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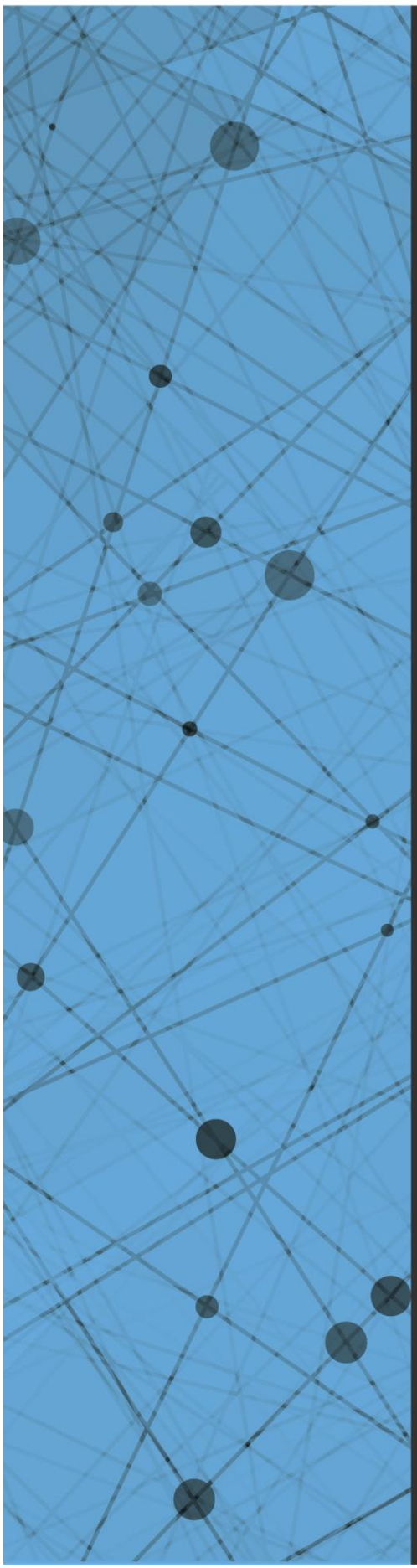

Absorptive capacity in New Zealand firms: Measurement and importance

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Abstract

To the best of our knowledge, this paper reports the first set of nationally representative results on the importance of 'absorptive capacity'. Absorptive capacity is generally defined as a firm's ability to internalise external knowledge. Using data principally from the New Zealand Business Operations Survey, we measure absorptive capacity across a 10-year period and investigate if it remains stable in the long term. This is followed by considering how firms' characteristics vary across levels of absorptive capacity and most importantly whether such capacity determines firms' productivity performance across the primary, manufacturing and service sectors. Our results show that relative to other influences, absorptive capacity as measured here has a substantial influence on exporting, innovation, and undertaking R&D. Set against relatively poor performance, the paper concludes with a discussion of how government should consider helping firms to boost their levels of absorptive capacity.

JEL codes

L25; O24; O32; R11

Keywords

Exports; R&D; innovation; absorptive capacity

Summary haiku

Internalising
knowledge from outside the firm
is key to success.

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1 Introduction

To the best of our knowledge, this paper reports the first set of nationally representative results on the importance of 'absorptive capacity' (generally defined as the ability to internalise external knowledge) for firms. Like the ability of an individual to learn, absorptive capacity involves firms being able to benefit from spillovers but more importantly using knowledge from the external environment to improve their productivity. If firms are not able to learn, then new strategies or technology designed to help firms become more productive are likely to have only limited impact.

This also has important consequences for policy initiatives like the new industrial strategies that are coming back into vogue in many economies. Firms with low absorptive capacity are likely to benefit in a limited way from such initiatives.[1] Between 2012 and 2017, the main form of assistance to firms in New Zealand was through its 'Business Growth Agenda' (BGA, 2012),[2] with the major aim of "… building a stronger economy by creating conditions for firms to be more productive and internationally competitive." (BGA, op. cit., p.1).

However, this needs to be set against what actually happened with productivity (OECD, 2017), suggesting that the BGA may have delivered on many things, but this did not coincide with an improvement in NZ (labour) productivity (indeed there was further lost ground during 2012-2016 that now needs to be made up). That is, a key question for policymakers is whether the BGA agenda was *sufficient* for delivering on productivity, given that its initiatives were more about setting the right macro-environment and/or influencing the business environment, and not *directly* about helping firms achieve higher absorptive capacity, which this paper shows is very important. Although the BGA stated that it was about "… ensuring that businesses with smart ideas have support, capability, and connections they need to succeed…" it also recognised the ongoing need for "… evaluating our programmes to make sure they deliver the best value for money in the long run" (p. 27 of BGA, 2017).

Using data from the NZ Business Operation Survey (2005-2015), this paper aims to understand the different elements that constitute absorptive capacity, to examine how the impact of firms' characteristics varies across levels of absorptive capacity, and to investigate the impact of absorptive capacity on the propensity of firms to innovate, undertake R&D, and

[1] This raises the important topic, to which we return below, as to whether government policy should help firms directly to increase their own absorptive capacity – i.e., policy should centre on help to the firm - or should the emphasis be on improving the flow of (local) knowledge through supporting networks, given that the latter may be a major source of knowledge spillovers?

[2] The incoming 2017 New Zealand Government has indicated that it will be developing a new approach to policy; at the time of writing, this was still under development.

export. This is followed by a broader discussion of how government policy might be refreshed to have a more direct impact on increasing absorptive capacity. This is in order to suggest avenues that may increase the number of firms exporting, undertaking R&D and innovating – all which are known to be key drivers of productivity.

In the next section, we overview the causes of New Zealand's productivity problem as identified by the Productivity Commission, as well as past industrial policy in New Zealand (the BGA and its constituent parts). Next, we discuss the concept of absorptive capacity briefly and how we measure it. Section 4 describes the data used, and our measures of absorptive capacity, including which firms have higher levels, and whether these persist over time. The main results are then presented, showing how higher absorptive capacity coincides with higher exporting, R&D and innovation. In presenting these results we separate primary, manufacturing and services firms. The paper concludes by returning to the question of whether policy (cf. the BGA) did enough to build sufficient absorptive capacity to help boost productivity – which is vital to long run growth – and if not, how should policy now change (and in which direction)?

2 Low productivity and industrial policy in New Zealand

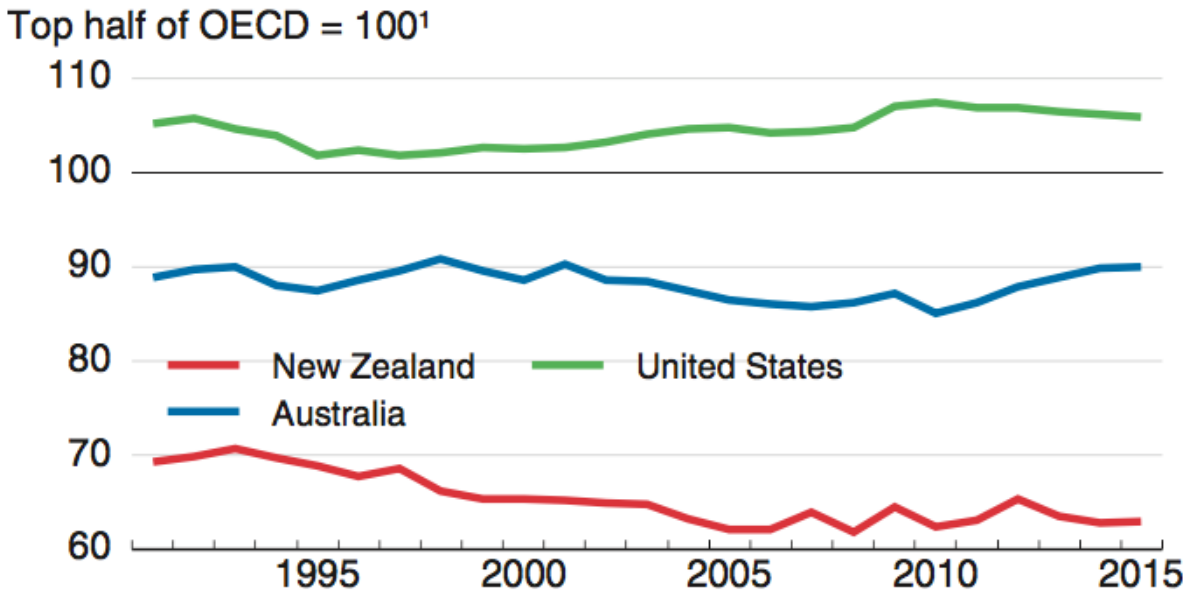
This section begins with a short overview of how productivity compares in New Zealand vis-à-vis other OECD countries, as well as discussing some of the recent analysis that has been undertaken to understand the nature of the 'productivity problem', and its causes. Figure 1 shows clearly that New Zealand underperformed compared to similar developed OECD countries, and in particular its nearest geographical rival Australia.

The main reasons for this underperformance have been summarised in Conway (2016). A key reason is barriers to diffusing best-practice technology to (smaller) domestic firms in New Zealand. This relates to inadequate stocks of knowledge-based intangible assets in these firms (such as management know-how and innovation capacity). It is also linked to the limitations placed on firms due to market size and geography. New Zealand is small and located far from large international markets, making exporting and (outward and inward) foreign direct investment (FDI) relatively more important for overcoming these limitations. Internationalisation generally requires higher productivity pre-entry into overseas markets, which itself is linked to the need for higher investment in intangible assets (absorptive capacity). And foreign-owned firms, whilst having higher productivity, have less of an impact than expected on increasing productivity in domestic New Zealand firms through spillovers, again because of inadequate knowledge-based intangible assets (and thus absorptive capacity) – see MBIE (2014), Doan, Mare and Iyer (2015) and Conway, Meehan and Zheng (2015) for evidence. In general, New Zealand has a low level of business investment in R&D (as a

percentage of GDP) compared to most other OECD countries – in 2015 the figures were 0.64% (New Zealand), 1.65% (OECD average), 1.19% (Australia), and 1.99% (USA). Firms in New Zealand tend to have limited connectivity with (domestic) research institutions, and in general limited international connections, which Wakeman and Le (2015) show to be very important in determining innovation. Again, poorer absorptive capacity linked to investment in intangible assets is deemed to be a major factor in determining low rates of connectivity. Lastly, management capability is also found to be underdeveloped (e.g., Green et al., 2011, found that there is a substantial tail of mediocre and poorly-managed firms in New Zealand); while to boost productivity requires an "all-of-firm innovation mind-set to lift the capability of firms to absorb new technology and maximise its benefits … working on the business is just as important as developing new and improved products" (Conway, 2016, p. 48).

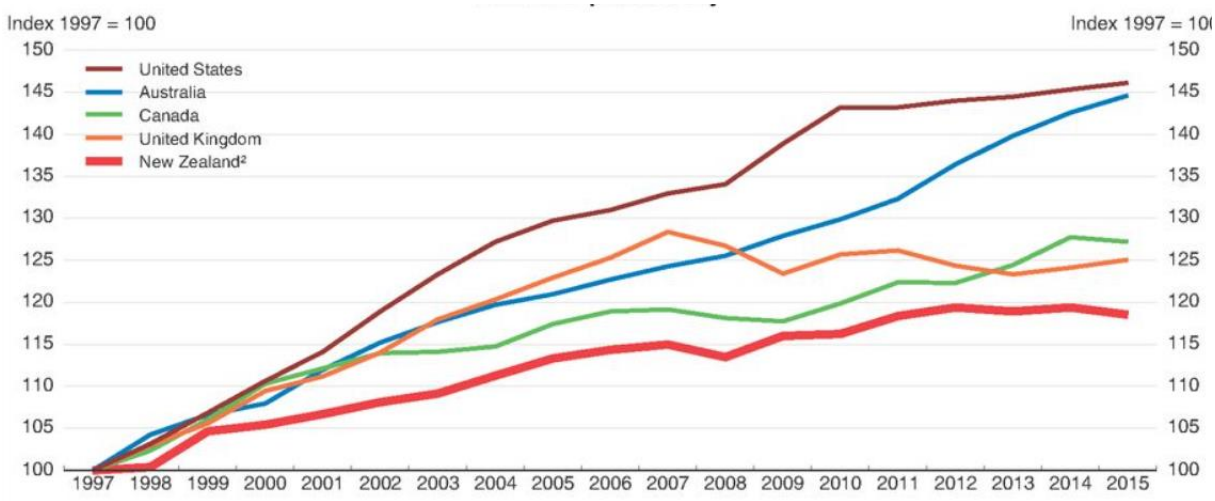
Figure 1: Labour productivity in New Zealand: whole economy and business sector

Whole economy



Population-weighted average for the top 17 OECD countries for labour productivity, calculated using 2010 purchasing power parity exchange rates.

Business sector



Source: OECD (2017) Figures 1.1 and 1.4

The above suggests that a lack of investment in intangible assets – and thus lower absorptive capacity – is likely to be a major reason for New Zealand's productivity problem. This has not yet, however, been reflected in how policymakers attempt to solve the problem. Until recently the major approach to helping New Zealand firms was through the operation of the Business Growth Agenda (BGA, 2012), which concentrated on building up:

1. export markets,
2. business investment (including inward and outward FDI),
3. innovation,
4. skilled and safe workplaces,
5. natural resources, and
6. infrastructure.

A major part of the BGA was about setting the right macro-environment and/or influencing the business environment, and not directly about helping firms. This assertion is supported by looking at the list of projects being undertaken in 2017 to support the BGA (see MBIE, 2017). Only a few were designed specifically to assist firms.[3] Thus, when discussing how to build innovation the "… main focus is on improving the system – making sure that our regulations, funding and infrastructure support businesses to grow and innovate, and our education and training systems provide our people with skills and capability" (BGA, 2017, p. 29).

[3] Some examples of such firm-orientated projects were: to grow the number of companies that received 'client-managed' assistance from New Zealand Trade and Enterprise (NZTE) from 500 to 700; increase the number of high value manufacturing and services firms engaged in business improvement schemes (e.g., 'Better by Design', 'Better by Lean'); attract more inward investment by firms willing to conduct R&D in New Zealand (especially in innovation hubs); increase R&D grant availability to firms (and develop Callaghan Innovation tasked with building innovation capabilities).

3 Defining and measuring absorptive capacity

The concept of absorptive capacity is related to the role and use of intangible assets (which can be defined as knowledge embodied in intellectual assets).[4] Intangible assets are recognised as a key driver of enterprise performance (e.g., Eustace, 2000; Corrado *et. al.*, 2011; Haskel, 2015) and thus, ultimately, aggregate productivity. Their role derives from the 'resource-based' theory of the firm (e.g., Penrose, 1959; Barney, 1991; Kogut and Zander, 1996; Teece *et. al.*, 1997). However, there are significant difficulties in measuring these assets (OECD, 2006), both from a theoretical and empirical standpoint. In addition, building intangible assets requires that firms understand how to create new knowledge from the resources they possess (see Harris and Moffat, 2013, section 2 for a discussion). Through a combination of organisational routines and processes, firms must apprehend, acquire, share, assimilate, transform and exploit new knowledge in order to compete and grow in markets.[5] This ability to exploit internal and especially external knowledge is a critical component of a firm's capabilities and it constitutes the firm's "absorptive capacity" (Zahra and George, 2002).

Absorptive capacity starts from firms wanting to absorb external knowledge, but the ability of the firm to understand external knowledge, to assimilate it, to transform it, and to apply it, depends on the level of its prior (stock of) knowledge. This presupposes the firm having invested in its own internal absorptive capacity, which, in turn, is often associated with the firm's own internal R&D and/or human capital[6] (Cohen and Levinthal, 1989, 1990; Mowery et. al., 1996; Stock et. al., 2001; Carayannis and Alexander, 2002; Todorova and Durisin, 2007; Tsai, 2009). Thus, acquisition of internal and external knowledge is complementary (and indeed they are interrelated and both are necessary – Veugelers, 1997; Teece, 2000; Caloghirou et. al., 2004; Garcia-Morales et. al., 2007).

In terms of defining the latent variable absorptive capacity, it is often stated that "no single (definition) is superior to all others, under all circumstances" (Escribano et. al., 2009, p. 99). The original definition by Cohen and Levinthal (1989) defines absorptive capacity as the ability of the firm to learn from external knowledge through the processes of knowledge identification, assimilation and exploitation. R&D and/or measures of human capital were deemed sufficient as proxies. Zahra and George (2002) more precisely link the construct to a set of organisational routines and strategic processes through which firms acquire, assimilate,

[4] Indeed firms that internalise external knowledge are both using and adding to their stock of intangible assets.
[5] Garcia-Morales et. al. (2007) set out in more detail what it means to acquire, assimilate, transform, and exploit (see especially p. 531). In particular, they note that "absorptive capacity is a dynamic capability that influences the firm's ability to create and deploy the knowledge necessary to build other organisational capabilities [i.e. other intangible assets]" (p. 528; note the text in parenthesis has been added to the original); in this sense absorptive capacity is itself an intangible asset.
[6] Muscio (2007) stresses the importance of human capital over (formal) R&D in the case of SMEs.

transform and apply knowledge with the aim of creating their dynamic organisational capacity.[7] Their approach to measurement (and those of others such as Todorova and Durisin, 2007) is to try to identify, quasi-theoretically, the components of absorptive capacity rather than use a proxy like R&D and/or human capital for the construct. Instead, firms are typically asked to rank a series of statements relating to their self-assessed ability to search and obtain external information (acquisition), to use information internally (assimilation), to structure and link new information to existing knowledge (transformation), and to adapt existing technologies using new information (exploitation).[8] In most instances the numerically ranked answers are then used with factor analysis to obtain a smaller number of principal component indices that combine and represent the survey data collected. This approach is based on accurately identifying the processes firms adopt in internalising external knowledge, linking them to separate components of absorptive capacity, and then adequately measuring them. It assumes that researchers have enough information to develop adequate statements capturing the processes, and that firms have the ability to consistently rank these statements in an objective and accurate manner.

In contrast, the approach used in the present study is based on Harris and Li (2009) and Harris and Yan (2017), using nationally representative data from the firm-level NZ Business Operation Survey (2005-2015).[9]

The advantage of using BOS data is that firms are asked to report information on key elements of organisational learning and networking processes (i.e. external sources of knowledge or information used in innovation activities and their importance[10]; partnerships with external bodies on innovation co-operation[11]; and the introduction of any changes in

[7] This is similar to creating 'dynamic capabilities' (Teece, 2007, 2012; and Teece et. al., 1997), which we return to below.

[8] Good examples of this type of approach are provided by Flatten et. al. (2015, Appendix A), Camisón and Forés (2010, Appendix A), and Cho (2014, Table 1).

[9] BOS is a large-scale business sample survey that has been conducted annually by Statistics New Zealand since 2005. The target population for BOS is all businesses in New Zealand that have at least six employees, and have been active for at least one year. The sample design is a two-level stratification according to Australian and New Zealand Standard Industrial Classification (ANZSIC) industry and employment size groups. The first level of stratification is 36 ANZSIC groupings. Within each of the ANZSIC groups there is a further stratification by four employment size groups, namely 6–19 employees (small), 20–29 employees (medium 1), 30–49 employees (medium 2), and 50 or more employees (large). Each BOS survey always includes a module A that asks general questions on business operations, plus typically two specialised modules. Module B alternates between innovation (odd years) and business use of Information and Communication Technology (even years), while module C is a contestable, sponsored annually by various government departments. The biennial Module B, designed in accordance with the Oslo manual guidelines (OECD and Eurostat 2005) is the main survey instrument for the collection of innovation data in New Zealand. This study uses data from module A and module B of odd years (see http://www.stats.govt.nz/browse_for_stats/businesses/business_growth_and_innovation/BusinessOperationsSurvey_HOTP2015.aspx).

[10] See Q.20 in the BOS Innovation Module where firms are asked to identify the sources of ideas or information important to innovation activity, starting with suppliers, customers, and competitors through to technical publications.

[11] See Q.23 in the BOS Innovation Module where firms state if they cooperated with suppliers, customers, competitors, through to research institutes at the following locations: 'New Zealand'' or 'overseas'. From this we

organisational or management processes and/or new marketing methods[12]), all of which can be related to the use of external knowledge and developing internal capabilities and thus absorptive capacity. Such data are objective in that firms are asked to state if certain activities are taking place (rather than, for example, ranking their self-assessed ability to search, obtain and use information and adapt existing technologies using such new information). It is also more generalisable since it is obtained from large datasets covering many countries and for significant time periods (e.g., the European Community Innovation Survey[13] asks broadly similar questions, allowing for comparisons between countries and variations over time).

Using factor analysis, Appendix Table 1 shows the results based on pooled data from BOS 2005-15 (the results from a year-by-year analysis are very similar, confirming the validity of the approach). The numbers in the first five columns of data show the correlations (greater than 0.5) between the principle component factors extracted (these are continuous variables with a mean of 0 and standard deviation of 1 and comprise measures of absorptive capacity capturing the firm's capacity to exploit external sources of knowledge and build up partnerships with other enterprises or institutions at both the national and international level) and the underlying data from which they are derived. The factor analysis was then confirmed by estimating a structural equation model (SEM), which also included 24 covariances between the endogenous variables modelled. The results are presented in Table 1[14] (Appendix Table 4 provides the equation-level goodness of fit statistics for the SEM model suggesting the model is appropriately specified).[15] The absorptive capacity indices based on the SEM model are preferred, since they allow for a residual term in constructing each latent variable, and they also consider covariances between endogenous variables.

Based on the SEM model, the correlation between each individual index and the overall index of absorptive capacity (derived from the underlying indices – see the structural part of the model in Table 1) is 0.80, 0.87, 0.78, 0.37 and 0.81 for 'external knowledge' 'national cooperation with business', 'links with national researchers', 'international cooperation with researchers', and 'international cooperation with business', respectively (see Appendix Table 5).

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could identify different cooperation arrangements (coded 1 if present, 0 otherwise) at the national and international level.

[12] See Q.10 and Q.12 in the BOS Innovation Module.

[13] For example, see https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/558476/UKIS_2015_Final_version_of_the_questionnaire.pdf.

[14] Again estimating the model year-by-year produces very similar results. Note also, the SEM maps the impact of the overall index of absorptive capacity on (0/1) dummy variables that indicate whether the firm exported, undertook R&D or innovated, showing that there was a strong relationship (especially for doing R&D and innovating).

[15] In terms of the results from the SEM model and the approach based on factor analysis, the correlation between each individual index of absorptive capacity is high (>=0.77 – see the figures in italics in Appendix Table 5).

Table 1: (Weighted) SEM model of absorptive capacity, NZ, 2005-15 (6 waves covering every other year)

Standardised	$\hat{\beta}$	Z-value
Structural		
External knowledge ← Absorptive capacity	0.669	28.9
National cooperation with business ← Absorptive capacity	0.716	16.5
Links with national researchers ← Absorptive capacity	0.612	12.7
International cooperation with researchers ← Absorptive capacity	0.252	8.7
International cooperation with business ← Absorptive capacity	0.630	13.1
Measurement		
Customers ← External knowledge	0.685	38.8
Suppliers ← External knowledge	0.647	46.2
Other businesses ← External knowledge	0.681	56.2
Professional advisors, consultants, banks or accountants ← External knowledge	0.644	72.3
Books, journals, patent disclosures or Internet ← External knowledge	0.676	74.4
Conferences, trade shows or exhibitions ← External knowledge	0.690	103.0
Industry or employer organisations ← External knowledge	0.604	56.5
New organisational or managerial processes ← External knowledge	0.537	75.3
New marketing methods ← External knowledge	0.530	30.2
National customers ← National cooperation with business	0.774	62.9
National suppliers ← National cooperation with business	0.799	44.0
Other national businesses ← National cooperation with business	0.733	79.6
Source of knowledge: universities or polytechnics ← Links with national researchers	0.550	31.1
Source of knowledge: crown research institutes, other research institutes/associations ← Links with national researchers	0.365	12.7
Source of knowledge: government agencies ← Links with national researchers	0.547	20.9
Co-operation with national universities or polytechnics ← Links with national researchers	0.511	16.1
Co-operation with national crown research institutes, other research institutes/associations ← Links with national researchers	0.400	12.9
International universities or polytechnics ← International cooperation with researchers	0.840	21.3
International crown research institutes, other research institutes/associations ← International cooperation with researchers	0.821	18.7
International customers ← International cooperation with business	0.477	19.1
International suppliers ← International cooperation with business	0.567	18.4
Other international businesses ← International cooperation with business	0.688	14.7
Export ← Absorptive capacity	0.166	8.5
R&D ← Absorptive capacity	0.353	21.7
Innovation ← Absorptive capacity	0.467	20.9
(unweighted, randomly rounded to base 3) N	31,983	
Log pseudo-likelihood	69,823,372	

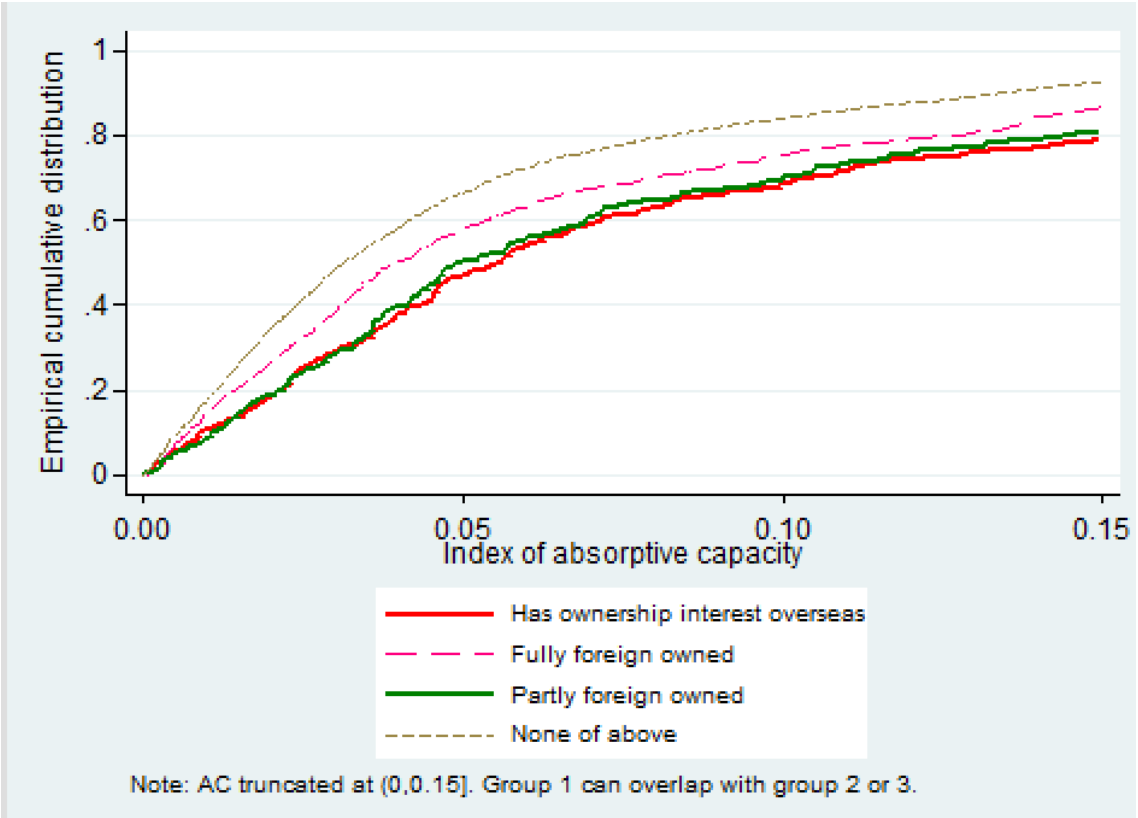
Note: Standard errors adjusted for 182 clusters. 24 covariances between endogenous variables modelled but not reported. Also estimates of the constant for each endogenous relationship are not reported.

4 Which NZ firms have higher levels of absorptive capacity?

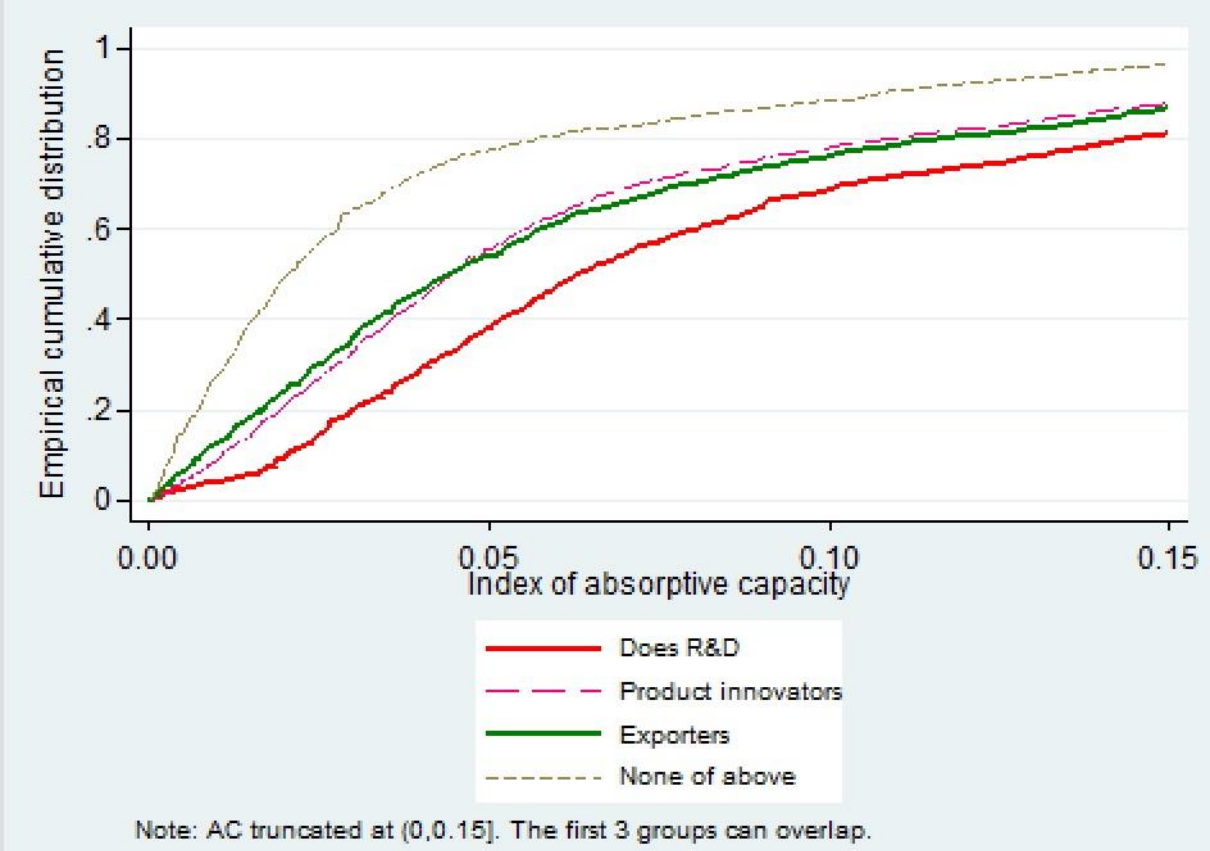
Figure 2 shows the cumulative distribution of the absorptive capacity index (obtained from the SEM model) separately for firms with a range of different characteristics. Firms with overseas interests (New Zealand multinationals) generally had higher absorptive capacity throughout (their distribution lies to the right of the distributions of other sub-groups, see panel a). Next highest were partly-foreign owned firms (less than 100% foreign ownership) and then fully-foreign owned firms. Finally, domestic firms had the lowest levels of absorptive capacity. Panel b shows that firms that undertook R&D had the highest levels of absorptive capacity, followed by innovators/exporters. These firms ranked significantly above those that did none of these activities. Larger firms had higher absorptive capacity (panel c), while firms employing greater relative numbers of professionals, managers, technicians and associate professional staff (and thus an overall higher stock of human capital) had significantly better absorptive capacity levels (panel d). Panel e shows that firms primarily engaged in manufacturing performed the best, followed firms engaged in services, while the primary sector (dominated by agriculture) tended to have lower absorptive capacity. A wider set of results based on a more detailed set of establishment-level characteristics are presented in Table 2.

Figure 2: (Weighted) Absorptive capacity indices by various firm characteristics, New Zealand, 2005-2015

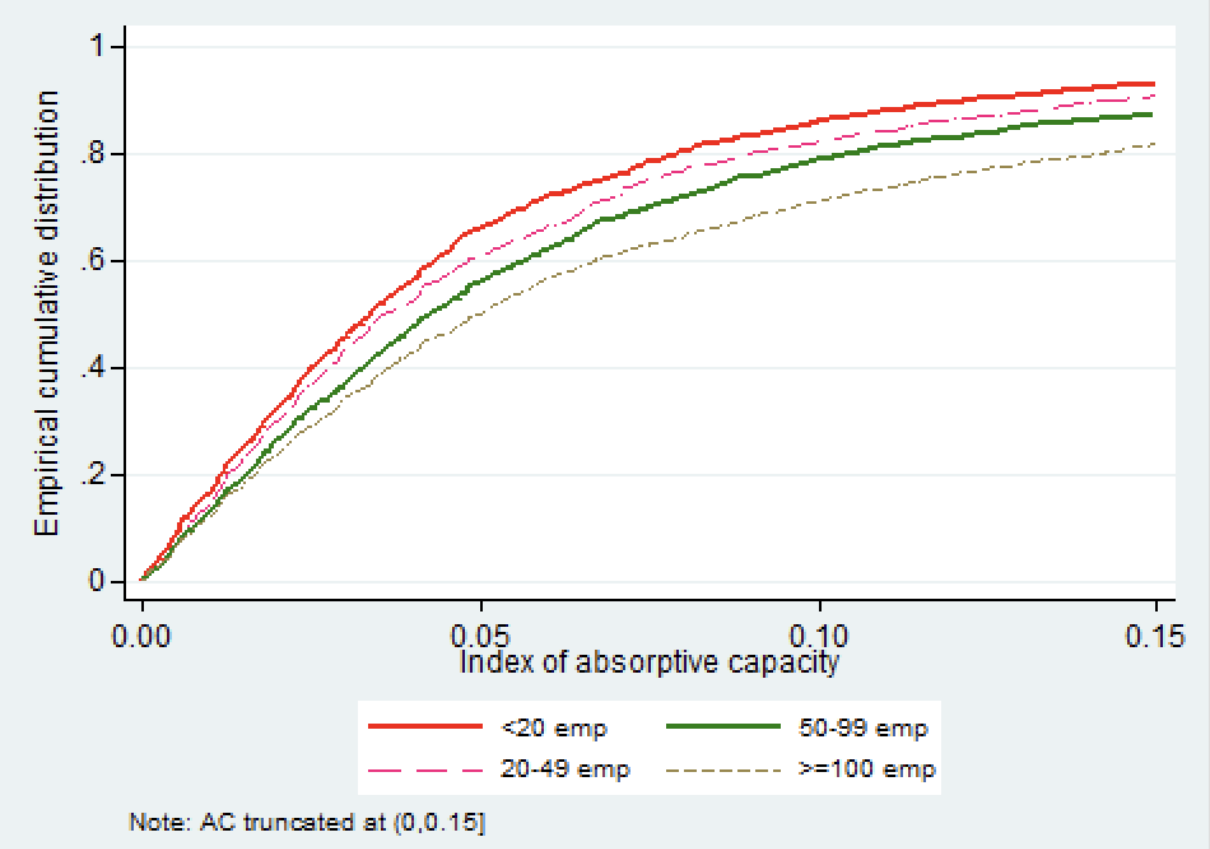
(a) By foreign investment



(b) By R&D, innovation and exporting status

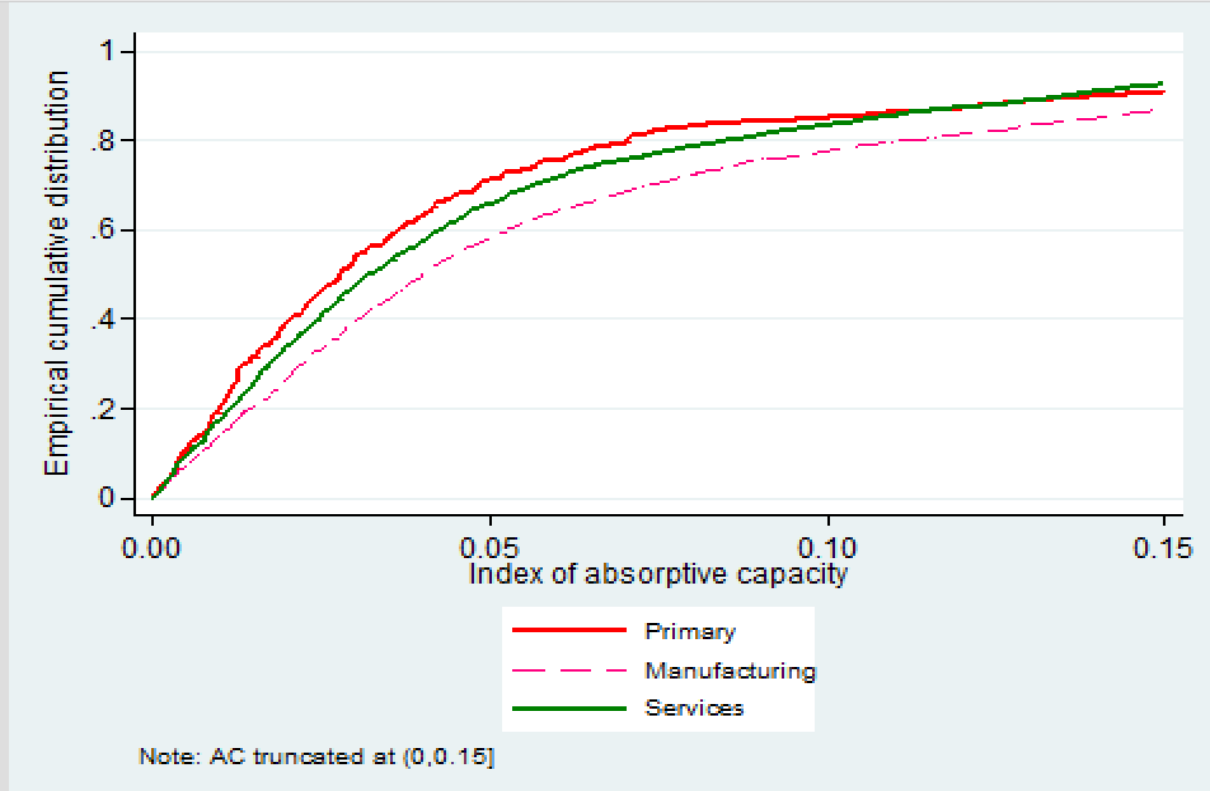


(c) By employment



(d) By employment of professional, managerial and technical staff

(e) By sector[a]



[a] Appendix Figure 1 (in the appendix) presents a kernel density version of this diagram.

Source: based on SEM model (Table 1)

Table 2: (Weighted) Ordered probit of determinants of absorptive capacity, New Zealand, 2005-15 (marginal effects reported)

(a) Primary

VARIABLES	$\frac{\partial p(AC < -0.03)}{\partial x}$	$\frac{\partial p(-0.03 < AC < -0.0}{\partial x}$	$\frac{\partial p(-0.025 < AC < 0.01}{\partial x}$	$\frac{\partial p(AC > 0.01)}{\partial x}$
20-49 employees	-0.055**	0.001	0.016**	0.038**
50-99 employees	-0.212***	-0.015***	0.043***	0.184***
100+ employees	-0.261***	-0.027***	0.041***	0.246***
1-5% managers & professionals employed	0.005	-0.001	-0.002	-0.002
6-20% managers & professionals employed	-0.122***	0.007**	0.039***	0.075***
21-50% managers & professionals employed	-0.157***	0.007*	0.049***	0.102***
>50% managers & professionals employed	-0.221***	0.001	0.062***	0.158***
5-9 years	0.016	0.000	-0.004	-0.012
10-19 years	0.069**	-0.001	-0.020**	-0.048*
20-49 years	0.044	-0.000	-0.012	-0.032
50+ years	0.239**	-0.024	-0.081**	-0.135***
Single-plant enterprise	0.058**	-0.001	-0.017**	-0.040*
Has plants in more than one TTWA	0.062	-0.003	-0.019	-0.039
Multi-industry enterprise	-0.002	0.000	0.000	0.001
Belongs to a business group	0.029	-0.001	-0.009	-0.019
Metropolitan	-0.074	-0.000	0.020	0.055
NZ-owned outward FDI	-0.050	-0.000	0.014	0.037
Part foreign-owned	-0.057	-0.000	0.015	0.042
Fully foreign-owned	-0.126	-0.005	0.029**	0.101
Links with HEI	-0.443***	-0.158***	-0.208***	0.809***
Many competitors, several dominant	-0.034	0.001	0.010	0.024
Many competitors, none dominant	0.004	-0.000	-0.001	-0.002
Herfindahl index	0.161	-0.004	-0.047	-0.110
Agglomeration index	-0.022	0.001	0.006	0.015
Diversity index	-0.119	0.003	0.035	0.082
Waikato	-0.066	0.007	0.023	0.036
Wellington	-0.271***	0.001	0.072***	0.199***
Rest of North Island	-0.120**	0.010	0.040*	0.071**
Canterbury	-0.115**	0.010	0.038*	0.067**
Rest of South Island	-0.156**	0.010	0.050**	0.097***
Year 2007	0.021	-0.000	-0.006	-0.014
Year 2009	-0.002	0.000	0.001	0.002
Year 2011	0.058	-0.002	-0.017	-0.038
Year 2013	0.023	-0.000	-0.007	-0.016
Year 2015	-0.003	0.000	0.001	0.002
Services to agriculture, Hunting and trapping	0.071**	-0.002	-0.021**	-0.047**
Forestry and logging	0.088***	-0.004*	-0.027***	-0.057***
Commercial fishing	-0.041	-0.001	0.010	0.031
Mining	0.058	-0.002	-0.017	-0.039
Observations		3,069		
Pseudo-R^2		0.060		

(b) Manufacturing

VARIABLES	$\frac{\partial p(AC < -0.03)}{\partial x}$	$\frac{\partial p(-0.03 < AC < 0.00)}{\partial x}$	$\frac{\partial p(0.00 < AC < 0.04)}{\partial x}$	$\frac{\partial p(AC > 0.04)}{\partial x}$
20-49 employees	-0.099***	0.002*	0.032***	0.065***
50-99 employees	-0.176***	-0.007***	0.051***	0.132***
100+ employees	-0.203***	-0.013***	0.056***	0.160***
1-5% managers & professionals employed	-0.097**	0.020**	0.037**	0.041***
6-20% managers & professionals employed	-0.169***	0.027***	0.062***	0.080***
21-50% managers & professionals employed	-0.268***	0.026***	0.093***	0.150***
>50% managers & professionals employed	-0.303***	0.022**	0.101***	0.180***
5-9 years	0.030	0.001	-0.009	-0.022
10-19 years	0.080***	-0.000	-0.025***	-0.055***
20-49 years	0.050**	0.001	-0.015**	-0.036**
50+ years	0.118***	-0.004	-0.038***	-0.077***
Single-plant enterprise	0.022	-0.000	-0.007	-0.014
Has plants in more than one TTWA	0.004	-0.000	-0.001	-0.003
Multi-industry enterprise	0.006	-0.000	-0.002	-0.004
Belongs to a business group	-0.000	0.000	0.000	0.000
Metropolitan	0.097***	-0.001	-0.030***	-0.066***
NZ-owned outward FDI	-0.185***	-0.021***	0.043***	0.163***
Part foreign-owned	-0.005	0.000	0.002	0.003
Fully foreign-owned	-0.030	0.000	0.009	0.020
Links with HEI	-0.405***	-0.201***	-0.182***	0.787***
Many competitors, several dominant	-0.030*	0.001	0.009*	0.020*
Many competitors, none dominant	0.021	-0.001	-0.007	-0.013
Herfindahl index	-0.003	0.000	0.001	0.002
Agglomeration index	0.000	-0.000	-0.000	-0.000
Diversity index	-0.200**	0.004	0.063**	0.133**
Waikato	-0.003	0.000	0.001	0.002
Wellington	0.017	-0.000	-0.005	-0.011
Rest of North Island	0.046	-0.002	-0.015	-0.029
Canterbury	-0.004	-0.000	0.001	0.003
Rest of South Island	0.025	-0.001	-0.008	-0.017
Year 2007	0.024	0.000	-0.007	-0.017
Year 2009	0.041**	0.000	-0.013**	-0.029**
Year 2011	0.043**	0.000	-0.013**	-0.030**
Year 2013	0.062***	-0.001	-0.019***	-0.042***
Year 2015	0.061***	-0.001	-0.019***	-0.042***
Textile, clothing, footwear and leather	0.043*	-0.001	-0.014*	-0.028*
Wood and paper product and Printing	0.082***	-0.004***	-0.027***	-0.051***
Non-metallic mineral and Metal product	-0.041	-0.002	0.012	0.031
Petroleum, Coal, Chemical etc	0.035	-0.001	-0.011	-0.023
Machinery and Equipment	-0.001	-0.000	0.000	0.001
Other Manufacturing	-0.039	-0.001	0.011	0.029
Observations		7,344		
Pseudo-R^2		0.082		

(c) Services

VARIABLES	$\frac{\partial p(AC < -0.03)}{\partial x}$	$\frac{\partial p(-0.03 < AC < -0.0}{\partial x}$	$\frac{\partial p(-0.01 < AC < 0.03)}{\partial x}$	$\frac{\partial p(AC > 0.03)}{\partial x}$
20-49 employees	-0.060***	0.001**	0.017***	0.042***
50-99 employees	-0.086***	0.000	0.024***	0.062***
100+ employees	-0.112***	-0.001	0.030***	0.084***
1-5% managers & professionals employed	-0.089***	0.013***	0.032***	0.044***
6-20% managers & professionals employed	-0.145***	0.017***	0.051***	0.078***
21-50% managers & professionals employed	-0.218***	0.017***	0.071***	0.130***
>50% managers & professionals employed	-0.212***	0.017***	0.070***	0.125***
5-9 years	0.053***	0.001*	-0.013***	-0.041***
10-19 years	0.091***	0.000	-0.024***	-0.067***
20-49 years	0.137***	-0.003**	-0.039***	-0.095***
50+ years	0.223***	-0.014***	-0.069***	-0.139***
Single-plant enterprise	-0.014	0.000	0.004	0.010
Has plants in more than one TTWA	-0.029*	0.000**	0.008*	0.021*
Multi-industry enterprise	-0.043**	0.000	0.012***	0.030**
Belongs to a business group	-0.048***	0.000	0.013***	0.034***
Metropolitan	0.014	-0.000	-0.004	-0.009
NZ-owned outward FDI	-0.125***	-0.005*	0.030***	0.101***
Part foreign-owned	-0.070**	-0.001	0.019***	0.052**
Fully foreign-owned	-0.038**	0.000	0.011**	0.027**
Links with HEI	-0.441***	-0.163***	-0.191***	0.795***
Many competitors, several dominant	-0.036**	0.001	0.010**	0.025**
Many competitors, none dominant	0.050***	-0.003***	-0.016***	-0.031***
Herfindahl index	0.098	-0.003	-0.029	-0.067
Agglomeration index	-0.046	0.001	0.013	0.031
Diversity index	-0.012	0.000	0.004	0.008
Waikato	0.032	-0.002	-0.010	-0.021
Wellington	-0.058***	0.000	0.016***	0.042***
Rest of North Island	0.007	-0.000	-0.002	-0.005
Canterbury	-0.011	0.000	0.003	0.007
Rest of South Island	-0.012	0.000	0.004	0.008
Year 2007	0.017	-0.001	-0.005	-0.011
Year 2009	0.013	-0.000	-0.004	-0.009
Year 2011	0.019	-0.001	-0.006	-0.013
Year 2013	-0.013	0.000	0.004	0.009
Year 2015	-0.020	0.000	0.006	0.014
Wholesale trade	-0.136***	-0.001	0.036***	0.101***
Retail and Hospitality	-0.015	0.001	0.005	0.009
Transport, Communication, Finance	-0.051**	0.002*	0.016**	0.034**
Property services	-0.056**	0.002*	0.017**	0.037**
Business services	-0.018	0.001	0.006	0.011
Other services	-0.042**	0.002	0.013**	0.028**
Observations		20,406		
Pseudo-R^2		0.053		

Definitions of variables are provided in Table A.2. A table with standard errors is available on request. ***/**/* indicates significance levels at the 1/5/10% levels. Numbers of observations have been randomly rounded to base 3 to protect confidentiality.

Separately for the primary, manufacturing and service sectors, absorptive capacity was divided into quartiles[16] and ordered probit models were estimated. This was in order to provide an indication of which factors are most highly correlated with absorptive capacity. (Appendix Table 2 provides definitions of the variables used, together with some descriptive statistics.) Over time, there has been a general decline in absorptive capacity in manufacturing but not in the primary or service sectors. Relative to the benchmark sub-group (firms employing less than 20 employees), larger firms (especially in manufacturing) had higher absorptive capacity (for example, employing 100+ employees increased the likelihood of being in the highest absorptive capacity quartile by 16 percentage points in manufacturing). Employing a larger proportion of manager and professionals was also associated with the highest levels of absorptive capacity (e.g., 12-18 percentage points higher in all sectors when 51+% of employees were managers and professionals). Older firms were associated with lower absorptive capacity. Being a single-plant enterprise increased the probability of belonging to the lowest absorptive capacity sub-group by (cet. par.) 4 percentage points in the primary sector. Service-sector firms with plants in more than one travel-to-work area, or that were part of a multi-industry firm or conglomerate had an increased likelihood of higher absorptive capacity.

Being located in a metropolitan area was associated with lower absorptive capacity for manufacturing, while belonging to a NZ-owned outward FDI firm was strongly associated with higher absorptive capacity in manufacturing and services. Having a link with a higher-education institution (HEI) was, cet. par., strongly associated with higher absorptive capacity (around 80 percentage points more likely to be in the top quartile). Operating in monopolistically competitive markets (ie. "many competitors, several dominant") increased the likelihood of higher absorptive capacity in manufacturing and services. Agglomeration and operating in a concentrated industry had no impact, while being located in a travel-to-work area where there was higher diversity in terms of the breadth of industries represented had a strong positive impact on having higher absorptive capacity, but only in manufacturing.

In the primary sector and services, and relative to other regions, firms in Wellington were more likely to experience high absorptive capacity. In the primary sector, this also extended, to a lesser extent, to other areas except the Waikato and Auckland (the benchmark sub-group). Belonging mainly to certain service sectors, e.g., in wholesale trade, was associated with higher absorptive capacity while other sectors were associated with relatively lower absorptive capacity.

[16] The distribution of absorptive capacity is highly non-normal, and therefore OLS regression was not a feasible option. The Sharpiro-Wilk W test for normality of the index produced a W (V) value of 0.833 (2177.3), with an associated *z*-value of 21.14. See also Appendix Figure 1 in the appendix.

Having examined which types of establishments did better in terms of absorptive capacity, this section concludes by looking at whether those with high (low) absorptive capacity maintained their relative position in the distribution over time. Firstly, Table 3 reports the transition matrix across 2005-2015 based on grouping firms by absorptive capacity quintiles. The diagonal shows that firms in most quintiles had a high probability of remaining in that quintile over time (e.g., 61.1% in the lowest quintile did not move, while nearly 44% in the highest remained in the same sub-group), or only moving up or down one sub-group. This suggests a considerable degree of stability over time, showing that it takes a considerable period to build absorptive capacity (or to see it erode). Table 4 produces similar evidence based on regressing absorptive capacity in time *t* on its lagged values. Again, establishments tend to remain with high (low) absorptive capacity for long periods.

Table 3: Transition matrix for absorptive capacity (cells show row percentage of firms)

	Quintile of absorptive capacity (t+1)					
Quintile (t)	**1**	**2**	**3**	**4**	**5**	**Total**
1	**61.1**	4.8	17.1	10.7	6.3	100
2	15.1	**40.6**	19.6	14.8	9.9	100
3	31.0	7.5	**29.6**	19.8	12.2	100
4	20.2	6.0	23.1	**28.7**	22.0	100
5	13.0	4.5	15.4	23.2	**43.9**	100
Total	33.2	8.0	20.6	19.2	19.1	100

Source: index of absorptive capacity obtained from Table 1

Table 4: (Weighted) OLS regression of absorptive capacity (AC) on its lagged value

	$\widehat{\boldsymbol{\beta}}$	$\widehat{\boldsymbol{\beta}}$	$\widehat{\boldsymbol{\beta}}$	$\widehat{\boldsymbol{\beta}}$	$\widehat{\boldsymbol{\beta}}$
AC_{t-1}	0.374***				
	(0.019)				
AC_{t-2}		0.340***			
		(0.018)			
AC_{t-3}			0.311***		
			(0.020)		
AC_{t-4}				0.222***	
				(0.025)	
AC_{t-5}					0.162***
					(0.034)
(unweighted) N	16,386	10,881	7,194	4,254	2,007

Robust standard errors in parenthesis. *** p<0.01, ** p<0.05, * p<0.1. All regressions include an intercept. Numbers of observations have been randomly rounded to base 3 to protect confidentiality.

Source: index of absorptive capacity obtained from Table 1

5 How important is absorptive capacity in determining productivity drivers?

In this section, the absorptive capacity indices obtained from the SEM are used as determinants of whether a firm exported, innovated (a new good or service), or undertook any R&D.[17] The (weighted) BOS data covering 2005-2015 is used, merged with Longitudinal Business Database (LBD, which provide annual data for these firms[18]), and (stepwise) random-effects probit models are estimated that include lagged values of the dependent variables[19] and by treating absorptive capacity as predetermined.[20] Essentially, the equations estimated are reduced-form. While there is a valid case for including contemporaneous values of the productivity-enhancing activities covered, such current values of exporting, innovation and R&D requires modelling a simultaneous probit system (see Harris and Moffit, 2011).[21] Here the goal is to emphasise how influential absorptive capacity is in determining these activities.

[17] R&D is defined in the BOS Survey as spending on any activity characterised by originality: it should have investigation as its primary objective, and an outcome of gaining new knowledge, new or improved materials, products, services, or processes; and/or the buying abroad of technical knowledge or information. The firm is asked not to include: market research, efficiency studies, or style changes to existing products.

[18] See http://m.stats.govt.nz/browse_for_stats/businesses/business_characteristics/longitudinal-business-database.aspx for details.

[19] The lagged values of whether the firm exported or undertook R&D is taken from BOS Module A thus *t -1* refers to the previous year; information on innovation comes from BOS Module B and thus the lagged value is *t -2*.

[20] This is justified on both theoretical and empirical grounds that absorptive capacity is a dynamic capability that it takes time for a firm to build-up. Theory is based on a resource-based view of the firm; Teece and his colleagues – see Teece et. al., 1997; Teece and Pisano, 1998 – argue that these capabilities are the sub-set of its competences and capabilities that allow the firm to create new products and processes and to respond to changing market conditions; they are the core of its competitiveness. The competitive advantage of firms rests on processes of coordinating and combining assets, shaped by the firms' (prior) knowledge asset positions, as well as path dependencies in asset acquisition and development. Fundamentally, Teece and other proponents of the resource- and knowledge-based views of the firm argue that such competencies and capabilities by their very nature cannot be bought; they can only be built by the firm. That is, they cannot easily be acquired, replicated, diffused, or copied – they therefore cannot easily be transferred or built-up outside the firm. This in part is due to the key role that learning plays both in enabling the firm to align and thus exploit its resources, competencies and capabilities, and in allowing the firm to internalise outside information into knowledge; and the way the firm learns is not acquired but it is determined by its unique 'routines', culture and its current position (i.e., stock of – tacit – knowledge). The empirical evidence was in part presented above in Table 3 and Table 4.

[21] This is econometrically complicated, so instead right-hand-side values of exporting_t, innovation_t, and $\text{R\&D}_t$ are substituted out using the exogenous variables determining each activity.

Table 5: (Weighted) Estimates of (stepwise) random-effects probit models determining exporting, R&D and innovation, NZ, 2005-2015 (by sector) – marginal effects reported

	Primary			Manufacturing			Services		
	Exporting	**Innovation**	**R&D**	**Exporting**	**Innovation**	**R&D**	**Exporting**	**Innovation**	**R&D**
$export_{t-1}$	0.545***	0.018***	-0.003	0.650***	0.032***	0.033***	0.451***	0.044***	0.031***
$innovation_{t-2}$	0.001	0.080***	0.041***	0.016***	0.098***	0.048***	0.012***	0.114***	0.010***
$R\&D_{t-1}$	0.003	-0.013*	0.274***	0.036***	0.126***	0.321***	0.030***	0.092***	0.273***
External knowledge[a]	0.001	0.037***	0.009**	0.008*	0.116***	0.039***	0.015***	0.085***	0.016***
National cooperation with business[a]	0.005	0.012***	0.023***	0.014***	0.023***	0.007***	0.006***	0.013***	-0.000
Links with national researchers[a]	0.025***	-0.002	0.001	0.017***	0.008	0.019***	-0.008***	-0.008***	0.007***
International cooperation with researchers[a]	0.014*	-0.014***	-0.013***	-0.014***	-0.032***	-0.017***	-0.004***	-0.012***	-0.002**
International cooperation with business[a]	0.028**	0.010**	0.004	-0.004	0.061***	0.016***	0.007***	0.053***	0.012***
20-49 employees	-0.048***	0.010	-0.008	0.042***	0.031***	0.040***	-0.003	0.003	0.011***
50-99 employees	-0.076***	0.057***	0.035***	0.075***	-0.009	0.031***	-0.008**	0.006	0.015***
100+ employees	-0.035	0.029**	0.053***	0.076***	0.014	0.060***	-0.023***	-0.005	0.018***
1-5% managers & professionals employed	-0.027*	0.027***	0.008	0.031**	0.020	0.055***	0.017***	0.021***	0.006**
6-20% managers & professionals employed	-0.085***	0.005	0.035***	0.052***	0.058***	0.035***	-0.003	0.020***	0.031***
21-50% managers & professionals employed	-0.042***	0.046***	0.080***	0.081***	0.041***	0.050***	0.019***	0.017***	0.025***
>50% managers & professionals employed	-0.063***	0.062***	0.025**	0.090***	0.038**	0.054***	0.010***	0.038***	0.050***
5-9 years	-0.027	-0.023**	-0.049***	-0.045***	-0.004	-0.030***	-0.025***	0.020***	0.014***
10-19 years	-0.093***	-0.029***	-0.067***	-0.041***	-0.003	-0.018*	-0.014***	0.015***	0.005**
20-49 years	-0.052***	-0.007	-0.066***	-0.062***	-0.006	-0.023**	-0.018***	-0.001	0.007***
50+ years	-0.118***	-0.073***	-0.072***	-0.033**	-0.038**	-0.025*	-0.017***	-0.013*	0.015***
Single-plant enterprise	-0.009	0.014**	0.026***	0.016**	0.001	-0.008	0.001	0.015***	0.016***
Has plants in more than one TTWA	-0.030*	0.020	0.003	-0.004	-0.003	-0.026***	0.012***	0.009**	0.002
Multi-industry enterprise	0.097***	-0.013*	0.058***	0.048***	0.022**	-0.022***	0.032***	0.036***	0.004
Belongs to a business group	0.002	-0.007	0.006	-0.011	-0.008	-0.002	-0.004*	0.031***	-0.001
Metropolitan	-0.025	-0.002	0.010	-0.037***	-0.043***	-0.018*	0.028***	0.019***	0.015***
NZ-owned outward FDI	-0.159***	0.015	0.080***	0.082***	0.073***	0.036***	0.047***	-0.001	0.032***
Part foreign-owned	0.101***	0.011	0.014	-0.025*	-0.057***	-0.005	0.015***	0.004	0.006*
Fully foreign-owned	0.330***	-0.017	0.008	0.022*	-0.015	0.009	0.021***	0.058***	-0.008***
Links with HEI	-0.067**	0.065**	0.138***	0.048**	-0.098***	0.010	0.004	-0.090***	-0.008**
Many competitors, several dominant	0.041***	-0.015**	0.002	-0.011*	-0.021***	-0.016***	0.013***	-0.005*	0.000
Many competitors, none dominant	0.043***	-0.031***	0.025***	0.013*	-0.019**	-0.019***	0.013***	-0.011***	-0.010***
Herfindahl index	-0.013***	0.010***	-0.004**	0.003	0.005**	0.008***	-0.005***	0.001	-0.000
Agglomeration index	0.043***	-0.006**	0.007***	0.006**	0.001	0.004**	0.009***	-0.003**	-0.001
Diversity index	0.156***	0.032**	0.035***	-0.004	-0.000	0.003	0.027***	0.030***	-0.017***

Waikato	0.012	-0.028*	0.004	-0.086***	-0.057***	0.024*	0.012**	0.047***	0.001
Wellington	0.187***	-0.011	0.015	0.001	-0.034**	0.016	-0.010***	0.000	-0.002
Rest of North Island	0.042*	-0.007	-0.008	-0.060***	-0.050***	-0.014	0.036***	0.021***	0.016***
Canterbury	-0.006	-0.039***	-0.007	-0.018**	-0.048***	0.011	0.015***	-0.020***	0.003
Rest of South Island	0.102***	-0.011	0.059***	-0.048***	-0.095***	-0.022*	0.038***	0.006	0.004
Year 2009	-0.011	0.001	0.018***	-0.035***	0.005	0.014**	0.006**	0.001	0.018***
Year 2011	-0.009	-0.028***	0.023***	0.027***	-0.006	0.016**	-0.001	0.010***	0.020***
Year 2013	0.043***	-0.021***	0.025***	0.065***	-0.034***	0.019***	0.024***	-0.003	0.023***
Year 2015	0.048***	-0.020***	0.021***	0.042***	-0.025***	-0.008	0.055***	-0.009**	0.033***
Services to agriculture, Hunting and trapping	-0.080***	0.018**	0.017**	–	–	–	–	–	–
Forestry and logging	-0.108***	-0.006	0.015	–	–	–	–	–	–
Commercial fishing	-0.008	0.032	0.043**	–	–	–	–	–	–
Mining	-0.150***	0.001	-0.020**	–	–	–	–	–	–
Textile, clothing, footwear and leather	–	–	–	0.018	-0.006	-0.007	–	–	–
Wood and paper product and Printing	–	–	–	-0.037***	-0.053***	-0.039***	–	–	–
Non-metallic mineral and Metal product	–	–	–	0.011	0.020	0.016	–	–	–
Petroleum, coal, chemical and associated product	–	–	–	-0.055***	-0.025**	-0.015	–	–	–
Machinery and equipment	–	–	–	0.003	-0.014	0.003	–	–	–
Other manufacturing	–	–	–	-0.054***	0.040**	-0.033***	–	–	–
Wholesale trade	–	–	–	–	–	–	0.126***	0.024***	0.013***
Retail and Hospitality	–	–	–	–	–	–	0.031***	-0.031***	-0.005**
Transport, Communication, Finance	–	–	–	–	–	–	0.033***	-0.019***	0.007**
Property services	–	–	–	–	–	–	0.017***	-0.059***	0.008
Business services	–	–	–	–	–	–	0.055***	-0.029***	-0.006**
Other services	–	–	–	–	–	–	0.003	-0.011**	-0.012***
Observations	1,602	1,602	1,602	4,539	4,539	4,539	11,370	11,370	11,370
No. of enterprises	717	717	717	1,761	1,761	1,761	4,890	4,890	4,890
Pseudo log-likelihood	-2777	-1361	-1187	-5716	-6901	-4513	-16911	-23833	-11120
McFadden's Pseudo-R^2	0.291	0.278	0.403	0.361	0.256	0.308	0.301	0.245	0.307
Nagelkerke's Pseudo-R^2	0.765	0.530	0.690	0.773	0.660	0.623	0.732	0.747	0.615

Definitions of variables are provided in Appendix Table 2. A table with standard errors is available on request. ***/**/* indicates significance levels at the 1/5/10% levels. Numbers of observations have been randomly rounded to base 3 to protect confidentiality.

Note: absorptive capacity variables have been standardised with mean 0 and standard deviation of 1, so marginal effects show the impact of a one-standard deviation increase.

Table 6: Marginal effects of changing absorptive capacity (the median value to the 99 percentile) on exporting, innovation and R&D in NZ, 2005-2015 (by sector)

	Primary			Manufacturing			Services		
	Exporting	**Innovation**	**R&D**	**Exporting**	**Innovation**	**R&D**	**Exporting**	**Innovation**	**R&D**
External knowledge	0.003	0.205***	0.032**	0.022**	0.498***	0.151***	0.053***	0.411***	0.062***
National cooperation with business	0.020	0.070***	0.183***	0.061***	0.112***	0.035***	0.024***	0.061***	0.000
Links with national researchers	0.125***	-0.009	0.004	0.085***	0.037	0.114***	-0.025***	-0.025***	0.030***
International cooperation with researchers	0.010	-0.009***	-0.008***	-0.010***	-0.022***	-0.011***	-0.002***	-0.006***	-0.001***
International cooperation with business	0.103***	0.043*	0.014	-0.018	0.400***	0.099***	0.026***	0.279***	0.057***
Mean(weighted) value of dependent variable	0.285	0.081	0.069	0.395	0.296	0.175	0.126	0.175	0.060

***/**/* indicates significance levels at the 1/5/10% levels.

Source: Table 5 and Appendix Table 6

Table 5 produces the results separately for the primary, manufacturing and service sectors. The pseudo-R2 values obtained are high for this type of model, suggesting they are well-specified. The value of the lagged values in each model show the importance of fixed and sunk costs in determining productivity enhancement. Thus, firms that exported last period were (cet. par.) some 45-65 percentage points more likely to export in *t* in manufacturing and services. Past innovation and/or R&D both tend to impact on current decisions to innovate/undertake R&D, but the impacts are much smaller when compared to lagged exporting impacts on exporting.[22] In manufacturing and services especially, all three activities in previous years' impact to some extent on undertaking activities in year *t*, showing that all three are indeed interrelated and part of enhancing the overall productivity and competitiveness of the firm.

The key variables in Table 5 relate to the impact of absorptive capacity. Table 6 shows the impact of a change in absorptive capacity from the value experienced by the median firm to the value that defines the start of the 99 percentile. The latter are more informative than the marginal effects produced in Table 5[23], and we concentrate on them here, as they effectively relate to the impact of moving an average firm in a sector to the frontier value of each measure of absorptive capacity. The strongest impacts on exporting in the primary sector are 'links with national researchers' and 'international cooperation with business', increasing the probability of exporting by some 10-13 percentage points. Given the average propensity to export was 28.5%, this is a substantial increase. Absorptive capacity has a smaller impact on exporting in the other sectors covered, although a 5.3 percentage point increase associated with 'external knowledge' in services (given only 12.6% exported) is relatively large.

Innovation is strongly influenced by an increase in 'external knowledge' – around 21/50/41 percentage points higher in the primary/manufacturing/service sector – while 'international cooperation with business' has a strong impact in manufacturing and especially services (given just over 17% of the latter innovated in this period). The likelihood of undertaking R&D in the primary sector increases by just over 18 percentage points when 'national cooperation with business' increases from the median to the 99 percentile (against a benchmark propensity to do R&D of only 6.9%); 'external knowledge' and 'national cooperation with researchers' produce sizable impacts in manufacturing and services, while 'international cooperation with business' is also relatively important in services.

[22] However, note the impact of lagged exporting on current exporting is higher because a larger share of firms export. When evaluated relative to the share of firms that export/innovation/R&D, the (relative) effects of the corresponding lags are very similar.

[23] Table 5 is based on the default output from using the *margins* command in Stata (which is effectively the marginal effect of increasing standardised absorptive capacity by one standard deviation i.e., the effect of adding 1 to the current value).

The unexpected result is the impact on firms gaining specialised knowledge from 'international cooperation with researchers'; there is, cet. par., generally a relatively small but significant negative impact on innovation in manufacturing in particular). The negative impact of such cooperation from HEI's, consultants, labs, government and research organisations is likely due to firms not being able to easily internalise this specialised information, because public research knowledge is hard to transfer into "ready-to-produce" innovations (Mueller 2006, p.1502). The gap between specialised knowledge and practical innovations may mean that the more firms try to reduce the gap, the greater the negative impact.[24]

To test for robustness, the results in Table 6 were also reproduced using two alternative approaches. Firstly, whilst we have argued (and presented evidence) that the measures of absorptive capacity can be considered as pre-determined variables (see footnote 20), we have re-estimated the random effects probit models using a one-for-one 'matching' approach. In this approach 'treated' firms are those with absorptive capacity (based on the overall index) in the top quartile (25%) and a 'control' sub-group comprises those with similar characteristics to the 'treated' (e.g., size, ownership, location, age), but with absorptive capacity values outside the top quartile. The results from the 'matching' model therefore help to mitigate against selectivity bias that could arise if the characteristics of firms with high absorptive capacity also 'push them' into productivity enhancing activities (exporting, innovating and undertaking R&D). The second model recognises the likely upward bias in the lagged dependent variables of the dynamic models estimated, due to the 'initial conditions problem' associated with the correlation between initial exporting, innovation and R&D (i.e., $export_0$, $innovation_0$ and $R\&D_0$) and the other variables in each equation. Wooldridge (2005) suggests a simple solution is to include $export_0$, $innovation_0$ and $R\&D_0$ in the models estimated. The results from 'matching' and the Wooldridge approach are presented in Appendix Table 3[25], and suggest that the baseline results (Table 6) are generally robust to different modelling approaches (the results from matching are generally smaller, due to the fact we are concentrating more on firms with characteristics associated with higher levels of absorptive capacity; the 'Wooldridge' results are very similar to those presented in Table 6[26]).

The impact of other variables included in the model are generally as expected. Larger firms are usually more likely to engage in innovation and R&D (and exporting in manufacturing), but size effects are less important in the primary and service sectors, especially

[24] This finding is consistent with the fact that, for example, EU firms do worse to commercialise specified knowledge generated in universities and research institutions than their U.S. counterparts (EC 2001; Arundel and Geuna 2004).
[25] The full results are presented in Appendix Table 7 and Appendix Table 8 of the appendix.
[26] Note, the 'matching' and 'baseline' results tend to differ more with respect to those firms engaged in international cooperation with either businesses or researchers; these are atypical activities. On average 42/86/86/99/93% of firms did not record any positive links to external knowledge/national cooperation with business/links with national researchers/international cooperation with researchers/international cooperation with business, respectively (overall 41% of firms had no external links).

in determining whether exporting is undertaken. Having (more) managers and professional staff is usually positive (except in determining exporting in the primary sector), and older firms are less likely to export, innovate or do R&D (except with respect to R&D in services). Single-plant enterprises are marginally more likely to innovate and do R&D in the primary and service sectors, and export in manufacturing. Belonging to a multi-industry enterprise is usually significantly positive, while operating in a metropolitan area is negative for manufacturers and positive in the service sector.

Being internationalised benefits all three activities, with the major exception that primary sector NZ-owned multinational firms are some 16% less likely to export. Links with universities has a mixed effect: strongly positive with regard to doing R&D in the primary sector, but (cet. par.) reducing innovation in manufacturing and services. Industry competition and concentration varies across sectors and activities; whereas being located in areas with higher agglomeration and diversity are generally beneficial. Location in certain regions is important, without any clear-cut patterns emerging. And, relative to 2007, exporting and R&D was higher in more recent years, while innovation (cet. par.) was much marginally lower. Lastly, industry impacts were important but mixed in terms of sectors and activities.

Relative to these other impacts, Table 5 shows that absorptive capacity as measured here – e.g., net of the impact of foreign-ownership and human capital – has a substantial influence on exporting, innovation and undertaking R&D, and thus firm-level productivity.

6 The role of government in increasing absorptive capacity

We start from the position taken by the New Zealand Productivity Commission that "… while there have been some areas of improvement, policy has been unable to shift the economy to a more dynamic high-productivity growth path" (Conway, 2016, p.53). Given the results in this paper, it is our contention (backed here by empirical evidence) that, *inter alia*, a focus on improving firms' absorptive capacity will have a positive and likely substantial impact on increasing productivity in the heterogeneous firms that make up the New Zealand business sector.

As was noted in section 2, direct help for building absorptive capacity was mainly limited to the operation of 'client-managed' export businesses by New Zealand Trade and Enterprise (NZTE) and increasing the number of R&D grants available to firms, which included the role of Callaghan Innovation (a Crown entity established in 2013)[27] in building innovation capabilities. Government support to up to 700 (large) exporting companies is currently delivered through

[27] See https://www.callaghaninnovation.govt.nz/.

assigned 'client-managers'. This support includes building capabilities following a company audit (e.g., ensuring they have appropriate marketing or supply-line functions,[28] as well as a product that can generate overseas demand). It is, however, widely accepted that these 'client-managed' companies have relatively low productivity. Staff at NZTE also made it clear that the main role of their organisation is to boost exporting totals (e.g., through current assisted exporters selling more overseas), rather than to build 'dynamic capabilities' (Teece, 2017a), with firms outside the 'top 700' ineligible for assistance.

Callaghan Innovation generally provides R&D grants and access to specialised help in developing new products (e.g., through a team of scientists that can assist with R&D that firms themselves would struggle to achieve, because of scale issues). It can also help build a firm's capability to innovate before they commit to spend on R&D (especially through 'accelerator' programmes such as 'Lighting Lab' which provides firms "with structure, startup methodologies, business skills and focused support so they can prove, build and launch their ideas into market, with speed"[29]). However, Callaghan Innovation has limited reach because of budgeting constraints.[30] In addition, the need to turn R&D into narrowly defined innovation outcomes (new products and/or processes), ignores the 'second face' of R&D (Griffith et al., 2004) which is about increasing absorptive capacity. It is also important to note that, given the size of New Zealand's domestic markets, innovating firms almost always need to go 'global' if they are to generate sufficient sales. Help for exporting via NZTE tends to be limited to the 'top 700' firms, which are not the focus of support for Callaghan Innovation.

The activities of NZTE and Callaghan Innovation, while important, are limited in their impact on absorptive capacity. To favour policies designed to improve absorptive capacity, it is useful to consider the issue of how firms should and can improve their dynamic capabilities (and thus *de facto* their absorptive capacity).[31] This requires a brief discussion of a recent trend in industrial policies that shifts away from placing the firm at the centre of the policy debate (so

[28] Teece (2017a) calls these ordinary (or 'necessary') capabilities which support "… technical efficiency in performing a fixed group of productive activities…. Quality control performance measurement and payroll execution are examples" (pp. 696-697). However, Teece (op. cit.) goes on to state that "… best operational practices … alone, however, are generally insufficient to ensure firm growth and survival…. This is because much of the knowledge behind ordinary capabilities can be secured through consultants or through modest investment in training" (p. 697). This is in contrast to what Teece labels dynamic capabilities; he states "….doing things right (technical efficiency) is not the same as doing the right things (evolutionary fitness)" (p.698). Dynamic capabilities are discussed later on, but it is worth emphasising that if ordinary capabilities can be bought, "… dynamic capabilities must be 'built' through a process of investment in discovery, knowledge generation and learning ….dynamic capabilities are non-tradeable" (Teece, op. cit., p.699).

[29] See https://www.callaghaninnovation.govt.nz/access-experts/accelerators.

[30] The NZ Ministry of Business, Innovation and Employment (MBIE) publish information on who has been funding through grants for scientific research and associated activities – see http://www.mbie.govt.nz/info-services/science-innovation/investment-funding/who-got-funded - and up until October 2017 Callaghan Innovation had received NZ$418m against a total spend of NZ$10,710m, i.e., 3.9%). The majority of funding goes to universities in New Zealand.

[31] Teece (2017a, p.711) goes as far as saying "… without the conceptual lens of the capabilities approach, policymakers may inadvertently impede innovative and capability-building activities".

called 'picking winners') and towards a greater emphasis on networks and collaboration, particularly in smaller firms (Jacobsson and Bergek, 2011). Chandler (2001, p.5) recognised this tension when he stated: "… the competitive strength of national industries depends on the abilities of the core firms to function effectively and to maintain and enhance their integrated learning bases".

Essentially Teece (2017a) argues that firms' dynamic capabilities are the sub-set of its competencies and capabilities, which allow the firm to create new products and processes and respond to changing market conditions. This is the core of its competitiveness, which essentially comprises how it searches, learns, approaches R&D, and its managerially-directed asset orchestration process. According to Teece and Pisano (1998), these dynamic capabilities shape (and are shaped by):

1. the firm's managerial and organisational *processes* (i.e., its 'routines' or current practices and learning[32]);
2. its *position* (current endowment of technology and intellectual property); and
3. its *paths* (the choices it makes that lock it into a trajectory, i.e. the notion of path dependency – see David, 1985; Arthur, 1989).

'Processes' are essentially concerned with how an organisation has learned to behave, the routines and practices that epitomise the 'culture' of the firm. This includes how the firm:

- searches for opportunities,
- hears and processes threats and opportunities,
- mobilises creativity and innovation, and
- manages learning and knowledge accumulation activities (Bessant *et. al.*, 2001).

In all, such processes define the firm's problem-solving capability. Such processes evolve over time and cannot be copied in any simple fashion. In essence, they allow the firm (via its top management) "…to develop conjectures about the evolution of consumer preferences, business problems and technology; validate and fine-tune them; and then act on them by realigning assets and activities" (Teece, 2017a, p.698).[33]

[32] Nelson and Winter (1984) refer to this as the collectivity of routines.
[33] Traù (2017) states that "growing means to invent a future for the firm. Such a passage is by no means automatic, and requires … above all … the firm to be able to successfully cope" (p. 751).

Teece breaks down activities in which firms with dynamic capabilities are involved as follows:

1. identification, development, co-development and assessment of technological opportunities in relationship to customer needs (*sensing*);
2. mobilisation of resources to address needs and opportunities, and to capture value from so doing (*seizing*); and
3. continued renewal (*transforming*).

As stated above, the firm's 'position' reflects its current endowment of technology and intellectual property, but also other assets such as relationships with key suppliers and customers. Such competence is therefore firm specific and mostly describes the static environment in which the firm currently operates. In contrast, the 'path' of the firm refers to the strategic direction it takes, and as such is both firm specific and shaped by its past experience and activities. Such a technological trajectory is thus path-dependent.

Fundamentally, Teece and other proponents of the resource-based view of the firm argue that competencies and capabilities by their very nature cannot be bought; they can only be built by the firm. That is, the factors involved in building unique specialised assets and keeping the firm aligned with its business environment, cannot easily be acquired, replicated, diffused, or copied – they therefore cannot easily be transferred or built-up outside the firm. This, in part, comes from the key role that learning plays both in enabling the firm to align its resources, competencies and capabilities, and in allowing the firm to internalise outside information into knowledge. The way the firm learns is not acquired but it is determined by its unique 'routines', culture and its current position (stock of knowledge).

Thus, the processes of knowledge generation and acquisition *within* the firm (i.e. internal knowledge generation) are essentially organisational learning processes (Reuber and Fisher, 1997; Autio, *et. al.*, 2000). The processes of incremental learning are important sources of both codified and tacit knowledge which may have great competitive impact. Although some firms could develop and acquire much of the knowledge internally (through their own resources and routines), few (and especially SMEs) virtually possess all the inputs required for successful and sustainable (technological) development. Therefore, the fulfilment of firms' knowledge requirements necessitates the use of external sources to acquire and internalise knowledge. Rosenkopf and Nerkar 2001; Almeida *et. al.*, 2003 set out the main *external* sources of knowledge available to firms.

The relationship between internal and external knowledge sourcing is complex in nature. Much of the theoretical literature concerned with transaction cost economics and property rights examines the choices between internal development and external sourcing. It also commonly considers the conditions that may favour one route rather than the other or the

decision not to proceed with a particular development at all (Coase, 1937; Williamson, 1990). In contrast, Teece's capabilities approach centres on the role of the firm. He argues that

> "… building and assembling assets designed specifically to perform some joint purpose inside the firm rather than accessing commercially available assets through … contracts… is done to ensure the maintenance of effective coordination and alignment of assets/resource/competences over time … this is more easily accomplished by managerial fiat inside the firm than through the price system (market)" (Teece, 2017a, p. 708).[34]

Teece acknowledges that because the market for information/knowledge about new opportunities is not well developed, the firm must build capabilities inside the business to assist knowledge creation and knowledge capture. Thus,

> "… firms are the 'engines' of economic development … (and the role of) … policymakers must therefore not only get the legal system and institutions of government right; they must also understand learning and value capture processes inside firms" (p.714).[35]

He advocates policy that is more than start-ups and individual entrepreneurs. Rather policy needs to create and help support "entrepreneurial managerial capitalism", where,

> "… the distinctive role of the (entrepreneurial) manager is … 'orchestration' of cospecialised assets and of business activity to achieve value-creating and value-capturing alignment"[36] (Teece, 2017b, p. 20).

He gives as examples: supporting entrepreneurial and management education (including running incubators and accelerators), periods of overseas employment, and having inward foreign investment firms help provide managerial training to local businesses.[37] All of these have featured to a very limited extent in the New Zealand policy arena, and need greater attention and resourcing.

Teece (2017b) provides policymakers with more specific guidance on how to calibrate how far the firm is from the 'capability frontier', in terms of its technological distance; its market distance (i.e., its target customers); and business model distance (see Figure 2 in Teece, 2017b). Once 'gaps' are identified (often through a process of trying to do something and failing), he

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[34] Teece (2017b, p. 18) states that "most strategic assets have no market price in isolation because the value of an asset is context-dependent"; this is especially so for certain knowledge assets. Even where an outside option is available, Hakanson (2010) argued the reason that a firm exists is because it is capable of managing knowledge, in particular, tacit knowledge, more cheaply and efficiently than is possible under other forms of governance

[35] Teece recognises that governments must provide favourable economic, political and legal conditions to facilitate firm growth, including fit-for-purpose infrastructure, macroeconomic stability, a benign corporate taxation system, the rule of law and a good education system. But he argues "this is not enough. An entrepreneurial-managerial class that can create and populate dynamically capable firms is also necessary" (p.714).

[36] Teece (2011) put it slightly differently: "because knowledge assets by themselves will not yield value, they must almost always be combined with other intangible and physical complements and bundled as a product to yield value for a customer".

[37] Teece (2017a, p. 715) notes that many local firms in global value-chains never develop the capabilities to compete on their own, but those that do (e.g., Acer and Samsung) establish managerial processes to facilitate the absorption and integration of technical and industrial knowledge from partner firms.

provides some discussion on how to close these gaps, noting that there is little in the literature that relates to how firms close all three gaps at once.[38] Learning and transformation in the firm are vital, requiring both leadership and teamwork, and for the firm to be strategically agile (i.e., able to build "a coherent set of analyses, concepts, policies, arguments, and actions that respond to a high-stakes challenge" – Rumelt, 2011, p.6).

This approach is based on a resource-based view of the firm, and centres on building absorptive capacity and dynamic capabilities in a manner that is generally not reflected in mainstream industrial policies. Rather, policy tends to concentrate more on technology infrastructure[39]; as Metcalfe and Georgiou (1997) stated:

> "recognition of the complex systems characteristics of the innovation process takes us to a different rationale for policy, a rationale which recognises the ambiguity and uncertainty of the policy environment and the futility of picking winners as distinct from encouraging winners to emerge by strengthening the innovation process in general… from the system perspective, it follows that individual firms are unlikely to be the focus of policy, rather the emphasis will be… upon all the co-operating groups of institutions defining a particular innovation system".

Building-up the technology infrastructure system is the central focus of the innovation process (cf. the 'pillars' underpinning the current approach in the UK to industrial strategy – BEIS, 2017). While Teece argues that capability building is best done within the firm, a second reason for policy to continue to place the firm at the centre of the policy debate is that firms will not fully benefit from external knowledge unless they have sufficient absorptive capacity. Because indigenous R&D and technology transfer share a complementary relationship (e.g. Cohen and Levinthal 1989, Griffith et al. 2004; Hu et al. 2005) instead of a substitutable relationship, firms who undertake in-house R&D are more likely to benefit from technology transfers. For example, Griffith et al. (2004) found that indigenous R&D enhances technology transfer in a panel of industries across twelve OECD countries. Indeed, Hu et al. (2005) found that indigenous R&D significantly complements both domestic and foreign technology transfer based on a large dataset for China's medium-large sized firms. Braga and Willmore (1991) found robust complementarity between R&D and technology imports in Brazilian industry. This

[38] Johnston (2017) advocates that firms think of capability building as operating along an S-curve (a well-established model for learning and improvement). Firms then need to ask themselves what does operating at the top of the S-curve look like; and how fast and how much is needed to invest to get there. Answering such questions means getting the assistance of those at the top, whether in the same or in other industries. This may happen through social networks, but there is also a role for government to resource business organisations (e.g., BusinessNZ) or industry groups (e.g., New Zealand Winegrowers, Meat Industry Association, etc.) to organise capability building.

[39] Another way of viewing this is that in a neoclassical economic framework, which concentrates on the efficient allocation of scare resources in a static (rather than growth-orientated dynamic) framework, the case for government intervention is generally limited to 'horizontal' support to business where there would otherwise be a 'market failure', thus with respect to education, infrastructure, fundamental research and public sector efficiency (Pitelis and Runde, 2017, p. 683). As Peneder (2017, p. 830) puts it:"… the static rationale of market failure and allocative efficiency is a poor guidepost in a dynamic world, where the continuous transformation of consumer preferences, technologies and production structures enables multiple trajectories of development".

complementary relationship also has been found in Taiwan (Kim and Nelson 2000), Korea (Kim 1997) and India (Katrak 1997). This complementary relationship suggests that outsourcing research activities alone is not enough and much more is needed, because external cooperation can possibly stimulate in-house R&D but it is not able to replace the firms' self-innovation activity. That in-house R&D and technology transfer complement rather than substitute each other implies that firms with high levels of absorptive capacity may have better external networks in terms of breadth and depth. However better networks do not necessarily guarantee firms benefiting from technology transfer if the absorptive capacity is lacking. As Veugelers (1997) concluded:

> "cooperation in R&D has no significant effect on own R&D unless the firms have an own R&D infrastructure, in which case cooperation stimulates internal R&D expenditures. These results support the idea that indeed absorptive capacity is necessary to be able to capitalise on the complementarities between internal and external know-how" (p. 312).

7 Summary and conclusions

Set against a background of underperformance in terms of productivity, and a policy environment that generally avoided 'picking winners' and instead concentrated on setting the right macro-environment and/or influencing the business environment, this paper used nationally-representative Business Operations Survey data to measure absorptive capacity in New Zealand firms between 2005-15. It provides evidence on which firms are mostly likely to have higher absorptive capacity (and whether they maintain this advantage over time); and how important is it in impacting on the propensity of firms to innovate, undertake R&D and export (i.e., enhance productivity).

Using a Structural Equations Modelling approach (built on an initial factor analysis), some of the main results show that larger firms had higher absorptive capacity, while firms employing greater relative numbers of professional and managerial staff had significantly better absorptive capacity levels. Older firms were associated with lower absorptive capacity. Firms with plants in more than one travel-to-work area, belonging to a multi-industry firm or being part of a conglomerate all increased the likelihood of higher absorptive capacity but only in services. Being located in a metropolitan area was detrimental for manufacturing, while belonging to a NZ-owned outward FDI firm was strongly beneficial in manufacturing and services. Having a link with an HEI was, all other things being equal, strongly associated with higher absorptive capacity. Operating in markets with many competitors but where several were dominant increased the likelihood of higher absorptive capacity in manufacturing and services. Agglomeration and operating in a concentrated industry had no impact, while being located in a travel-to-work area where there was higher diversity in terms of the breadth of

industries represented had a strong positive impact on having higher absorptive capacity, but only in manufacturing. Being foreign-owned was only beneficial in services. Moreover, firms with high (low) absorptive capacity maintained their relative position over time, suggesting a considerable degree of stability and thus that it takes a considerable period to build absorptive capacity (or to see it erode).

As to the productivity-enhancing role of absorptive capacity, and relative to other influences, the results showed that absorptive capacity as measured here – net of the impact of, for example, foreign-ownership and human capital – has a substantial influence on exporting, innovation and undertaking R&D, and consequently on firm-level productivity.

In terms of public policy, there has been limited policy assistance to build dynamic capabilities and thus absorptive capacity. The activities of NZTE and Callaghan Innovation, while important, are limited in this area. To understand how to increase absorptive capacity, it was argued that policymakers need to understand how firms can improve their dynamic capabilities to allow them to create new products and processes and to respond to changing market conditions. Key is the firm's problem-solving capability which involves building (through investment and learning) unique specialised assets and keeping the firm aligned with its business environment. This building and assembling of complementary intangible assets to assist knowledge creation and capture, can only be done within the firm and cannot be purchased from the market. Thus, policymakers must understand these learning and value capture processes in firms; they must encourage, build and sustain entrepreneurial managerial capitalism (see footnotes on p.27).

To put these concepts into practice, the approach advocated in the dynamic capabilities paradigm is for firms to identify how far they are from the 'capability frontier' after 'gaps' have been identified. Learning and transformation in the firm are vital, requiring leadership, teamwork, and strategic agility.

Building absorptive capacity and dynamic capabilities is generally not reflected in today's mainstream approaches to industrial policy, where developing networks and systems are favoured over directly helping firms. However, firms are unlikely to fully gain and benefit from external knowledge generated by networks and collaboration unless they have sufficient absorptive capacity.

Following the general election of October 2017, and the subsequent abandonment of the Business Growth Agenda, there is currently an opportunity to look at how government policy might be refreshed. We would recommend work to assess more fully how dynamic capabilities and absorptive capacity can be built in order to enhance activities that improve productivity. Obtaining more information through, for example, undertaking more work on how to foster and create entrepreneurial managerial capitalism, and bringing the relevant parties (key firms,

business organisations and government) together to plan for a new industrial policy focused on increasing absorptive capacity, will help provide policymakers with an improved conceptual lens to understand the learning and value capture processes inside firms.

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Appendix

Appendix Table 1: (Weighted) Factor loadings from PFA model, New Zealand, 2005-2015

Variable	External knowledge	National co-operation with business	Links with national researchers	Intl co-operation with researchers	Intl co-operation with business	KMO
Sources of knowledge/info for innovation						
customers	0.7484	–	–	–	–	0.9111
suppliers	0.7159	–	–	–	–	0.9066
other businesses	0.7276	–	–	–	–	0.9358
professional advisors, consultants, banks or accountants	0.6859	–	–	–	–	0.9403
books, journals, patent disclosures or Internet	0.6934	–	–	–	–	0.9422
conferences, trade shows or exhibitions	0.7068	–	–	–	–	0.9333
industry or employer organisations	0.6244	–	–	–	–	0.9258
universities or polytechnics	–	–	0.6572	–	–	0.8458
crown research institutes, other research institutes/associations	–	–	0.7144	–	–	0.8136
government agencies	–	–	0.5306	–	–	0.9137
Co-operation partners on innovation activities (national/international)						
national customers	–	0.7573	–	–	–	0.8566
national suppliers	–	0.7979	–	–	–	0.8252
other national businesses	–	0.7556	–	–	–	0.8866
national universities or polytechnics	–	–	0.5619	–	–	0.8068
national crown research institutes, other research institutes/associations	–	–	0.5981	–	–	0.7839
international customers	–	–	–	–	0.7125	0.8882
international suppliers	–	–	–	–	0.7753	0.8047
other international businesses	–	–	–	–	0.5915	0.8684
international universities or polytechnics	–	–	–	0.8901	–	0.6554
international crown research institutes, other research institutes/associations	–	–	–	0.9002	–	0.6408
New organisation, managerial or marketing processes						
new organisational or managerial processes	0.5932	–	–	–	–	0.9253
new marketing methods	0.5978	–	–	–	–	0.9246
Overall						0.8709

Only loadings>0.5 are shown. Note all 5 retained factors have eigenvalues>1. N=31,983 (randomly rounded to base 3)

Source: BOS surveys 2005-15 (6 waves covering every other year)

Appendix Table 2: (Weighted) means and standard deviations for variables, New Zealand, 2005-2015

Variable *x*:	Definition	Variable *x*:		Mean value of absorptive capacity		Source
		Mean	Std. Dev	*x* = 0	*x* = 1	
export	Whether firm sold goods & services outside NZ (coded 1)	0.181	0.385	0.003	0.036	BOS
innovation	Whether firm had product innovation in last 2 years (coded 1)	0.185	0.388	-0.010	0.074	BOS
R&D	Whether firm undertook R&D (coded 1)	0.078	0.268	0.000	0.087	BOS
External knowledge[a]	External knowledge latent variable (based on SEM)	0.000	1.000	na	na	
National cooperation with business[a]	National cooperation with business latent variable (based on SEM)	0.000	1.000	na	na	
Links with national researchers[a]	Links with national researchers latent variable (based on SEM)	0.000	1.000	na	na	
International cooperation with researchers[a]	International cooperation with researchers latent variable (based on SEM)	0.000	1.000	na	na	
International cooperation with business[a]	International cooperation with business latent variable (based on SEM)	0.000	1.000	na	na	
<20 employees	Whether firm employed <20 workers (coded 1)	0.698	0.459	0.017	0.000	LBD
20-49 employees	Whether firm employed 20-49 workers (coded 1)	0.203	0.402	0.000	0.010	LBD
50-99 employees	Whether firm employed 50-99 workers (coded 1)	0.054	0.226	0.000	0.017	LBD
100+ employees	Whether firm employed 100+ workers (coded 1)	0.045	0.208	0.000	0.028	LBD
No managers & professionals employed	Whether firm employed no managers & professionals (coded 1)	0.117	0.322	0.013	-0.012	BOS
1-5% managers & professionals employed	Whether firm employed 1-5% managers & professionals (coded 1)	0.062	0.242	-0.012	-0.002	BOS
6-20% managers & professionals employed	Whether firm employed 6-20% managers & professionals (coded 1)	0.388	0.487	-0.012	0.010	BOS
21-50% managers & professionals employed	Whether firm employed 21-50% managers & professionals (coded 1)	0.259	0.438	-0.012	0.020	BOS
>50% managers & professionals employed	Whether firm employed 51+% managers & professionals (coded 1)	0.174	0.379	-0.012	0.021	BOS
<5 years	Firms <5 years old (coded 1)	0.189	0.391	0.011	0.012[b]	LBD
5-9 years	Firms 5-9 years old (coded 1)	0.258	0.438	0.012	0.009	LBD
10-19 years	Firms 10-19 years old (coded 1)	0.321	0.467	0.012	0.010	LBD
20-49 years	Firms 20-49 years old (coded 1)	0.200	0.400	0.012	0.015	LBD
50+ years	Firms 50+ years old (coded 1)	0.032	0.176	0.012	0.013 [a]	LBD

Single-plant enterprise	Whether firm was a single-plant enterprise (coded 1)	0.488	0.500	0.015	0.006	LBD
Has plants in more than one TTWA	Firm has plants located in more than one labour market area (coded 1)	0.103	0.305	0.010	0.016	LBD
Multi-industry enterprise	Firm with (multi) plants in more than one ANSIC 4-digit industry (coded 1)	0.147	0.354	0.007	0.020	LBD
Belongs to a business group	Firm is part of a conglomerate (coded 1)	0.134	0.340	0.007	0.022	LBD
Metropolitan	Firm's primary plant is based in Auckland, Manukau, Wellington or Christchurch TTWAs	0.509	0.500	0.006	0.015	LBD
NZ-owned outward FDI	Whether firm belongs to a NZ enterprise with firms overseas (coded 1)	0.033	0.178	0.008	0.057	BOS
Not foreign-owned	Fully New Zealand owned firm (coded 1)	0.932	0.252	0.029	0.008	BOS
Part foreign-owned	Whether firm has <100% foreign ownership (coded 1)	0.023	0.151	0.008	0.036	BOS
Fully foreign-owned	Whether firm has 100% foreign ownership (coded 1)	0.045	0.207	0.008	0.026	BOS
Foreign-owned	Whether firm has any foreign ownership (coded 1)	0.068	0.252	0.008	0.029	BOS
Links with HEI	Whether firm sourced information or cooperated with HEI (coded 1)	0.091	0.287	0.005	0.186	BOS
0-2 competitors	(Self-assessed) Business competition involves 0-2 rivals (coded 1)	0.220	0.414	0.012	0.011 [b]	BOS
Many competitors, several dominant	(Self-assessed) Business competition involves any competitors, several dominant (coded 1)	0.528	0.499	0.011	0.015	BOS
Many competitors, none dominant	(Self-assessed) Business competition involves many competitors, none dominant (coded 1)	0.252	0.434	0.011	0.005	BOS
Auckland	Whether firm has its main presence in Auckland (coded 1)	0.331	0.470	0.009	0.015	LBD
Waikato	Whether firm has its main presence in the Waikato (coded 1)	0.088	0.283	0.015	0.010	LBD
Wellington	Whether firm has its main presence in Wellington (coded 1)	0.091	0.287	0.015	0.017 [b]	LBD
Rest of North Island	Whether firm has its main presence in rest of North Island (coded 1)	0.224	0.417	0.015	0.005	LBD
Canterbury	Whether firm has its main presence in Canterbury region (coded 1)	0.139	0.346	0.015	0.011	LBD
Rest of South Island	Whether firm has its main presence in rest of South Island (coded 1)	0.128	0.334	0.015	0.007	LBD
Herfindahl index	Herfindahl index of industry concentration (at 4-digit level)	0.042	0.085	na	na	
Agglomeration index	proportion of sales in each industry (36 ANZSIC sectors) in travel-to-work area in which firm mainly located	0.135	0.169	na	na	
Diversity index	proportion of 36 ANZSIC sectors with sales>0 in travel-to-work area in which firm located	0.808	0.162	na	na	
(unweighted) N	(unweighted, randomly rounded to base 3) number of observations	31,983				

[a] These variables have been standardised. [b] *t*-test of whether mean absorptive capacity difference was different between the two sub-groups (x=0,1) was not statistically significant at 1% level or better.

Appendix Table 3: Marginal effects of changing absorptive capacity (the median value to the 99 percentile) on exporting, innovation and R&D in NZ, 2005-2015 (by sector): various models

	Primary			Manufacturing			Services		
	Exporting	Innovation	**R&D**	**Exporting**	**Innovation**	**R&D**	**Exporting**	**Innovation**	**R&D**
Baseline model									
External knowledge	0.003	0.205***	0.032**	0.022**	0.498***	0.151***	0.053***	0.411***	0.062***
National cooperation with business	0.020	0.070***	0.183***	0.061***	0.112***	0.035***	0.024***	0.061***	0.000
Links with national researchers	0.125***	-0.009	0.004	0.085***	0.037	0.114***	-0.025***	-0.025***	0.030***
International cooperation with researchers	0.010	-0.009***	-0.008***	-0.010***	-0.022***	-0.011***	-0.002***	-0.006***	-0.001***
International cooperation with business	0.103***	0.043*	0.014	-0.018	0.400***	0.099***	0.026***	0.279***	0.057***
Matching model									
External knowledge	0.017	0.120***	-0.021	0.060***	0.408***	0.221***	0.040***	0.325***	0.043***
National cooperation with business	0.039	0.076*	0.280***	0.018	0.018	-0.009	0.022***	0.031***	-0.024***
Links with national researchers	0.091***	-0.003	0.047	0.012	-0.061*	0.060	-0.041***	-0.098***	0.065***
International cooperation with researchers	0.050	-0.107***	-0.097***	-0.099***	-0.222***	-0.121***	-0.019*	-0.086***	-0.021***
International cooperation with business	0.327***	0.270***	0.142*	0.025	0.329***	0.107**	0.045***	0.354***	0.140***
Wooldridge model									
External knowledge	0.119***	0.253***	0.049***	0.020**	0.376***	0.143***	0.042***	0.294***	0.054***
National cooperation with business	-0.023	0.026*	0.119***	0.079***	0.110***	0.027***	0.042***	0.049***	-0.008**
Links with national researchers	0.010	-0.041***	-0.022**	0.016	0.042**	0.035***	-0.034***	-0.025***	0.030***
International cooperation with researchers	-0.002	-0.006***	-0.003	-0.006***	-0.019***	-0.007***	-0.003***	-0.005***	-0.002***
International cooperation with business	0.110**	0.050***	0.003	-0.062***	0.318***	0.046***	0.012***	0.221***	0.053***

***/**/* indicates significance levels at the 1/5/10% levels.

Source: See text for details.

Appendix Table 4: Equation-level goodness of fit of (weighted) SEM model

	Variance				
	fitted	predicted	residual	mc	mc^2
Observed					
customers	0.208	0.098	0.110	0.685	0.470
suppliers	0.188	0.079	0.110	0.647	0.418
other businesses	0.205	0.095	0.110	0.681	0.463
professional advisors, consultants, banks or accountants	0.184	0.076	0.108	0.644	0.415
books, journals, patent disclosures or Internet	0.175	0.080	0.095	0.676	0.457
conferences, trade shows or exhibitions	0.177	0.084	0.093	0.690	0.476
industry or employer organisations	0.129	0.047	0.082	0.604	0.365
new organisational or managerial processes	0.171	0.049	0.122	0.537	0.288
new marketing methods	0.171	0.048	0.123	0.530	0.281
national customers	0.051	0.031	0.021	0.774	0.598
national suppliers	0.055	0.035	0.020	0.799	0.639
other national businesses	0.068	0.036	0.031	0.733	0.537
source of knowledge: universities or polytechnics	0.045	0.014	0.031	0.550	0.303
source of knowledge: crown research institutes, other research institutes/associations	0.029	0.004	0.020	0.606	0.367
source of knowledge: government agencies	0.051	0.015	0.036	0.547	0.299
co-operation with national universities or polytechnics	0.016	0.004	0.014	0.332	0.110
co-operation with national crown research institutes, other research institutes/associations	0.014	0.002	0.012	0.400	0.160
international universities or polytechnics	0.005	0.004	0.002	0.840	0.706
international crown research institutes, other research institutes/associations	0.005	0.003	0.001	0.821	0.674
international customers	0.013	0.003	0.010	0.477	0.228
international suppliers	0.022	0.007	0.015	0.567	0.321
other international businesses	0.020	0.010	0.011	0.688	0.474
exporter	0.148	0.004	0.144	0.166	0.027
R&D	0.072	0.009	0.063	0.353	0.125
product innovation	0.150	0.033	0.117	0.467	0.218
Latent					
External knowledge	0.098	0.044	0.054	0.669	0.448
National cooperation with business	0.031	0.016	0.015	0.716	0.512
Links with national researchers	0.014	0.005	0.008	0.612	0.374
International cooperation with researchers	0.004	0.000	0.004	0.252	0.064
International cooperation with business	0.003	0.001	0.002	0.630	0.397

mc = correlation between the dependent variable and its prediction
mc^2 = the Bentler-Raykov squared multiple correlation coefficient

Appendix Table 5: Correlations between ACs indices from SEM and Factor Analysis (FA) models

	External knowledge (FA)	**National co-operation with business (FA)**	**Links with national researchers (FA)**	**Intl co-operation with researchers (FA)**	**Intl co-operation with business (FA)**	**External knowledge (SEM)**	**National co-operation with business (SEM)**	**Links with national researchers (SEM)**	**Intl co-operation with researchers (SEM)**	**Intl co-operation with business (SEM)**
External knowledge (FA)	1.000	.	.	.	.	.	.	.	.	.
National cooperation with business (FA)	0.027	1.000	.	.	.	.	.	.	.	.
Links with national researchers (FA)	0.035	0.092	1.000	.	.	.	.	.	.	.
International cooperation with researchers (FA)	0.010	0.012	0.012	1.000	.	.	.	.	.	.
International cooperation with business (FA)	0.034	0.056	0.114	-0.014	1.000	.	.	.	.	.
External knowledge (SEM)	*0.949*	0.176	0.284	0.049	0.169	1.000	.	.	.	.
National cooperation with business (SEM)	0.365	*0.865*	0.259	0.125	0.290	0.534	1.000	.	.	.
Links with national researchers (SEM)	0.542	0.288	*0.769*	0.103	0.225	0.728	0.634	1.000	.	.
International cooperation with researchers (SEM)	0.079	0.150	0.130	*0.950*	0.206	0.181	0.311	0.263	1.000	.
International cooperation with business (SEM)	0.313	0.351	0.248	0.406	*0.781*	0.490	0.657	0.540	0.598	1.000
Absorptive capacity (SEM)	0.634	0.560	0.353	0.160	0.455	0.799	0.868	0.775	0.365	0.806

N= 31,983 (randomly rounded to base 3)

Appendix Table 6: (Weighted) means and standard deviations for variables New Zealand, 2005-2015, by sector

Variables	Primary sector		Manufacturing		Services		All sectors	
	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev
External knowledge	-0.060	0.263	0.037	0.302	-0.000	0.290	0.000	0.291
National cooperation with business	-0.018	0.131	0.022	0.190	-0.002	0.156	-0.000	0.160
Links with national researchers	0.000	0.114	0.012	0.112	-0.002	0.093	0.000	0.098
International cooperation with researchers	0.000	0.060	0.002	0.065	-0.000	0.054	-0.000	0.056
International cooperation with business	-0.005	0.041	0.007	0.056	-0.001	0.043	-0.000	0.045
Overall Absorptive capacity	-0.010	0.045	0.012	0.064	-0.001	0.051	-0.000	0.053
export	0.285	0.452	0.395	0.489	0.126	0.332	0.181	0.385
Innovation (product innovation only)	0.081	0.273	0.296	0.456	0.175	0.380	0.185	0.388
R&D	0.069	0.254	0.175	0.380	0.060	0.237	0.078	0.268
Product or process innovation	0.175	0.380	0.390	0.488	0.265	0.441	0.276	0.447
Product, process, market, business innovation	0.267	0.443	0.433	0.496	0.394	0.489	0.389	0.487
<20 employees	0.750	0.433	0.612	0.487	0.708	0.454	0.698	0.459
20-49 employees	0.189	0.391	0.246	0.431	0.197	0.397	0.203	0.402
50-99 employees	0.039	0.195	0.076	0.265	0.051	0.220	0.054	0.226
100+ employees	0.022	0.146	0.066	0.249	0.044	0.205	0.045	0.208
No managers & professionals employed	0.206	0.405	0.072	0.259	0.116	0.320	0.117	0.322
1-5% managers & professionals employed	0.131	0.337	0.063	0.243	0.054	0.226	0.062	0.242
6-20% managers & professionals employed	0.372	0.483	0.488	0.500	0.370	0.483	0.388	0.487
21-50% managers & professionals employed	0.231	0.421	0.321	0.467	0.250	0.433	0.259	0.438
>50% managers & professionals employed	0.061	0.239	0.056	0.229	0.211	0.408	0.174	0.379
<5 years	0.175	0.380	0.139	0.346	0.200	0.400	0.189	0.391
5-9 years	0.271	0.445	0.216	0.411	0.265	0.442	0.258	0.438
10-19 years	0.332	0.471	0.304	0.460	0.323	0.468	0.321	0.467
20-49 years	0.203	0.403	0.294	0.456	0.181	0.385	0.200	0.400
50+ years	0.018	0.134	0.046	0.210	0.031	0.172	0.032	0.176

Single-plant enterprise	0.615	0.487	0.483	0.500	0.474	0.499	0.488	0.500
Has plants in more than one TTWA	0.057	0.232	0.107	0.310	0.108	0.311	0.103	0.305
Multi-industry enterprise	0.131	0.338	0.216	0.412	0.135	0.342	0.147	0.354
Belongs to a business group	0.105	0.307	0.172	0.377	0.130	0.336	0.134	0.340
Metropolitan	0.114	0.318	0.542	0.498	0.548	0.498	0.509	0.500
NZ-owned outward FDI	0.021	0.144	0.060	0.237	0.029	0.168	0.033	0.178
Foreign-owned	0.047	0.213	0.094	0.292	0.066	0.248	0.068	0.252
Not foreign-owned	0.953	0.213	0.906	0.292	0.934	0.248	0.932	0.252
Part foreign-owned	0.032	0.175	0.035	0.183	0.020	0.141	0.023	0.151
Fully foreign-owned	0.016	0.125	0.059	0.236	0.045	0.208	0.045	0.207
Links with HEI	0.018	0.134	0.032	0.175	0.018	0.134	0.020	0.141
0-2 competitors	0.240	0.427	0.241	0.428	0.214	0.410	0.220	0.414
Many competitors, several dominant	0.400	0.490	0.553	0.497	0.537	0.499	0.528	0.499
Many competitors, none dominant	0.360	0.480	0.205	0.404	0.249	0.432	0.252	0.434
Auckland	0.061	0.239	0.371	0.483	0.354	0.478	0.331	0.470
Waikato	0.109	0.311	0.087	0.282	0.086	0.280	0.088	0.283
Wellington	0.028	0.164	0.065	0.247	0.103	0.304	0.091	0.287
Rest of North Island	0.423	0.494	0.207	0.405	0.204	0.403	0.224	0.417
Canterbury	0.160	0.366	0.146	0.353	0.135	0.342	0.139	0.346
Rest of South Island	0.220	0.414	0.124	0.329	0.118	0.322	0.128	0.334
Herfindahl index	0.026	0.065	0.099	0.148	0.033	0.062	0.042	0.085
Agglomeration index	0.086	0.127	0.151	0.182	0.137	0.169	0.135	0.169
Diversity index	0.671	0.164	0.825	0.152	0.821	0.156	0.808	0.162
(unweighted) N (randomly rounded to base 3)	3,291		7,569		21,123		31,983	

Appendix Table 7: (Weighted) Estimates of (stepwise) random-effects probit models determining exporting, R&D and innovation, NZ, 2005-2015 (by sector) – marginal effects reported (Wooldridge model)

	Primary			Manufacturing			Services		
	Exporting	**Innovation**	**R&D**	**Exporting**	**Innovation**	**R&D**	**Exporting**	**Innovation**	**R&D**
$export_{t-1}$	0.138***	-0.003	-0.007	0.335***	0.012**	0.005	0.185***	0.024***	0.015***
$innovation_{t-2}$	0.007	-0.006	0.022***	0.000	-0.013**	0.013***	-0.001	0.006**	0.001
$R\&D_{t-1}$	-0.004	0.004	0.088***	0.006	0.076***	0.148***	0.019***	0.068***	0.166***
$export_0$	0.591***	–	–	0.460***	–	–	0.521***	–	–
$innovation_0$	–	0.436***		–	0.397***	–	–	0.357***	–
$R\&D_0$	–	–	0.346***	–	–	0.434***	–	–	0.325***
External knowledge[a]	0.033***	0.036***	0.012***	0.007**	0.089***	0.035***	0.012***	0.062***	0.014***
National cooperation with business[a]	-0.006	0.005**	0.016***	0.017***	0.022***	0.006***	0.008***	0.011***	-0.002**
Links with national researchers[a]	0.002	-0.012***	-0.006**	0.003	0.009**	0.007***	-0.011***	-0.007***	0.007***
International cooperation with researchers[a]	-0.002	-0.009***	-0.004	-0.008***	-0.029***	-0.010***	-0.005***	-0.010***	-0.004***
International cooperation with business[a]	0.028***	0.011***	0.001	-0.013***	0.049***	0.008***	0.003***	0.042***	0.011***
20-49 employees	-0.010	0.007	0.003	0.004	0.006	0.024***	-0.010***	0.000	0.002
50-99 employees	-0.016	0.023***	0.033***	0.018**	-0.016*	0.013*	-0.013***	0.001	0.009***
100+ employees	-0.028*	0.005	0.032**	0.007	-0.005	0.034***	-0.012***	-0.010**	0.017***
1-5% managers & professionals employed	-0.066***	0.035***	-0.006	0.035***	0.008	0.047***	0.015***	0.023***	0.010***
6-20% managers & professionals employed	-0.101***	0.002	0.017**	0.059***	0.021*	0.035***	-0.004	0.014***	0.033***
21-50% managers & professionals employed	-0.075***	0.016**	0.042***	0.073***	0.009	0.041***	0.010***	0.006	0.027***
>50% managers & professionals employed	-0.085***	0.023**	0.002	0.099***	0.013	0.044***	-0.001	0.028***	0.052***
5-9 years	-0.032**	-0.016*	-0.026**	-0.016	-0.013	-0.026***	-0.023***	0.017***	0.014***
10-19 years	-0.058***	-0.019*	-0.022**	-0.010	-0.018	-0.019**	-0.015***	0.016***	0.009***
20-49 years	-0.025*	-0.016*	-0.025**	-0.023**	-0.019	-0.030***	-0.011***	0.010**	0.012***
50+ years	-0.099***	-0.066***	-0.071***	-0.006	-0.039**	-0.051***	-0.014***	-0.004	0.018***
Single-plant enterprise	-0.006	0.013**	0.028***	0.012**	0.007	0.004	0.004**	-0.005**	0.011***
Has plants in more than one TTWA	0.080***	0.049***	0.016	-0.018**	0.009	-0.033***	0.010***	-0.012***	0.000
Multi-industry enterprise	0.066***	-0.002	0.057***	0.036***	0.027***	-0.003	0.026***	0.023***	0.001
Belongs to a business group	-0.056***	-0.004	-0.001	-0.003	-0.014**	0.003	0.002	0.021***	-0.006***
Metropolitan	-0.031**	-0.008	-0.007	-0.039***	-0.032***	0.022***	0.003	-0.005	0.013***
NZ-owned outward FDI	-0.125***	0.018	0.065***	0.041***	0.051***	0.008	0.011***	-0.000	0.019***
Part foreign-owned	0.041***	0.025*	0.034**	-0.014	-0.036***	-0.026***	0.010**	-0.021***	0.014***
Fully foreign-owned	0.320***	-0.014	-0.003	0.002	-0.008	-0.003	0.008***	0.020***	-0.001
Links with HEI	-0.041	0.016	0.061**	0.042**	-0.087***	0.002	0.001	-0.086***	-0.017***
Many competitors, several dominant	0.080***	-0.005	0.006	-0.006	-0.024***	0.000	0.017***	-0.006**	0.002
Many competitors, none dominant	0.074***	-0.013**	0.014***	0.013**	-0.029***	-0.007	0.021***	0.001	-0.005**
Herfindahl index	-0.002	0.006***	-0.002	0.007***	0.002	-0.000	-0.004***	0.001	0.000
Agglomeration index	0.018***	0.006***	0.005**	0.006***	0.002	0.005***	0.004***	0.003***	-0.002***

Diversity index	0.027*	0.010	0.014	-0.005	-0.005	-0.025**	0.016***	-0.007	-0.012**
Waikato	-0.018	0.007	-0.001	-0.062***	-0.026*	0.038***	0.000	0.028***	-0.014***
Wellington	0.035	0.043**	0.030	0.012	0.006	0.022***	-0.006**	0.003	-0.007***
Rest of North Island	-0.055***	0.013	-0.016	-0.036***	-0.022*	0.027***	0.004	0.002	0.008**
Canterbury	-0.017	0.001	-0.025**	0.002	-0.023***	0.019***	0.014***	-0.016***	0.006***
Rest of South Island	0.003	0.027**	0.009	-0.051***	-0.042***	0.011	0.005	-0.020***	0.001
Year 2009	-0.007	0.010	0.022***	-0.026***	0.014*	0.016***	0.007***	0.009***	0.022***
Year 2011	-0.004	-0.015***	0.023***	0.024***	0.003	0.021***	0.003	0.004	0.021***
Year 2013	0.020**	-0.014**	0.026***	0.064***	-0.024***	0.022***	0.027***	-0.003	0.025***
Year 2015	0.021**	-0.008	0.014**	0.044***	-0.012	0.001	0.046***	-0.007**	0.036***
Mining	-0.112***	-0.001	-0.011	–	–	–	–	–	–
Services to agriculture, Hunting and trapping	-0.060***	-0.000	0.019***	–	–	–	–	–	–
Forestry and logging	-0.066***	0.003	0.005	–	–	–	–	–	–
Commercial fishing	0.011	-0.008	0.022	–	–	–	–	–	–
Textile, clothing, footwear and leather	–	–	–	0.015	0.001	-0.014	–	–	–
Wood and paper product and Printing	–	–	–	-0.019**	-0.029***	-0.022***	–	–	–
Non-metallic mineral and Metal product	–	–	–	-0.005	0.040***	0.007	–	–	–
Petroleum, coal, chemical and associated product	–	–	–	-0.029***	-0.009	-0.021***	–	–	–
Machinery and equipment	–	–	–	0.007	0.010	-0.012*	–	–	–
Other manufacturing	–	–	–	-0.036***	0.024*	-0.037***	–	–	–
Wholesale trade	–	–	–	–	–	–	0.045***	0.001	0.004
Retail and Hospitality	–	–	–	–	–	–	0.020***	-0.041***	0.003
Transport, Communication, Finance	–	–	–	–	–	–	0.019***	-0.035***	-0.002
Property services	–	–	–	–	–	–	0.011**	-0.050***	-0.005
Business services	–	–	–	–	–	–	0.027***	-0.028***	-0.013***
Other services	–	–	–	–	–	–	0.003	-0.027***	-0.012***
Observations	1,602	1,602	1,602	4,539	4,539	4,539	11,370	11,370	11,370
No. of enterprises	717	717	717	1,761	1,761	1,761	4,890	4,890	4,890
Pseudo log-likelihood	-1854	-973.7	-909.1	-4542	-5726	-3400	-12556	-20008	-9123
McFadden's Pseudo-R^2	0.527	0.483	0.543	0.492	0.383	0.479	0.481	0.366	0.431
Nagelkerke's Pseudo-R^2	0.931	0.750	0.807	0.873	0.805	0.792	0.883	0.873	0.748

Definitions of variables are provided in Appendix Table 2. A table with standard errors is available on request. ***/**/* indicates significance levels at the 1/5/10% levels. Numbers of observations have been randomly rounded to base 3 to protect confidentiality.

[a] Note absorptive capacity variables have been standardised with mean 0 and standard deviation of 1, so marginal effects show the impact of a one-standard deviation increase.

Appendix Table 8: (Weighted) Estimates of (stepwise) random-effects probit models determining exporting, R&D and innovation, NZ, 2005-2015 (by sector) – marginal effects reported ('matched' model)

	Primary			Manufacturing			Services		
	Exporting	**Innovation**	**R&D**	**Exporting**	**Innovation**	**R&D**	**Exporting**	**Innovation**	**R&D**
$export_{t-1}$	0.590***	0.018	-0.004	0.648***	0.041***	0.054***	0.544***	0.096***	0.059***
$innovation_{t-2}$	0.024	0.126***	0.079***	0.005	0.177***	0.079***	0.023***	0.191***	0.024***
$R\&D_{t-1}$	0.030	-0.021	0.410***	0.044***	0.158***	0.453***	0.046***	0.124***	0.391***
External knowledge[a]	0.007	0.036***	-0.009	0.025***	0.166***	0.074***	0.016***	0.115***	0.017***
National cooperation with business[a]	0.008	0.014**	0.035***	0.004	0.004	-0.002	0.005***	0.007***	-0.006***
Links with national researchers[a]	0.016**	-0.001	0.008*	0.002	-0.012*	0.010*	-0.010***	-0.024***	0.012***
International cooperation with researchers[a]	0.007	-0.030***	-0.025***	-0.014***	-0.035***	-0.020***	-0.003*	-0.016***	-0.004**
International cooperation with business[a]	0.042***	0.028***	0.016**	0.004	0.054***	0.016***	0.009***	0.065***	0.021***
20-49 employees	-0.038**	0.023*	-0.045***	0.048***	-0.026**	0.076***	0.015***	0.005	0.019***
50-99 employees	-0.093***	0.089***	0.034*	0.081***	-0.101***	0.034**	-0.001	0.010	0.028***
100+ employees	-0.058**	0.031	0.047*	0.079***	-0.075***	0.060***	-0.006	-0.001	0.022***
1-5% managers & professionals employed	-0.056**	0.010	-0.004	-0.036	-0.104***	0.082***	0.028***	0.025	0.034***
6-20% managers & professionals employed	-0.113***	-0.036*	0.028*	0.009	-0.128***	0.025	0.069***	-0.022**	0.067***
21-50% managers & professionals employed	-0.056**	0.013	0.075***	0.053**	-0.204***	0.036	0.101***	-0.024**	0.053***
>50% managers & professionals employed	-0.128***	0.064*	0.001	0.085***	-0.135***	0.051*	0.089***	0.017	0.104***
5-9 years	-0.073***	-0.083***	0.017	-0.093***	-0.036	-0.034*	0.003	0.003	0.024***
10-19 years	-0.074***	-0.102***	-0.023	-0.072***	-0.031	-0.005	0.003	-0.001	0.000
20-49 years	-0.016	-0.075***	-0.017	-0.121***	-0.016	-0.029	0.006	-0.041***	0.009
50+ years	-0.029	-0.191***	0.036	-0.081***	-0.068**	-0.005	-0.051***	-0.091***	0.046***
Single-plant enterprise	-0.013	0.020	0.025**	0.022**	-0.028*	0.004	0.013***	0.017***	0.023***
Has plants in more than one TTWA	0.035	0.040	0.013	-0.017	-0.040**	-0.067***	0.024***	0.009	0.006
Multi-industry enterprise	0.077***	-0.032**	0.053***	0.041***	0.005	-0.020	0.024***	0.053***	0.008
Belongs to a business group	-0.009	-0.002	0.005	-0.031***	0.034**	0.008	-0.005	0.030***	-0.003
Metropolitan	-0.051**	-0.009	0.010	0.005	0.046*	-0.019	0.021***	0.011	0.021***
NZ-owned outward FDI	-0.123***	0.037	-0.017	0.080***	0.076***	0.042***	0.071***	-0.006	0.056***
Part foreign-owned	0.121***	0.062*	0.057**	-0.085***	-0.036	-0.036	0.008	0.003	-0.001
Fully foreign-owned	0.199***	-0.032	-0.004	0.018	-0.024	0.028	0.011**	0.084***	-0.020***
Links with HEI	-0.087**	0.123***	0.242***	0.052**	-0.110***	0.053**	0.001	-0.129***	-0.002
Many competitors, several dominant	-0.001	-0.059***	-0.002	-0.003	-0.032**	-0.026**	0.014***	-0.025***	-0.010**
Many competitors, none dominant	0.050***	-0.105***	0.013	0.023*	-0.014	-0.021	0.010**	-0.010	-0.021***
Herfindahl index	-0.009**	0.032***	-0.007**	0.002	0.005	0.006	-0.006***	-0.003	-0.001
Agglomeration index	0.051***	-0.018***	0.016***	-0.004	0.002	0.010**	0.006***	-0.006**	-0.003*
Diversity index	-0.003	0.120***	0.104***	0.002	0.002	0.038	0.035**	0.099***	0.015
Waikato	-0.095***	-0.049	0.068***	-0.037*	0.020	0.066***	-0.014	0.081***	0.012
Wellington	0.007	-0.001	0.107***	-0.004	-0.009	0.065***	-0.013**	-0.026***	-0.011**

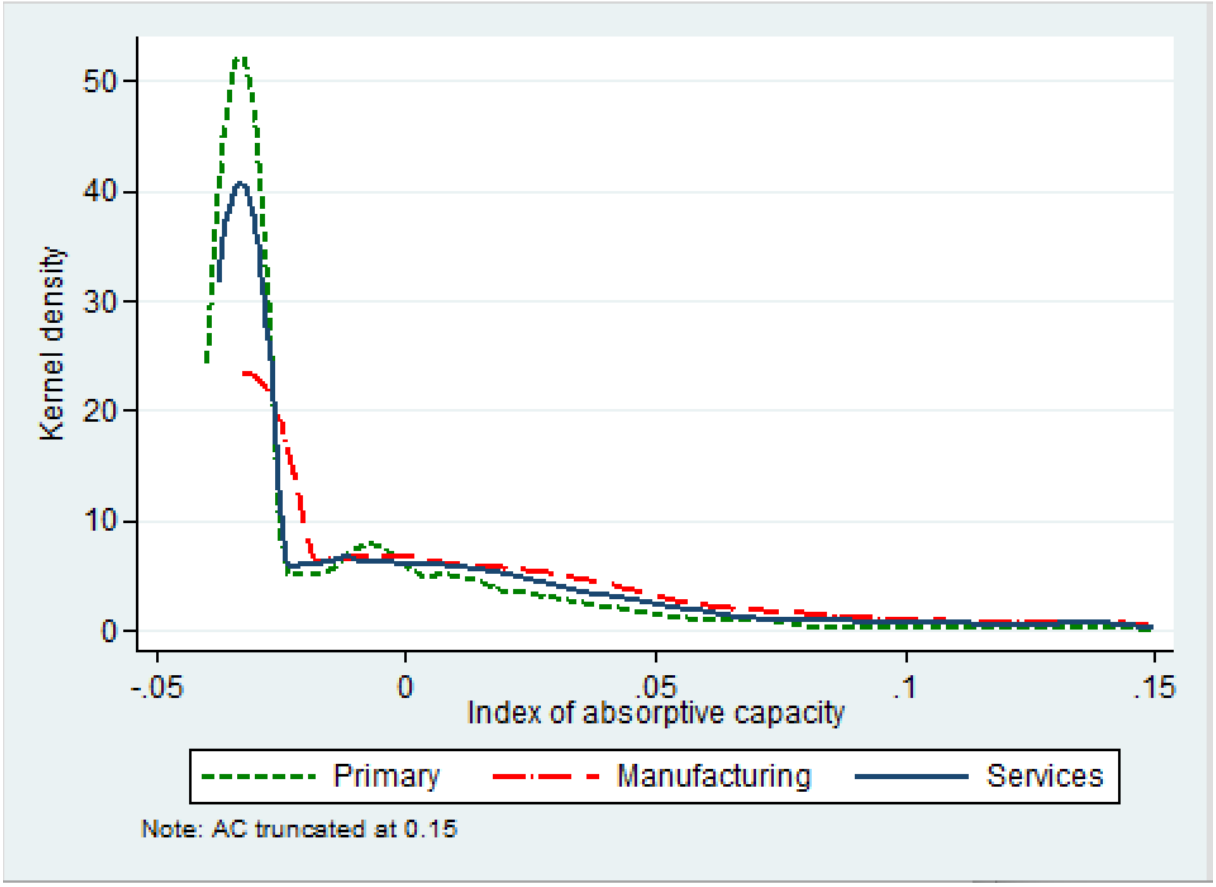
Rest of North Island	-0.058*	-0.010	0.043***	-0.014	0.036	-0.001	-0.007	0.009	0.030***
Canterbury	-0.043	-0.085***	-0.012	0.008	-0.048***	0.006	-0.005	-0.036***	0.003
Rest of South Island	0.024	-0.009	0.141***	0.006	-0.007	-0.016	0.008	-0.012	-0.020***
Year 2009	-0.010	0.025	0.014	-0.057***	0.045***	-0.000	0.011***	0.008	0.051***
Year 2011	-0.014	-0.023	0.045***	0.010	0.016	0.040***	0.016***	0.037***	0.048***
Year 2013	0.006	-0.031**	0.030**	0.067***	0.012	0.048***	0.034***	0.005	0.052***
Year 2015	0.065***	-0.023	0.053***	0.027**	-0.018	0.025*	0.075***	0.007	0.061***
Mining	-0.137***	-0.017	-0.029	–	–	–	–	–	–
Services to agriculture, Hunting and trapping	-0.064***	0.030*	0.014	–	–	–	–	–	–
Forestry and logging	-0.073***	-0.044***	0.044*	–	–	–	–	–	–
Commercial fishing	-0.089**	0.020	0.076*	–	–	–	–	–	–
Textile, clothing, footwear and leather	–	–	–	-0.024	-0.023	0.003	–	–	–
Wood and paper product and Printing	–	–	–	-0.083***	-0.035*	-0.041**	–	–	–
Non-metallic mineral and Metal product	–	–	–	-0.014	0.071***	0.009	–	–	–
Petroleum, coal, chemical and associated product	–	–	–	-0.066***	0.010	-0.036**	–	–	–
Machinery and equipment	–	–	–	-0.024*	-0.005	-0.012	–	–	–
Other manufacturing	–	–	–	-0.091***	0.053**	-0.073***	–	–	–
Wholesale trade	–	–	–	–	–	–	0.093***	0.077***	-0.001
Retail and Hospitality	–	–	–	–	–	–	0.012**	0.006	-0.024***
Transport, Communication, Finance	–	–	–	–	–	–	0.018**	0.035***	-0.007
Property services	–	–	–	–	–	–	0.023**	-0.013	0.017
Business services	–	–	–	–	–	–	0.019***	0.001	-0.030***
Other services	–	–	–	–	–	–	-0.026***	0.024**	-0.043***
Observations	819	819	819	2,304	2,304	2,304	5,877	5,877	5,877
No. of enterprises	477	477	477	1,245	1,245	1,245	3,387	3,387	3,387
Pseudo log-likelihood	-1240	-1094	-780.6	-2460	-3493	-2805	-7840	-16001	-8344
McFadden's Pseudo-R^2	0.423	0.223	0.416	0.432	0.256	0.309	0.392	0.187	0.276
Nagelkerke's Pseudo-R^2	0.896	0.554	0.772	0.822	0.658	0.683	0.831	0.716	0.675
Rubin's B[b]		23.4			14.9			10.7	
Rubin's R[b]		1.2			1.0			0.9	

Definitions of variables are provided in Appendix Table 2. A table with standard errors is available on request. ***/**/* indicates significance levels at the 1/5/10% levels. Numbers of observations have been randomly rounded to base 3 to protect confidentiality.

[a] Note: absorptive capacity variables have been standardised with mean 0 and standard deviation of 1, so marginal effects show the impact of a one-standard deviation increase.

[b] Measure of appropriateness of the overlap between the 'treatment' and 'control' groups (acceptable if B<25% and 0.5<R<2). See Rubin (2001). Other tests based on 'pstest' in STATA are available on request, which confirm that 'matching' has been done on well-defined sub-groups.

Appendix Figure 1: (Weighted) Absorptive capacity indices by firm sector, New Zealand, 2005-2015



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