding the scope and impact of services offshoring [with comments and discussion].* Paper presented at the Brookings trade forum.

Maré, D. C., Hyslop, D., & Fabling, R. (2015). Firm productivity growth and skill. *Available at SSRN*.

Papps, K. L., & Newell, J. O. (2002). Identifying Functional Labor Market Areas in New Zealand: A Reconnaissance Study Using Travel-to-Work Data.

Stabler, J. C., Olfert, M., & Greuel, J. B. (1996). Spatial labor markets and the rural labor force. *Growth and change, 27*(2), 206-230.

Appendix A Additional regression output

This section provides detailed instrumental variables regression estimates to correspond with the graphs in Figure 7 and Figure 8.

Table A.1 Productivity convergence estimates at the one-digit industry level

Variable	Agriculture, Forestry and Fishing	Manufactur-ing	Electricity, Gas, Water and Waste Services	Construction	Wholesale Trade	Retail Trade	Accommoda tion and Food services	Transport, Postal and Warehous-ing	Information media and Telecommun -ications	Financial and Insurance Services	Rental, Hiring and Real Estate Services	Professional, Scientific and Technical Services	Administra-tive and Support Services	Arts and Recreation Services	Other services
Productivity gap between NF and LF	0.2804	0.1449	-0.1332	-0.0357	0.2733	0.1746	-0.4323	0.1811	-0.1692	0.2117	0.1573	0.2292	0.0.2852	-0.0144	-0.0879
	0.0615	0.0467	0.0669	0.0498	0.0557	0.0587	0.0924	0.0660	0.1686	0.0784	0.0630	0.0652	0.0766	0.1186	0.0731
Distance to LF	0.6870	0.4079	-0.058	0.3940	0.3625	0.6323	0.1486	0.5184	-0.0121	0.2392	0.3883	0.5053	0.4210	0.1086	0.1910
	0.0490	0.0585	0.0806	0.0587	0.0461	0.0680	0.1147	0.0942	0.1852	0.0746	0.0561	0.0600	0.0685	0.1381	0.0697
Lagged productivity level	-0.0552	-0.3770	-0.8507	-0.3928	-0.4221	-0.1843	-0.6264	-0.2143	-0.6182	-0.4230	-0.3256	-0.2224	-0.2655	-0.6795	-0.5876
	0.0456	0.0576	0.0887	0.0587	0.0447	0.0679	0.1139	0.0966	0.1878	0.0707	0.0543	0.0592	0.0688	0.1420	0.0697
Changes in NF	0.5228	0.2092	-0.0377	0.0669	0.4373	0.2340	-0.2370	0.2964	-0.1051	0.2296	0.1520	0.2227	0.4426	0.0244	0.2805
	0.0456	0.033	0.0404	0.0336	0.0428	0.0565	0.0632	0.0646	0.1064	0.0582	0.0556	0.0413	0.0731	0.0847	0.0519
Changes in LF	0.8046	0.2652	0.1249	0.3891	0.2464	0.4720	0.5728	0.2534	0.1347	0.1169	0.2748	0.3459	1643	0.1719	0.2858
	0.0321	0.0386	0.0502	0.0361	0.0476	0.0516	0.0589	0.0548	0.0477	0.0469	0.0368	0.0444	0.0374	0.0105	0.0447
Firm size	0.0339	0.0113	0.021	-0.0029	0.0168	0.0250	0.0138	0.0289	0.0557	0.0417	0.0195	0.0277	0.0232	0.0240	0.0201

Variable	Agriculture, Forestry and Fishing	Manufactur-ing	Electricity, Gas, Water and Waste Services	Construction	Wholesale Trade	Retail Trade	Accommoda tion and Food services	Transport, Postal and Warehous-ing	Information media and Telecommun -ications	Financial and Insurance Services	Rental, Hiring and Real Estate Services	Professional, Scientific and Technical Services	Administra-tive and Support Services	Arts and Recreation Services	Other services
	0.0039	0.0033	0.0132	0.0026	0.0057	0.0036	0.0026	0.0058	0.0136	0.0147	0.0076	0.0047	0.0060	0.0150	0.0040
Speed of productivity convergence to the national frontier	0.2804	0.1449	-0.1332	-0.0357	0.2733	0.1746	-0.4323	0.1811	-0.1692	0.2117	0.1573	0.2292	0.0.2852	-0.0144	-0.0879
Speed of productivity convergence to the local frontier	0.4066	0.2630	0.0752	0.4297	0.0892	0.4577	0.5809	0.3373	0.1571	0.0275	0.2310	0.2761	0.1358	0.1230	0.2789
Firm counts	69,423	65,697	2,115	65,913	38,508	71,823	48,027	20,271	4,263	9,054	14,919	48,366	18,753	6,012	39,603
Adjusted R-square	0.5510	0.5485	0.5617	0.5567	0.5543	0.5458	0.5218	0.5276	0.4686	0.4941	0.5198	0.5340	0.5140	0.5546	0.5588
Weak instrument statistics	1815.7	606.6	18.6	1574.7	967.8	1840.4	1053.3	195.1	19.6	217.2	331.8	813.1	353.2	104.8	791.9

Source: Author's calculations using LBD

Notes:

1. Regression estimates are based on the Andersion-Hsiao method
2. The critical value at 10% statistical significance for weak instrument identification tests is 7.03. Instrumental variables are strong instruments when weak instrument statistics are greater than the critical value.
3. Figures on the speed of productivity convergence to the national frontier equal to coefficients on productivity gap between NF and LF. Figures on the speed of productivity convergence to the local frontier equal to coefficients on distance to LF subtracted by coefficients on productivity gap between NF and LF.