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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' (generally defined as a firm's ability to internalise external knowledge) for firms. Using data principally from the Business Operations Survey 2005–15, we measure absorptive capacity in New Zealand (NZ) firms 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—net of the impact of, for example, foreign-ownership and human capital—has a substantial influence on exporting, innovation and undertaking R&D, and thus consequently firm-level productivity. Set against relatively poor productivity performance, the paper concludes with a discussion of how government should consider helping firms to boost their levels of absorptive capacity in NZ.

Key words: exports; R&D; innovation; absorptive capacity.

1. Introduction

To the best of our knowledge, using data from the New Zealand (NZ) Business Operation Survey 2005–15, this paper reports the first set of nationally representative results on the importance of 'absorptive capacity' (generally defined as a firm's ability to internalise external knowledge) for firms. Like the ability of an individual to learn, absorptive capacity is not just about firms being able to benefit from spillovers but rather using knowledge from the external environment to improve their productivity; if firms are not able to learn, then new strategies or technology that are designed to help firms become more productive are likely to have only limited impact.

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 NZ was through its 'Business Growth Agenda' (BGA 2012), with the major aim of '… building a stronger economy by creating conditions for firms to be more productive and internationally competitive'. (BGA 2012: 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 2012–16 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' (BGA 2017: 27).

The main aim of this paper is to seek 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 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, so as to 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 NZ's productivity problem as identified by the Productivity Commission, as well as past industrial policy in NZ (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, separately for primary, manufacturing and services. The paper concludes by returning to the question of specifically whether policy (cf. the BGA) did enough to build sufficient absorptive capacity to help boost productivity—which is so vital to long-term growth—and if not, how should policy now change (and in which direction)?

2. Low productivity and industrial policy in NZ

This section begins with a short overview of how productivity compares in NZ 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. Figures 1.1 and 1.4 in OECD (2017) show clearly that NZ underperformed compared to similar developed OECD countries, and in particular its nearest geographical rival Australia.[2]

The main reasons for this underperformance have been summarised in Conway (2016). First, is the barriers to diffusing best practice technology to (smaller) domestic firms in NZ, and this is related to inadequate stocks of knowledge-based intangible assets in such firms (such as management know-how and innovation capacity). This is also linked to the limitations placed on firms due to market size and geography; NZ is small and located far from large international markets, making exporting and (outward and inward) FDI relatively more important for overcoming these limitations, with internationalisation generally requiring 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 NZ firms, through spillovers, again because of inadequate knowledge-based intangible assets (and thus absorptive capacity)—see MBIE (2014), Doan et al. (2015), and Conway et al. (2015) for evidence. In general, NZ 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 per cent (NZ), 1.65 per cent (OECD average), 1.19 per cent (Australia), and 1.99 per cent (USA). Firms in NZ tend to have limited connectivity with (domestic) research institutions, and in general limited international connections, which Wakeman and Le (2015) have shown 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 (Green et al. (2011) found that there is a substantial tail of mediocre and poorly-managed firms in NZ); 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: 48).

The above description suggests that a lack of investment in intangible assets—and thus lower absorptive capacity—is likely to be a major reason for NZ's productivity problem; and yet this is not reflected in how policymakers have sought to solve the problem. Until recently the major approach to helping NZ firms was through the operation of the 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: 29).

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] the latter are recognised as a key driver of enterprise performance (Eustace 2000; Corrado et al. 2011; Haskel 2015) and thus ultimately aggregate productivity, and their role derives from the 'resource-based' theory of the firm (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. And 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 which presupposes the firm having invested in its own internal absorptive capacity, with the latter 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: 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, 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).

Good examples of this type of approach are provided by Flatten et al. (2015; Appendix), Camisón and Forés (2010; Appendix), and Cho (2014; Table 1). As an illustration, Table 1 shows the results obtained by Camisón and Forés (2010) based on 952 Spanish firm responses in 2007; they asked firms to rank how well they did in each area relative to their competitors using a Likert scale ranging from 1 to 5, and then undertook factor analysis to obtain principal component indices capturing the latent variables potential and realised absorptive capacity.

Most other (recent) studies use a similar method to combine and represent the survey data collected. Clearly, 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, when using firm-level information economists generally prefer to use larger, more nationally representative data (often collected by government agencies) that is more objective[8] since surveyed firms are asked to state if certain activities are taking place (rather than, as in Table 1, rank their self-assessed ability to search, obtain and use information, and adapt existing technologies using such new information); and it is more generalizable since it is obtained from large datasets covering many countries and often for significant time periods. For example, Harris and Li (2009) and Harris and Yan (2017), used nationally representative data from the establishment-level Community Innovation Survey (CIS) that has been carried out in the UK (and other European Union (EU) Member States)[9] by the Office for National Statistics (and other relevant EU members' government agencies) over several years. Here we use nationally representative data from the comparable firm-level NZ Business Operation Survey (BOS, 2005–15), which asks very similar questions to those contained in the EU CIS surveys.[10]

The advantage of using BOS data is that firms are asked to report information on key elements of organisational learning and networking processes that show the extent to which a firm actually has absorptive capacity, that is, whether and to what extent external sources of knowledge or information are used when undertaking innovation activities, as well as their importance;[11] partnerships with external bodies on innovation co-operation;[12] and the introduction of any changes in organisational or management processes and/or new marketing methods;[13] all of which can be related to capturing external knowledge spillovers and developing internal capabilities which make up absorptive capacity. Such data are objective in that firms are asked to state if certain activities are taking place (rather than, e.g. rank their self-assessed ability to search, obtain and use information and adapt existing technologies using such new information); and it is more generalisable since it is obtained from large datasets covering many countries and for significant time periods.

We start by using factor analysis, with Table A.1 (in the Appendix) showing 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 statistically confirmed by estimating a structural equation model, which also included twenty-four covariances between the endogenous variables modelled. The results are presented in Table 2[14] (Table S.1 in the Supplementary Appendix provides the equation-level goodness of fit statistics for the Structural Equation Model (SEM) suggesting the model is appropriately specified).[15] The absorptive capacity indices based on the SEM model are preferred, since they show the significance of the relationships being estimated and also allow for a residual term in constructing each latent variable, as well as including 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 Table S.2).

4. Which NZ firms have higher levels of absorptive capacity?

To set the scene, Fig. 1 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 (NZ multinationals) generally had higher absorptive capacity throughout (their distribution lies to the right of the distributions of other sub-groups); followed by partly-foreign-owned firms (less than 100 per cent foreign ownership) and then fully-foreign-owned; and finally domestic firms had the lowest levels of absorptive capacity. The second panel shows that firms that undertook R&D followed by innovators/exporters had the highest levels of absorptive capacity, significantly above those that did none of these activities.

Larger firms had higher absorptive capacity, while firms employing greater relative numbers of professionals, managers, technicians, and associate professional staff (and thus having an overall higher stock of human capital) had significantly better absorptive capacity levels. The final panel in Fig. 1 shows that firms primarily engaged in manufacturing, and then services, performed the best, while the primary sector (dominated by agriculture) tended to have lower absorptive capacity. These results are as generally expected; a wider set of results (showing which firm level characteristics are *associated* with different levels of absorptive capacity) are presented in Table 3.[16] Separately for the primary, manufacturing and service sectors, absorptive capacity was divided into quartiles[17] and (stepwise) ordered probit models were estimated, to provide an indication of which factors are most highly correlated with absorptive capacity (Table A.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

Table 1. Factor loadings from PFA absorptive capacity model used by Camisón and Forés (2010).

Underlying questions[a]	Potential	Realised
Acquisition capacity		
Capacity to capture relevant, continuous, and up-to-date information and knowledge on current and potential suppliers	0.353	
Degree of management orientation towards waiting to see what happens, instead of concern for and orientation towards their environment to monitor trends continuously and ranging widely and to discover new opportunities to be exploited proactively	0.628	
Frequency and importance of cooperation with R&D organisations—universities, business schools, technological institutes, etc.—as a member or sponsor to create knowledge and innovations	0.653	
Effectiveness in establishing programmes orientated towards the internal development of technological acquisition of competences from R&D centres, suppliers or customers	0.741	
Assimilation capacity		
Capacity to assimilate new technologies and innovations that are useful or have proven potential	0.621	
Ability to use employees' level of knowledge, experience, and competencies in the assimilation and interpretation of new knowledge	0.637	
The firm benefits when it comes to assimilating the basic, key business knowledge, and technologies from the successful experiences of businesses in the same industry	0.581	
Degree to which company employees attend and present papers at scientific conferences and congresses, are integrated as lecturers at universities or business schools or receive outside staff on research attachments	0.692	
Transformation capacity		
Capacity of the company to use information technologies in order to improve information flow, develop the effective sharing of knowledge and foster communication between members of the firm, including virtual meetings between professionals who are physically separate—Internet B2E portals, e-mail, teleworking etc.		0.734
Firm's awareness of its competencies in innovation, especially with respect to key technologies, and capability to eliminate obsolete internal knowledge, thereby stimulating the search for alternative innovations and their adaptation		0.694
Capacity to adapt technologies designed by others to the firm's particular needs		0.591
Degree to which firm prevents all employees voluntarily transmitting useful scientific and technological information acquired to each other		0.402
Application capacity		
The organisation's capacity to use and exploit new knowledge in the workplace to respond quickly to environment changes		0.321
Degree of application of knowledge and experience acquired in the technological and business fields prioritised in the firm's strategy that enables it to keep itself at the technological leading edge in the business		0.625
Capacity to put technological knowledge into product and process patents		0.643
Ability to respond to the requirements of demand or to competitive pressure, rather than innovating to gain competitiveness by broadening the portfolio of new products, capabilities and technology ideas		0.692

[a]For each question the respondent was asked to evaluate the strength of the firm's competitive position in relation to the average for direct competitors using a scale of 1 to 5.

(firms employing less than twenty employees), larger firms (especially in manufacturing) had higher absorptive capacity (e.g. employing more than 100 employees increased the likelihood of being in the highest absorptive capacity quartile by 16 per cent in manufacturing). Employing a larger proportion of manager and professionals was also associated with the highest levels of absorptive capacity (e.g. 12–18 per cent higher in all sectors when more than 50 per cent of employees where 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 (ceteris paribus) 4 per cent, in the primary sector; while firms with plants in more than one travel-to-work area, belonging to a multi-SIC 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 a higher-education institute was, cet. par., strongly associated
with higher absorptive capacity (around 80 per cent more likely to be in the top quartile). Operating in monopolistically-competitive markets (i.e. '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 had beneficial effects, for example, in wholesale trade, while other sectors were associated with relatively lower absorptive capacity.

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 4 reports the transition matrix across 2005–15 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 per cent in the lowest quintile did not move, while nearly 44 per cent 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

Table 2. (Weighted) SEM model of absorptive capacity, NZ, 2005–15 (six 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	

Notes: Standard errors adjusted for 182 clusters. Twenty-four covariances between endogenous variables were modelled but not reported. Also estimates of the constant for each endogenous relationship were not reported.

takes a considerable period to build absorptive capacity (or to see it erode). Table 5 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.

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.[18] The (weighted) BOS data covering 2005–15 is used, merged with Longitudinal Business Database (LBD, which provide annual data for these firms[19]), and (stepwise) random-effects probit models are estimated that include lagged values of the dependent variables[20] and by treating absorptive capacity as predetermined.[21] 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 Moffat 2011).[22] Here the goal is to emphasise how influential absorptive capacity is in determining these activities.

Table 6 produces the results, separately for the primary, manufacturing and service sectors. The pseudo-R^2 values obtained are high for this type of model, suggesting they are well-specified. The value of the lagged values in each model show how important fixed and sunk costs are in determining productivity enhancement. Thus, firms that exported last period were (cet. par.) some 45–65 per cent 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.[23] In especially manufacturing and services, 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 6 relate to the impact of absorptive capacity. Table 7 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 6,[24] 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

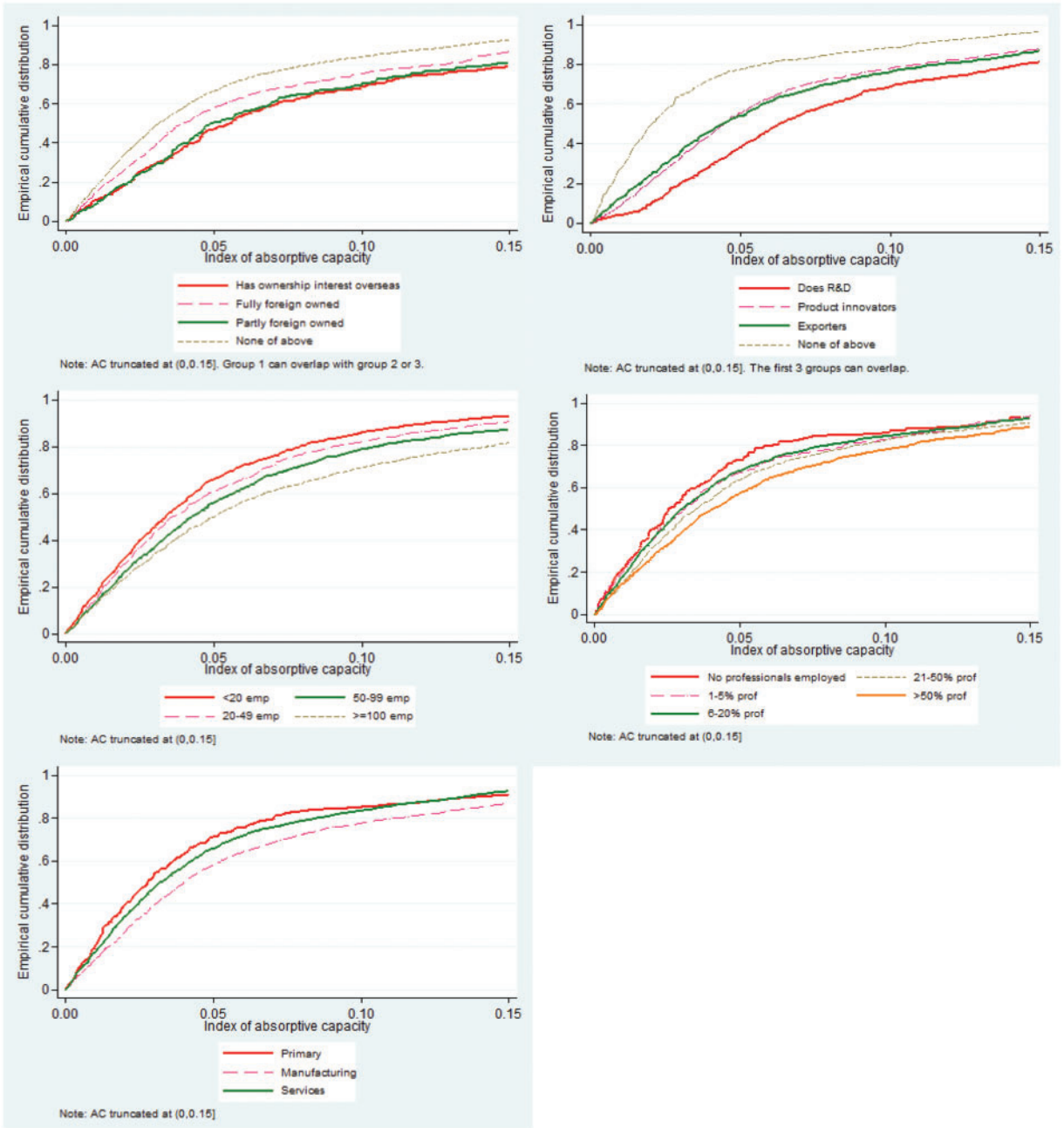

Figure 1. (Weighted) Absorptive capacity indices by various firm characteristics, NZ, 2005–15.
Source: based on SEM model (Table 1). Note: Figure S.1 (in the unpublished appendix) presents a kernel density version of this diagram.

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 per cent, 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 per cent exported) is relatively large.

Innovation is strongly influenced by an increase in especially '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 per cent 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 per cent); '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.

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 especially innovation in manufacturing). The negative impact of such cooperation from HEI's, consultants, labs, government and research organisations is likely due to firms not being able to

Table 3. (weighted) Ordered probit of determinants of absorptive capacity, NZ, 2005–15 (marginal effects reported).

Variables	Primary				Manufacturing			
	$\frac{\partial p(AC<-0.03)}{\partial x}$	$\frac{\partial p(-0.03<AC<-0.026)}{\partial x}$	$\frac{\partial p(-0.025<AC<0.01)}{\partial x}$	$\frac{\partial p(AC>0.01)}{\partial x}$	$\frac{\partial p(AC<-0.03)}{\partial x}$	$\frac{\partial p(-0.03<AC<0.00)}{\partial x}$	$\frac{\partial p(0.00<AC<0.04)}{\partial x}$	$\frac{\partial p(AC>0.04)}{\partial x}$
20–49 employees	−0.055**	0.001	0.016**	0.038**	−0.099***	0.002*	0.032***	0.065***
50–99 employees	−0.212***	−0.015***	0.043***	0.184***	−0.176***	−0.007***	0.051***	0.132***
100+ employees	−0.261***	−0.027***	0.041***	0.246***	−0.203***	−0.013***	0.056***	0.160***
1–5% managers and professionals employed	0.005	−0.001	−0.002	−0.002	−0.097**	0.020**	0.037**	0.041***
6–20% managers and professionals employed	−0.122***	0.007**	0.039***	0.075***	−0.169***	0.027***	0.062***	0.080***
21–50% managers and professionals employed	−0.157***	0.007*	0.049***	0.102***	−0.268***	0.026***	0.093***	0.150***
>50% managers and professionals employed	−0.221***	0.001	0.062***	0.158***	−0.303***	0.022**	0.101***	0.180***
5–9 years	0.016	0.000	−0.004	−0.012	0.030	0.001	−0.009	−0.022
10–19 years	0.069**	−0.001	−0.020**	−0.048*	0.080***	−0.000	−0.025***	−0.055***
20–49 years	0.044	−0.000	−0.012	−0.032	0.050**	0.001	−0.015**	−0.036**
50+ years	0.239**	−0.024	−0.081**	−0.135***	0.118***	−0.004	−0.038***	−0.077***
Single-plant enterprise	0.058**	−0.001	−0.017**	−0.040*	0.022	−0.000	−0.007	−0.014
Has plants in more than one TTWA	0.062	−0.003	−0.019	−0.039	0.004	−0.000	−0.001	−0.003
Multi SIC enterprise	−0.002	0.000	0.000	0.001	0.006	−0.000	−0.002	−0.004
Belongs to a business group	0.029	−0.001	−0.009	−0.019	−0.000	0.000	0.000	0.000
Metropolitan	−0.074	−0.000	0.020	0.055	0.097***	−0.001	−0.030***	−0.066***
NZ-owned outward FDI	−0.050	−0.000	0.014	0.037	−0.185***	−0.021***	0.043***	0.163***
Part foreign-owned	−0.057	−0.000	0.015	0.042	−0.005	0.000	0.002	0.003
Fully foreign-owned	−0.126	−0.005	0.029**	0.101	−0.030	0.000	0.009	0.020
Links with HEI	−0.443***	−0.158***	−0.208***	0.809***	−0.405***	−0.201***	−0.182***	0.787***
Many competitors, several dominant	−0.034	0.001	0.010	0.024	−0.030*	0.001	0.009*	0.020*
Many competitors, none dominant	0.004	−0.000	−0.001	−0.002	0.021	−0.001	−0.007	−0.013
Herfindahl index	0.161	−0.004	−0.047	−0.110	−0.003	0.000	0.001	0.002
Agglomeration index	−0.022	0.001	0.006	0.015	0.000	−0.000	−0.000	−0.000
Diversity index	−0.119	0.003	0.035	0.082	−0.200**	0.004	0.063**	0.133**
Waikato	−0.066	0.007	0.023	0.036	−0.003	0.000	0.001	0.002
Wellington	−0.271***	0.001	0.072***	0.199***	0.017	−0.000	−0.005	−0.011
Rest of North Island	−0.120**	0.010	0.040*	0.071**	0.046	−0.002	−0.015	−0.029
Canterbury	−0.115**	0.010	0.038*	0.067**	−0.004	−0.000	0.001	0.003
Rest of South Island	−0.156**	0.010	0.050**	0.097***	0.025	−0.001	−0.008	−0.017
Year 2007	0.021	−0.000	−0.006	−0.014	0.024	0.000	−0.007	−0.017
Year 2009	−0.002	0.000	0.001	0.002	0.041**	0.000	−0.013**	−0.029**
Year 2011	0.058	−0.002	−0.017	−0.038	0.043**	0.000	−0.013**	−0.030**
Year 2013	0.023	−0.000	−0.007	−0.016	0.062***	−0.001	−0.019***	−0.042***
Year 2015	−0.003	0.000	0.001	0.002	0.061***	−0.001	−0.019***	−0.042***
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	–	–	–	–
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, and associated product manufacturing	–	–	–	–	0.035	−0.001	−0.011	−0.023
Machinery and equipment manufacturing	–	–	–	–	−0.001	−0.000	0.000	0.001
Other manufacturing	–	–	–	–	−0.039	−0.001	0.011	0.029
Observations	3,069				7,344			
Psuedo-R^2	0.060				0.082			

Notes: 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, and 10% levels. Numbers of observations have been randomly rounded to base 3 to protect confidentiality.

Table 3. Continued

Variables	Services			
	$\frac{\partial p(AC<-0.03)}{\partial x}$	$\frac{\partial p(-0.03<AC<-0.01)}{\partial x}$	$\frac{\partial p(-0.01<AC<0.03)}{\partial x}$	$\frac{\partial p(AC>0.03)}{\partial x}$
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 and professionals employed	−0.089***	0.013***	0.032***	0.044***
6–20% managers and professionals employed	−0.145***	0.017***	0.051***	0.078***
21–50% managers and professionals employed	−0.218***	0.017***	0.071***	0.130***
>50% managers and 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 SIC 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		
Psuedo-R^2		0.053		

Notes: ***,**,* indicates significance levels at the 1, 5, and 10% levels. Numbers of observations have been randomly rounded to base 3 to protect confidentiality.

easily internalise this specialised information, because public research knowledge is hard to transfer into 'ready-to-produce' innovations (Mueller 2006: 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.[25]

To test for robustness, the results in Table 7 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 predetermined variables (see footnote 26), we have re-estimated the random effects probit models using a one-for-one 'matching' approach with 'treated' firms being those with absorptive capacity (based on the overall index) in the top quartile (25 per cent) and a 'control' sub-group comprising those with similar characteristics to the 'treated' (e.g. size, ownership, location, and 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).[26] 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.

Table 4. 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 5. (Weighted) Ordinary Least Squares regression of absorptive capacity (AC) on its lagged value.

	$\hat{\beta}$	$\hat{\beta}$	$\hat{\beta}$	$\hat{\beta}$	$\hat{\beta}$
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

Notes: 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.

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 Table A.3 in the Appendix,[27] 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[28]).

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 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-SIC 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 per cent 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—for example, net of the impact of foreign-ownership and human capital—has a substantial influence on exporting, innovation, and undertaking R&D, and thus consequently firm-level productivity.

6. The role of government in increasing absorptive capacity

We start from the position taken by the NZ 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; 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 NZ business sector.

The starting (traditional neoclassical) position justifying government intervention is usually that markets are efficient such that they are the best mechanism by which to allocate resources (cf. the model of Walrasian general equilibrium associated with Arrow and Debreu 1954); the exception is when there are market failures (European Commission 2002). Traditionally, such failures have been associated with imperfect and asymmetric information being available to (especially smaller) firms, and/or imperfect (risk) markets leading to higher (financial) costs for such firms (especially when seeking to invest in intangible assets) and more generally a problem of incomplete markets (Greenwald and Stiglitz 1986). Failures are also associated with not being able to capture positive externalities from other firms—such as knowledge spillovers—or the wider benefits gained from geographic agglomeration (e.g. intra-industry specialization through Marshall-Arrow-Romer economies and/or inter-industry Jacobian urbanization economies[29]).[30]

More recently, there has been an emphasis on dynamic factors that lead to a comparative advantage (Rodrik 2006), such as the importance of knowledge and firm capabilities as a source of firm performance and thus productivity growth.[31] Thus, government intervention to enhance both learning and learning spillovers is especially warranted to coordinate structural transformations that will close the 'knowledge' gap that exists with firms at the frontier, so moving resources from low- to high-productivity sectors.

As was noted in Section 2, direct help for building absorptive capacity was mainly limited to the operation of 'client-managed' export businesses by NZ Trade and Enterprise (NZTE) and increasing R&D grants availability to firms, which included the role of Callahan Innovation (a publically run Crown entity)[32] in building innovation capabilities. Government support through the operation of 'client-managers' to up to 700 (large) exporting companies includes building capabilities following a company audit; such

Table 6. (Weighted) Estimates of (stepwise) random-effects probit models determining exporting, R&D and innovation, NZ, 2005–15 (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 and professionals employed	−0.027*	0.027***	0.008	0.031**	0.020	0.055***	0.017***	0.021***	0.006**
6–20% managers and professionals employed	−0.085***	0.005	0.035***	0.052***	0.058***	0.035***	−0.003	0.020***	0.031***
21–50% managers and professionals employed	−0.042***	0.046***	0.080***	0.081***	0.041***	0.050***	0.019***	0.017***	0.025***
>50% managers and 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 SIC 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	−0.03[4]**	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	–	–	–

(continued)

Table 6. (continued)

	Primary			Manufacturing			Services		
	Exporting	Innovation	R&D	Exporting	Innovation	R&D	Exporting	Innovation	R&D
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

Notes: 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, and 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.

capabilities are, for example, in ensuring they have appropriate marketing or supply-line functions,[33] as well as a product that can generate overseas demand. But it is widely accepted that these 'client-managed' companies have reactively low productivity, and discussions with staff in NZTE also made clear that the main role of the organisation is to boost exporting totals (e.g. through current assisted exporters selling more overseas), rather than on building 'dynamic capabilities' (Teece 2017), with firms not included in the 'top 700' ineligible for assistance.

Callahan Innovation generally directly provides R&D grants, 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) and/or building firms capabilities 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'[34]). However, Callahan Innovation (which started in 2013) has limited reach because of budgeting constraints[35] while 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 domestic markets, innovating firms almost always need to go 'global' if they are to generate sufficient sales, and help for exporting (via NZTE) tends to be limited to the 'top 700', which are invariably not the firms being supported by Callaghan Innovation.

The activities of NZTE and Callaghan Innovation, while important, are limited in impacting on absorptive capacity. To favour policies designed to improve absorptive capacity, it is necessary to consider the issue of how firms should and can improve their dynamic capabilities (and thus *de facto* their absorptive capacity).[36] In a longer version of this paper (Harris and Le 2018), we set out the arguments put forward by Teece and other proponents of the dynamic capabilities approach, including specific recommendations made in the literature on how government might set about increasing absorptive capacity. Our main point here is the need to do this, rather than just enact policies that concentrate (mostly) on improving a nation's technological infrastructure.[37]

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 macroenvironment and/or influence the business environment, this paper used nationally-representative Business Operations Survey data to measure absorptive capacity in NZ firms between 2005 and 2015. 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 firms 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-SIC 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 a higher-education institute was,

Table 7. Marginal effects of changing absorptive capacity (the median value to the 99 percentile) on exporting, innovation and R&D in NZ, 2005–15 (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

Note: ***,**,* indicates significance levels at the 1, 5, and 10% levels.
Source: Table 5 and S.3.

cet. par., 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 thus consequently firm-level productivity.

In terms of public policy, it was noted that 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, 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 on 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 not by purchasing them from the market. Thus, policymakers must understand these learning and value capture processes in firms; they must encourage, build, and sustain entrepreneurial managerial capitalism.

However, 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, at the time of writing there was an opportunity to look at how government policy might be refreshed and assess more fully how dynamic capabilities and absorptive capacity can be built, especially since this paper shows it makes a major difference to productivity-enhancing activities. Obtaining more information through, for example, commissioning 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 continue to help provide policymakers with the conceptual lens to understand the learning and value capture processes inside firms.

Notes

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—that is, 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 first figure in the OECD report shows labour productivity in the whole economy was some 64% of the OECD average in 2015 (Australia was at 90% while the US reached 107%); the second shows productivity in the business sector, with NZ significantly underperforming the US, Australia, Canada and the UK in every year since 1997.
3. Some examples of such firm-orientated projects were: to grow the number of companies that received 'client-managed' assistance from NZ 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 NZ (especially in innovation hubs); increase R&D grant availability to firms (and develop Callahan Innovation tasked with building innovation capabilities).
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 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]' (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.
7. This is similar to creating 'dynamic capabilities' (Teece 2007, 2012; Teece et al. 1997), which we return to below.
8. Economists are cautious when undertaking empirical research relying on subjective data, as Bertrand and Mullainathan (2001) argued when they discussed its use noting '... this is one data source that economists rarely use (marking) an important divide between economists and other social scientists ... they doubt whether (subjective) questions elicit meaningful answers' (67). The main drawbacks of using data based on respondents' answers to subjective questions (such as those set out in Table 1) has been extensively discussed by especially psychologists (cf. Schwarz 1999). Bertrand and Mullainathan (2001) discuss how responses are affected by the ordering of questions (and thus the content of adjacent questions); that respondents often make little mental effort in answering questions and when they do they may not have an answer in a coherent or correct form. Schwarz (1999) discusses issues with 'understanding the question' especially with respect to what the researcher is looking for. And 'once respondents have determined the intended meaning of the question, they face additional tasks ... (including) the recall of relevant information from memory, the computation of a judgment, and the formatting of these judgments in line with the response alternatives provided by the researcher' (97).
9. For example, see <https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/558476/UKIS_2015_Final_version_of_the_questionnaire.pdf> (accessed December 2017).
10. BOS is a large-scale business sample survey that has been conducted annually by Statistics NZ since 2005. The target population for BOS is all businesses in NZ 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 NZ Standard Industrial Classification (ANZSIC) industry and employment size groups. The first level of stratification is thirty-six ANZSIC groupings. Within each of the ANZSIC groups there is a further stratification by four employment size groups, namely six to nineteen employees (small), twenty to twenty-nine employees (medium 1), thirty to forty-nine employees (medium 2), and fifty 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 NZ. 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>) (accessed December 2017).
11. 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. The fact that they actually engage in such internalisation of external information is taken here as evidence that they directly have absorptive capacity.
12. 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: 'NZ' or 'overseas'. From this we could identify different cooperation arrangements (coded 1 if present, 0 otherwise) that actually take place at the national and international level.
13. See Q.10 and Q.12 in the BOS Innovation Module.
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 ($\geq$0.77—see the figures in italics in Table S.2).
16. Note, this is not a causal model of what determines absorptive capacity, but rather its shows the partial correlations between the latter and establishment characteristics.
17. The distribution of absorptive capacity is highly non-normal, and therefore OLS regression was not a feasible option. The Shapiro–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 Figure S.1 in the Supplementary Appendix.
18. 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.
19. See <http://m.stats.govt.nz/browse_for_stats/businesses/business_characteristics/longitudinal-business-database.aspx> (accessed December 2017) for details.
20. 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 $t-2$.
21. 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 et al. (1997) and 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 Tables 4 and 5.

22. This is econometrically complicated, so instead right-hand-side values of exporting$_t$, innovation$_t$, and R&D$_t$ are substituted out using the exogenous variables determining each activity.
23. 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.
24. Table 6 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, that is, the effect of adding 1 to the current value).
25. 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 US counterparts (EC 2001; Arundel and Geuna 2004).
26. Of course, the 'matching' model is based on the assumption that the observed variables in the data are sufficient to achieve conditional independence (a lack of cofounding) in the 'treatment' and 'control' sub-groups in order to be valid. If this does not hold (because there are important unobserved factors), we still have a potential selectivity problem which biases the relationship between absorptive capacity and our outcome variables. At the very least, though, we are establishing correlation and the direction of the causal relationship.
27. The full results are presented in the Supplementary Appendix Tables S.4 and S.5.
28. 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 per cent 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 per cent of firms had no external links).
29. See Marshall (1890), Arrow (1962), Romer (1986), and Jacobs (1970, 1986)
30. Such justification for government intervention on the grounds of market failure has been criticised by those who do not adhere to the neoclassical tradition; for example, evolutionary economists (e.g. Metcalfe and Georghiou 1998) have argued that information costs, leading to asymmetric outcomes, are one of the features of the market, and they are in part necessary as a selection device (for promoting the fittest firms) and in providing incentives for learning and discovery, which is crucial to the process of variety creation upon which the evolutionary view of markets is based (as Metcalfe and Georghiou (1998) point out 'a profit opportunity known to everybody is a profit opportunity for nobody'). This does not mean that there is no rationale for government intervention, assuming that it sees a direct increase in economic benefits from more firms gaining information and thus acting on that information (e.g. by adopting certain technologies, increasing their overall capabilities, etc.). For example, Casson (1999) argues that in this situation the government has a comparative advantage in information, and it is on this basis (not market failure) that it can justify intervention. See also Cohen (2006; Section 3.1).
31. Note, this is not limited to 'catch-up' in developing economies; 'network failures' in general arise because technological know-how (broadly defined) is partly tacit and therefore cannot be diffused easily. Networks can be important for the transfer of such tacit knowledge (they are mutual learning processes fostered by well-managed collaboration between specialists in complementary fields, as well as between designers, producers, and end-users) , and they can also partly overcome the problems associated with firms experiencing bounded rationality and consequently bounded vision (Teece and Pisano 1998).
32. See <https://www.callaghaninnovation.govt.nz/> (accessed December 2017).
33. Teece (2017) 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' (696–7). However, Teece (2017) 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' (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)' (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 2017: 699).
34. See <https://www.callaghaninnovation.govt.nz/access-experts/accelerators> (accessed December 2017).
35. 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> (accessed December 2017)—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 NZ.
36. Teece (2017; 711) goes as far as saying '… without the conceptual lens of the capabilities approach, policymakers may inadvertently impede innovative and capability-building activities'.
37. As stated above, in the 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 it concentrates on

education, infrastructure, fundamental research and public sector efficiency (Pitelis and Runde 2017: 683). As Peneder (2017: 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'.

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Supplementary data

Supplementary data is available at *Science and Public Policy* online.

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Appendix

Table A.1. (Weighted) Factor loadings from PFA model, New Zealand, 2005–15.

Variable	External knowledge	National cooperation with business	Links with national researchers	International cooperation with researchers	International cooperation with business	KMO
Sources of knowledge/information 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).

Table A.2. (Weighted) means and standard deviations for variables, New Zealand, 2005–15.

Variable *x*:	definition	Variable *x*:		Mean value of absorptive capacity		Source
		Mean	Std. Dev	$x = 0$	$x = 1$	
Export	Whether firm sold goods and 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 2–49 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 and professionals employed	Whether firm employed no managers and professionals (coded 1)	0.117	0.322	0.013	−0.012	BOS
1–5% managers and professionals employed	Whether firm employed 1–5% managers and professionals (coded 1)	0.062	0.242	−0.012	−0.002	BOS
6–20% managers and professionals employed	Whether firm employed 6–20% managers and professionals (coded 1)	0.388	0.487	−0.012	0.010	BOS
21–50% managers and professionals employed	Whether firm employed 21–50% managers and professionals (coded 1)	0.259	0.438	−0.012	0.020	BOS
>50% managers and professionals employed	Whether firm employed 51+% managers and 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 SIC enterprise	Firm with (multi) plants in more than one 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

(continued)

Table A.2. (continued)

Variable *x*:	definition	Variable *x*:		Mean value of absorptive capacity		Source
		Mean	Std. Dev	$x = 0$	$x = 1$	
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.

Table A.3. Marginal effects of changing absorptive capacity (the median value to the 99 percentile) on exporting, innovation, and R&D in NZ, 2005–15 (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***

Note: ***,**,* indicates significance levels at the 1, 5, and 10% levels.
Source: See text for details.