RESEARCH PAPER

The impact of persistent innovation on Australian firm growth

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ABSTRACT

This paper assesses the contribution of innovation persistence to surviving Australian firm growth performance over the period 2007–08 to 2013–14 with the added advantages that new firms, micro-sized firms and all industry sectors are included in our analysis. Over this period, firms with high sales and/or employment growth accounted for the majority of aggregate economic and employment growth in Australia, which is consistent with similar studies in other countries. Using a randomized, stratified sample from a firm population-level database that links administrative, tax and survey data, we created a matched, balanced sample of surviving firms to show that short-term persistent innovators (particularly young SMEs) significantly outgrow their less persistent and non-innovator counterparts in terms of sales, value added, employment and profit growth. Persistent innovators are more likely to be high-growth firms and more likely to introduce multiple types of innovation that are more novel. Our findings suggest that broad-based innovation policies may support successive waves of high-growth firms that help to sustain economic and employment growth in Australia.

Introduction

The literature on the persistence of innovation and its positive association with firm growth has itself experienced high growth. Understanding what drives high-growth episodes in firms is fundamental for designing industry policies to drive employment and/or economic growth. High-growth firms, not surprisingly, contribute disproportionately to aggregate economic and employment growth in most countries, but high-growth firms themselves tend not to maintain their high growth in the medium to long term (Coad, 2018).

Research to date shows that Australian economic and employment growth dynamics are consistent with the stylized facts for high-growth firms identified in Moreno and Coad (2015) and Coad *et al.* (2018). High employment growth and/or high sales growth (high-growth) firms generated the majority of Australia's net aggregate growth, accounting for 92% of net positive employment growth, 86% of net positive sales growth, 92% of net export sales growth, and 89% of net positive economic growth over the period 2007–14 (Hendrickson *et al.*, 2018; Table A1). While the definition of a high-growth firm used was broad, the findings had the added advantages that they included all economically active firms in Australia, including new firms and micro-sized firms from all sectors of the Australian economy. These results were consistent with other research using a narrower definition of high growth (Hendrickson *et al.*, 2015; Moreno and Coad, 2015). More than half of Australian firms end their high sales growth episode within four years. This tends to occur when the firm is new, more innovative and more strategic (Hendrickson *et al.*, 2015; Australian Government,

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2016; Hendrickson *et al.*, 2016; Majeed *et al.*, 2021). Collective evidence points to innovative firms growing more on average than their non-innovator counterparts and also being more likely to be high-growth firms, all else being equal (Cefis and Ciccarelli, 2005; Hasan and Tucci, 2010; Czarnitzki and Delanote, 2013; Audretsch *et al.*, 2014; Ciriaci *et al.*, 2016; Bianchini *et al.*, 2017; Calvino and Virgillito, 2018). These results, while significant, are often small or inconsistent and vary by country, firm size, age and sector, especially when using dummy variables based on community innovation survey-style data (Mohnen and Hall, 2013). The persistence with which firms innovate appears to be one mechanism mediating the strength of this relationship, at least in the short term (Segarra and Teruel, 2014; Bianchini and Pellegrino, 2019).

There is no commonly accepted definition of firm innovation persistence. The basic concept is that a firm must introduce one or more innovations in any given year in consecutive years. The theoretical arguments exploring why a firm should persistently innovate and why its many associations with different forms of growth have been shown to overlap, be complementary and be self-reinforcing have been exhaustively reviewed elsewhere. Most researchers invoke the Schumpeterian argument of creative-destruction, whereby innovation promotes competitive reallocation of market shares to the innovators that enjoy higher growth and/or profitability. Persistence in innovation can be driven by sunk investment in learning that increases or locks in the probability of later innovation, or where innovation success generates profits that can be reinvested in more innovation (Duguet and Monjon, 2004; Ganter and Hecker, 2013; Haned *et al.*, 2014; Hecker and Ganter, 2014; Le Bas and Scellato, 2014; Máñez *et al.*, 2015; Moreno and Coad, 2015; Calvino and Virgillito, 2018).

Research on British, Swedish, Italian, Spanish, Flemish, Finnish and French firms shows strong correlations between innovation persistence and growth in profitability, sales, employment and/or productivity growth (Cefis and Cicarelli, 2005; Czarnitzki and Delanote, 2013; Deschryvere, 2014; Triguero *et al.*, 2014; Lhuillery, 2014; Baum *et al.*, 2015; Bartoloni and Baussola, 2015, 2016). It is rare, however, that more than one growth indicator is measured. A study of young, small, innovative Flemish companies that had 11% and 5% higher sales and employment growth, respectively, compared firms with some of these characteristics but not all three (Czarnitzki and Delanote, 2013).

Predicting the success of innovation investment is more often a random exercise at the firm level because it is an inherently uncertain 'double-edged sword' (Moreno and Coad, 2015). The returns to innovation are highly skewed in a population of firms, with the most extreme impacts of R&D expenditure on firm growth found at the tails of a growth distribution (Coad and Rao, 2008; Majeed *et al.*, 2021). Given the similarities, the unpredictable and stochastic nature of firm growth may reflect, in part, the unpredictable and stochastic outcomes of innovation (Geroski, 1999). Evidence from Spanish manufacturers and Finnish firms suggests that there is no point targeting specific firms to generate long-term employment growth for society as the benefits of innovation are highly uncertain; competitive advantages seem to erode over time and quite quickly (Deschryvere, 2014; Coad *et al.*, 2018; Bianchini and Pellegrino, 2019).

In this context, many prior research efforts tend to isolate our understanding to the role of a specific type or types of innovation[1] and its persistence in driving a particular type of growth (typically employment growth). Few studies tend to embrace all types of innovation and fewer still focus on sales or industry value-added growth. Panel studies of French and Luxembourg firms show that those introducing more than one type of innovation are more persistent innovators than those introducing only one type in any given year, with the authors arguing that there are synergistic relationships between new products and the new processes and the organizational changes required to support them (Mohnen and Hall, 2013; Haned *et al.*, 2014; Le Bas and

[1]Here we refer to the separation by the Working Party of the National Experts on Scientific and Technology Indicators (2005) of innovation into four interrelated types: product, process, organizational/managerial and marketing innovation.

Poussing, 2014; Hecker and Ganter, 2014). Recent research shows that firms introducing more than one type of innovation were found to have superior growth and market share performance, as the development of complementary innovations encourages more repeated, systematic innovation capability in firms (Bartoloni and Baussola, 2016; Bianchini *et al.*, 2018; Arranz *et al.*, 2019). This was shown to have overall positive effects on economic growth (Evangelista and Vezzani, 2012).

This paper responds to calls for a multi-dimensional approach to examining the contribution of innovation to firm growth (Audretsch *et al.*, 2014) with a more systematic effort to link firm-level and country-level dynamics (Calvino and Virgillito, 2018). Our study sought to validate earlier economic and employment growth research on predominantly European firms. Australia arguably has a strong national innovation system compared with many other countries so we would expect to see a stronger relationship between innovation output and firm growth (Segarra-Blasco *et al.*, 2018). Our research questions are: What is the contribution of persistent innovation to high growth compared with that of firms that do not innovate or innovate less frequently? Are persistent innovators more likely to be high-growth firms? We used a longitudinal dataset of all economically active Australian firms where the contribution of high sales and/or employment growth to a range of aggregate growth indicators has been established (see Hendrickson *et al.*, 2018). We used a randomized, stratified sample of firms from this same population where innovation activity is more extensively measured to confirm the firm-level relationship between short-run innovation persistence and growth across a range of growth indicators at the firm level. Our paper measures different degrees of persistence in innovation to help quantify the magnitude of the effect of innovation on different types of firm-level growth, and the relationship of innovation persistence to high-growth spells. In our study, we include all types of innovation (product, process, organizational/managerial and marketing) in our measure of persistence and we measure their combined effects on several types of growth (turnover, gross output, value-added output, and/or employment).

Method

A complete description of the data and methods employed is available at http://www.prometheus-journal.co.uk/ *Supplementary Data*. Figures A1 and A2, and Tables A1–A11 are all to be found among the supplementary data.

Data

We used 2007–08 to 2013–14 firm-level data extracted from the Australian Bureau of Statistics, *Business Longitudinal Analytical Data Environment* (Australian Bureau of Statistics, 2015). Our study overcomes the disadvantage of many studies of innovation persistence and growth in that both new and micro firms are included in our dataset (see Coad *et al.*, 2018). Unlike many persistence studies that work with manufacturing firm datasets (e.g., Guarascio and Tamagni, 2019) our dataset includes firms from all sectors of the economy. No market information, such as stocks, prices or volumes of sale, was available in this dataset.

To validate the presence of cumulative effects from innovation persistence, we used a balanced panel sample derived from the business characteristics survey and additional units selected from the business longitudinal database SME panels that exist in all financial years from 2010–11 to 2012–13. In total, there were 6,142 firms; among these, 74% were simple-structured firms[2] and 26%

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[2]These firms operate in one industry, have a single Australian business number and are concentrated in the small to medium business size group (i.e., employing fewer than 200 employees). Only 4% of this sample were businesses with 200 or more employees.

were large, complex-structured firms[3] (see Table A2). Firms that had abandoned innovation projects or had innovation projects still in development were excluded from the sample. Innovation activity was measured on a winsorized, randomized, stratified and representative sub-sample (approximately 14,000 to 17,000 firms per annum) of the full Australian firm population using the business characteristics survey conducted by the Australian bureau of statistics. This survey is collected following the guidelines of the Oslo Manual (National Experts on Scientific and Technology Indicators, 2005) and generally shares the innovation definitions and collection practices of community innovation survey datasets. However, the response rates are higher at ~95% and firm size and industry classifications are slightly different, based on Australian and New Zealand industry classifications. Persistent innovators comprised 13,107 individual observations or 37% of the sample.

Definitions

For growth analysis at the national level, we define a high-growth firm as having annual growth in total sales and/or employment of greater than 20% over the previous year. This definition is based on organization for economic cooperation and development (OECD) relative definitions of high growth. For modelling, we sub-classified firms by age and size. SME firms are generally defined as 0–199 employees and large firms with 200+ employees.

There is no commonly accepted definition of firm innovation persistence. Our concept of innovation persistence is that a firm must introduce one or more innovations in any given year in consecutive years. In this study, we examined the performance of Australian firms that reported innovation persistence over a three-year period similar to the method used by Lhuillery (2014) and Bartoloni and Baussola (2016). In our study, the most persistently innovating firm would be one that introduced at least one innovation in three out of the three years examined. A non-innovating firm would have introduced no innovations over the same three-year period.

Given the balanced nature of our panel data, we were able simply to look at the frequency with which a firm reported introducing one or more innovations within a three-year window. We note that this is not a true measure of innovation frequency. A recently introduced innovation survey question shows that most Australian firms introduce only one or two innovations of each type every year; however, at least 20% of innovation-active firms introduced three or more of each type of innovation in 2014–15. This appears to be size- or age-dependent (Australian Bureau of Statistics, 2016). We also chose to consider all types of innovation in our definition of persistence as recent evidence suggests that the interaction between the types of innovation can be both synergistic and simultaneous (Arranz *et al.*, 2019), with these complex innovators being more persistent than single innovators (Le Bas and Scellato, 2014). Isolating each type of innovation may therefore create significant omitted-variable bias.

Longer panels were not possible because of the way the Australian Bureau of Statistics rotates SMEs out of the survey sample frame every three to five years. Censoring of the innovation window was not employed in this paper as we were more interested in an intensity measure than specific timing or lag effect. Given that more than 90% of innovating Australian firms in our dataset reported some benefit of their innovation(s) in the same year as introducing it (Australian Bureau of Statistics, 2014),[4] we allowed for analysis of growth patterns in the same year as an innovation(s) was introduced. This approach is consistent with the findings from Spanish firms

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[3]Large, complex-structured firms operate in more than one industry, and have more than one Australian business number. All complex-structured firms in the sample had 200 or more employees, with the majority (96%) having 300 or more employees.
[4]The reference year for this survey question was 2012–13.

(Triguero *et al.*, 2014; Arranz *et al.*, 2019). Benefits reported by Australian firms in the same year included improved customer service, increased revenue, competitive advantage and reduction in costs (Australian Bureau of Statistics, 2014). Time lags were therefore considered less relevant for these short-term benefits and therefore not included in our models at the risk of reverse causality constraints.

We used new to market innovation as our measure of novelty. New to market innovations are innovations of any type that are reported either as new to the world, new to Australia or new to the industry. As the new to market innovation (novelty) question is asked only every second year, values were imputed based on highest response from the years the questions were asked. Novelty was not included in our matching study because of the imputation.

Outcome and performance measures

For firm-level analyses, we measured growth in turnover or total sales, employment and value-added output, but we also report gross operating profit (sales of goods and services minus cost of goods sold) and gross output (total firm income plus the value of changes in inventories of goods produced as outputs). Table A3 provides variable definitions and derivations from the dataset.

Descriptive analysis and Analysis of Variance (ANOVA)

We undertook a cross-sectional ANOVA and measured interaction effects for innovation novelty and average turnover or total sales, value-added, gross operating profit and employment growth outcomes against innovation persistence. We used percentile distribution analysis to describe variation in firm growth variables by innovation persistence and firm size-age classes. We compared the 10th, 25th, 50th, 75th and 90th percentiles of the growth distribution of each level of innovation persistence (see Ciriaci *et al.*, 2016). Quantile regression was used to validate statistical significance of each innovation treatment at each of the above quantiles.

Regression modelling

Propensity score matching is a statistical technique that improves the estimate of a treatment effect by accounting for the covariates that predict receiving the treatment (see Rosenbaum and Rubin, 1983, 1985). We used a doubly robust method of outcome regression and propensity score matching to limit selection bias by matching each innovating firm with one or more non-innovating firms that otherwise have the same or similar observed characteristics (Funk *et al.*, 2011; Tavassoli and Karlsson, 2017). The variables used to construct a propensity score are listed at Table A4.

In the current study, the inclusion and creation of the key firm characteristics for the propensity modelling are based on previous innovation studies and analysis already conducted and/or published by the Australian Bureau of Statistics (Todhunter and Abello, 2011; Antonelli *et al.*, 2013; Rotaru *et al.*, 2013; Rotaru, 2013; Fagerberg and Mowery, 2015; Soriano and Abello, 2015). Sample bias reduction using these variables is shown in Figure A1. The positive association between firm growth and firm size has been found to be the result of firm ageing, a form of Simpson's paradox (Coad, 2018). While we recognize this risk, we control for both age and size. While age can influence the likelihood of firm senescence, size can lead to variable investment and economies of scale and scope. We controlled for age to correct partially for high-growth bias from small, new firms in our dataset, following Ciriaci *et al.* (2016).

After matching firms based on their propensity score, we assessed the magnitude of the cumulative effect of the persistence of innovation on selected firm growth outcomes. We ran ordinary least square regressions on the matched sample, defined as the observations in the treatment group plus the matched observations in the control group. The model in this case can be written as:

$$\text{Log (Ratio of two outcomes)} = \text{F (Innovation persistence, } X_1\text{)}$$

where:

$$X_1 = \text{a vector of covariates defined as in the propensity model.}$$

Innovation persistence was an ordinal innovation variable with an increasing number of years in which a firm introduced at least one innovation. Two different model specifications were used. The first model used a dummy variable for each of the innovation persistence variables, while the second model used the years of persistence as a variable in the model. An example for log of value-added ratio between 2013 and 2011 is provided below using definitions from Table A3:

$$\begin{aligned}
&Log\left(VA\,Ratio_i\right) = \beta_0 + \sum \beta_{Pi} P_i + \beta_A Age_i + \sum \beta_{Ei} Emp_i + \sum \beta_{Ci} Comp_i + \sum \beta_{Ii} ICT_i + \\
&\sum \beta_{Fi} Foreign_i + \beta_G Gov_i + \beta_O Coop_i + \beta_W FWA_i + \beta_X Export_i + \beta_S Skills_i + \\
&\beta_K Skills_Def_i + \beta_T Other_finance_i + \sum \beta_{Di} Ind_i + \varepsilon_i
\end{aligned}$$

where:

VA Ratio_i is the ratio of 2013 Value Added and 2011 Value Added of firm *I;*

P_i is a binary variable for each of the innovation persistence categories – including being innovators for three, two and one year in the study period – three variables, reference case is not innovation active;

Age_i is a binary variable, taking value 1 if the firm's age is more than five years, zero otherwise;

Emp_i is a binary variable, taking value 1 for each of the firm's number of employees categories – 1–4, 5–19, 20–199, 200–99 and 300+ employees – five variables, reference case is non-employing firms;

Comp_i is a binary variable, taking value 1 for each of the degree of competition categories – Minimal and Moderate to Strong competition – two variables, reference case is no effective competition;

ICT_i is a binary variable, taking value 1 for each of the ICT intensity categories – Moderate, High and Most Intense – three variables, reference case is Low intensity;

Foreign_i is a binary variable, taking value 1 for each of the foreign ownership categories – 0–50% and >50% ownership, reference case is 100% Australian owned;

Gov_i is a binary variable, taking value 1 if the firm receives government assistance, zero otherwise;

Coop_i is a binary variable, taking value 1 if the firm is involved in any cooperative arrangement, zero otherwise;

FWA_i is a binary variable, taking value 1 if the firm has flexible working arrangements, zero otherwise;

Export_i is a binary variable, taking value 1 if the firm engages in exporting activity, zero otherwise;

$Skills_i$ is a binary variable, taking value 1 if the firm reported that its employees use some specific skills, zero otherwise;

$Skills\_Def_i$ is a binary variable, taking value 1 if the firm reported having skills deficiency or shortage, zero otherwise;

$Other\_finance_i$ is a binary variable, taking value 1 if the firm sought debt and equity, zero otherwise;

Ind_i is a binary variable, taking value 1 for each industry division – 16 variables for the market sector industries excluding public sectors, reference case is agriculture, forestry and fishing; and

ε_i is the error term, $\varepsilon_i \sim N\left(0,\sigma^2\right)$, $Cov\left(\varepsilon_i, \varepsilon_j\right) = 0 \; for \, i \neq j$.

We ran ordinary least squares (OLS) regression on all growth variables. We ran OLS regression with and without controlling for capital expenditure and found no major difference in the results. The results presented in this paper are those without controlling for capital expenditure. In this study, we measured growth as the difference between time *t* and time t_{-3} for simple- and complex-structured firms for each growth variable. An additional sample (called total sample) was used where we added a simple/complex dummy variable in the covariates for the propensity score modelling. This addressed the issue of a simple-structured firm being matched to a large, complex firm, and vice versa.

Results

The contribution of innovation persistence to growth

Figure 1 shows the median growth rates for SMEs (0–199 employees) and large firms (200+ employees) for two three-year panels between 2008 and 2014. The data suggest that innovation has a positive correlation with sales, value-added, profit and employment growth outcomes in Australian firms. The positive effect of innovation was greatest for persistently innovating firms. For example, median annual sales growth for SME non-innovators was –\$1,890 over this period. In contrast, median annual sales growth for persistent SME innovators was +\$12,763 over the same period (Figure 1). The less regularly that firms reported innovating over a three-year period, the weaker the differences between innovator and non-innovator growth rates became, suggesting an innovation dose effect.

It is interesting to note that the relationship between innovation persistence and median profit and employment growth is positive, but has quite different scales depending on the phase of the business cycle (data not shown). Analysis of variance on these two three-year panels confirmed that the mean differences in growth performance were significantly different between firms of varying innovation persistence. ANOVA and interaction effects tests on both three-year panels showed significant positive differences between innovation persistence least squares means for sales growth (F=42, $p<0.0001$), value added growth (F=537, $p<0.001$), gross operating profit growth (F=17, $p<0.0001$) and employment growth (F=12, $p<0.05$). Note that the panel data were pooled and are unlikely to satisfy the independence test.

Differences in growth rates between firms that innovated once in three years and non-innovators (zero out of three years) were often insignificant, particularly large firms, except at higher/lower percentiles in the growth distribution where the growth differences between levels of innovation persistence became distinct (Figure A2; Tables A5 and A6). Consistent with sales data from Coad and Rao (2008), quantile regression showed a significant difference in growth coefficients between innovation persistence categories for all growth measures (χ^2>1,900; DF=16, Pr>χ^2 <0.0001 in all cases). Errors are 95% confidence intervals using bootstrap resampling.

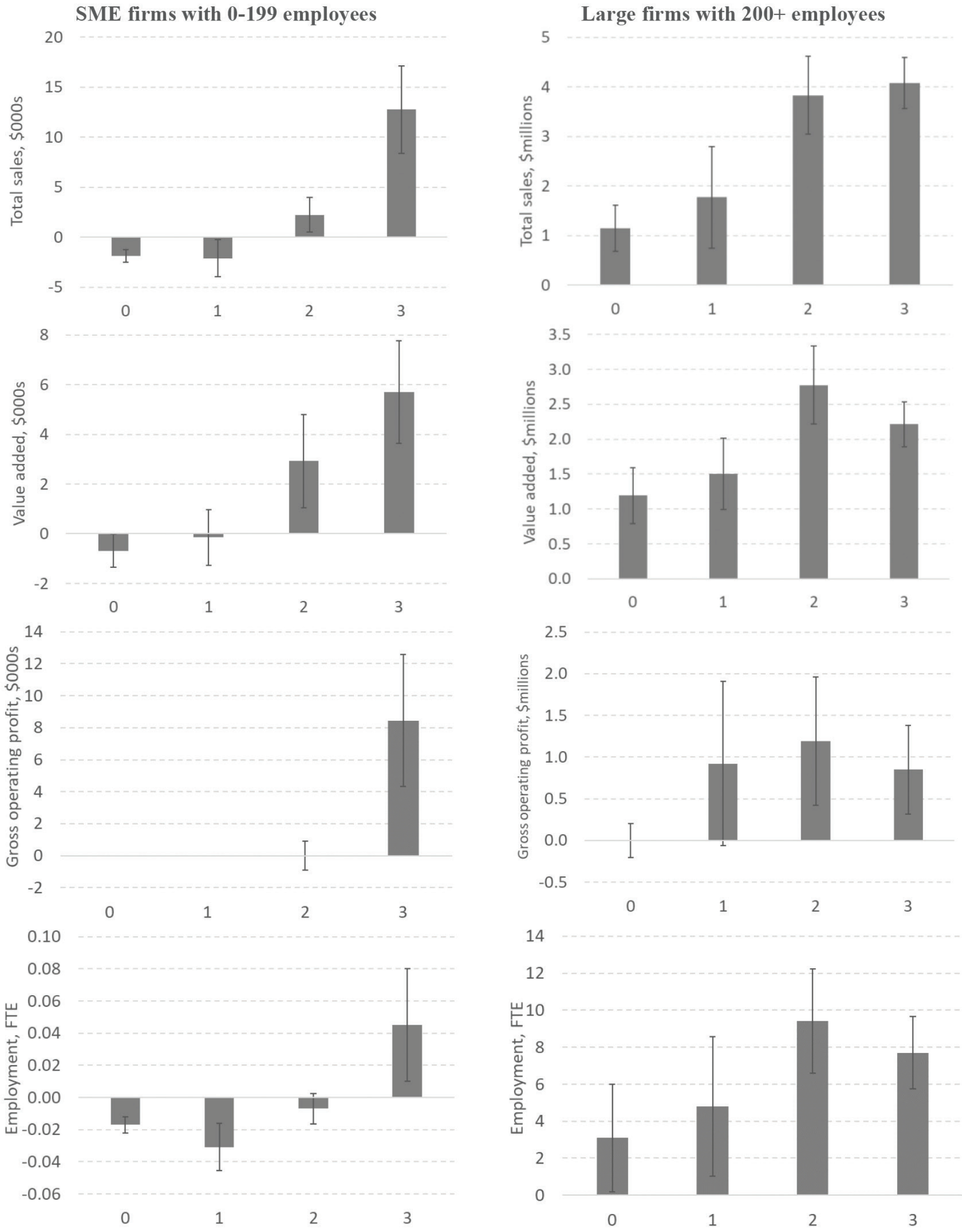

Figure 1. Median annual sales, value added, gross operating profit and employment growth by innovation persistence and firm size category, 2008–14

Note: Innovation persistence, number of years (out of three) in which a firm introduced an innovation. Employment growth is measured in full time equivalents. Sales, value-added and gross operating profit dollar values are not deflated. Errors are 95% confidence intervals using bootstrap resampling.

Source: Australian Bureau of Statistics (2017) *Business Longitudinal Analysis Data Environment*, 2001–2 to 2013–14.

As with the results of Czarnitzki and Delanote (2013) and Ciriaci *et al.* (2016), a stronger effect of innovation and innovation persistence on growth performance was found at the higher percentiles of the growth distributions for all four growth indicators examined (total sales, employment, value added and gross operating profit; Tables A5 and A6). Among the growing SMEs, persistently innovating SMEs grew more in absolute terms than non-innovators and less frequent innovators. Among the growing large firms, persistently innovating firms grew more in absolute terms than non-innovators and less frequent innovators. The results for large firm growth quantiles were consistent with the employment growth results from Spanish firms reported by Ciriaci *et al.* (2015). At the lower growth quantiles, persistent SME innovators had more extreme negative growth whereas there was either no difference or a protective effect at lower quantiles for large persistent innovators compared with non-innovators (Figure A2; Tables A5 and A6).

We compared the firms in this randomized and stratified sample with the full population of all economically active firms over that same period. Hendrickson *et al.* (2018) showed that high-growth firms (HGFs)[5] in the full population generated the majority of growth in all four growth measures over this period. As expected from the above results, Table 1 shows that the overall likelihood of satisfying the definition of a high growth firm increased with the level of innovation persistence across all growth indicators measured. By simulating a randomized control trial with the broadest range of firm characteristics available at the time, we were able to confirm the influence of innovation persistence on a range of three-year turnover, value-added output, gross output, gross operating profit and employment growth outcomes using firm characteristics from 2011 as covariates and non-innovators as the control group. Our definition of growth was the difference between the first- and third-year values of each performance variable.

Table 1. Percentage likelihood of being a high-growth firm by growth measure, innovation persistence and firm size, 2008–14

Percentage likelihood of high-growth-firm status			
Innovation persistence		**SMEs**	**Large firms**
Innovation persistence, number of years (out of three) introducing one or more innovations	***Annual net sales growth***		
	0	*14.6*	*9.1*
	1	*15.9*	*12.1*
	2	*17.2*	*12.4*
	3	*19.7*	*12.3*
	Annual net gross operating profit growth		
	0	*15.3*	*8.7*
	1	*16.0*	*12.1*
	2	*17.4*	*13.2*
	3	*20.8*	*12.5*
	Annual net value-added output growth		
	0	*15.0*	*9.2*
	1	*16.1*	*11.9*
	2	*17.6*	*12.3*
	3	*19.7*	*12.3*
	Annual net employment growth		
	0	*16.9*	*9.2*
	1	*18.2*	*12.2*
	2	*17.8*	*12.4*
	3	*19.6*	*12.3*

Note: A high-growth firm was defined as a firm achieving annual growth in sales and/or employment of more than 20% over the previous year.

Source: Australian Bureau of Statistics (2017) *Business Longitudinal Analysis Data Environment*, 2001–2 to 2013–14.

[5]HGFs defined as having annual growth in sales and/or employment of more than 20% over the previous year.
[6]A new-to-market innovation is one that is new-to-world, new-to-Australia or new-to-industry.

The regression results from the matched sample provide doubly robust evidence of the positive association between persistent innovation and a range of growth outcomes, particularly for SMEs and simple-structured large firms. Table 2 summarizes the results for two OLS regression models using persistence group dummy variables for a range of growth variables. Complete regression outputs are in *Supplementary Data* (Tables A7 to A11). Estimates are broken into their effect on simple-structured firms, complex-structured large firms and the total sample.

There were positive and significant coefficients for the persistence variables under both models, confirming the cumulative effects of innovation persistence measured by ANOVA and quantile regression. This effect was strongest in simple-structured firms, which were mostly SMEs. The effect of innovation on growth generally weakened the less persistently that simple-structured firms innovated over the three-year period. For example, persistent simple-structured innovators that innovated in all three years had 16% and 17% higher gross output and value-added output growth respectively compared with firms that did not innovate in any of those three years (Table 2). Although not presented here, we also tested the relationship with wage and salary growth and found this to have a significant, positive relationship with innovation persistence in simple-structured firms (see Hendrickson *et al.*, 2018). This is consistent with employment growth results.

The matching and regressions were less robust for large complex firms because the total firm counts were low and there were fewer controls to match. A consistent, significant effect was still found in large complex firms for turnover and profit. However, unlike the simple-structured firm cohort, large complex firms appeared to benefit from the presence of innovation rather than any innovation persistence *per se*.

Simple-structured firms that are new, have high ICT and skills intensity, have cooperative arrangements and demand for external finance are also more likely to grow after matching on other covariates (Tables A7–A11). Interestingly, once matched to similar firms, the results all agree that growth was less likely in simple-structured firms that have foreign ownership. There were some

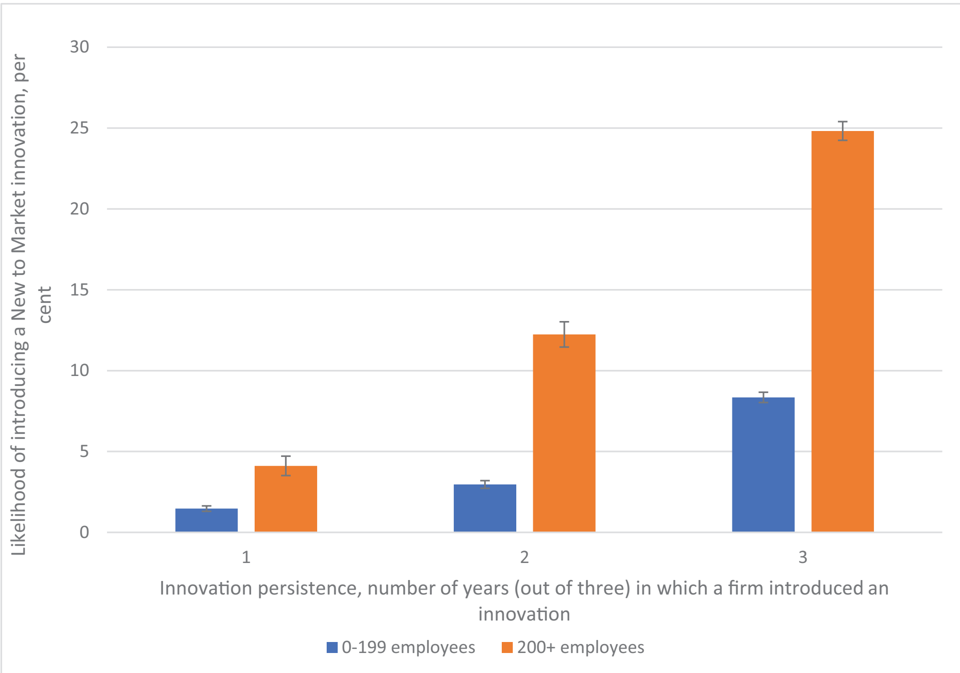

Figure 2. Percentage likelihood of introducing a new-to-market innovation by innovation persistence, 2008–2014

Note: New-to-market innovation includes new-to-industry, new-to-Australia and new-to-world degrees of novelty. Error bars are 95% confidence intervals taken from bootstrap resampling. Data from both panels were pooled for this chart.

Source: Australian Bureau of Statistics (2017) *Business Longitudinal Analysis Data Environment*, 2001–2 to 2013–14.

effects from firm size, although only statistically significant in one size category (20–199 employees), which may reflect controlling for age. The presence of competitors had a positive effect on the growth of simple-structured firms, but had no influence on larger, complex-structured firms.

Innovation persistence and innovation novelty were also found to be correlated in both large and SME firms (Figure 2). The percentage likelihood of a persistent SME innovator introducing a new-to-market[6] innovation is two to six times higher than that in less frequent innovators, consistent with Calvino and Virgillito (2018). Innovation persistence and multiple types of innovation are likewise correlated. In the matched, balanced panel sample, the majority of firms innovating in all three years was introducing multiple innovations in a single year, typically of different innovation types and many introducing three or more types of innovation in any given year of the panel (Table A2).

Table 2. Summary of the impacts of innovation persistence on various measures of firm growth using a derived balanced matched panel and OLS regression, 2010–13

		Persistence (model 1)			Persistence - (model 2)
Sample	**Growth variable**	**Innovators for 3 years**	**Innovators for 2 years only**	**Innovators for 1 year only**	**Number of years of innovation**
Simple-structured firms	Gross operating profit	0.111	0.007	0.053	0.029
	Employment (FTE)	0.173***	0.107***	0.006	0.057***
	Turnover	0.173***	0.115***	0.034	0.057***
	Gross output	0.163***	0.113***	0.008	0.055***
	Value added	0.174***	0.093***	-0.008	0.055***
Large, complex-structured firms	Gross operating profit	0.169**	–0.018	0.360***	0.044*
	Employment (FTE)	0.027	0.061**	0.090***	0.012*
	Turnover	0.070***	0.060**	0.096***	0.024***
	Gross output	0.025	0.014	–0.015	0.008
	Value added	–0.079	–0.021	–0.091	0.008
Total sample	Gross operating profit	0.174***	0.011	0.125***	0.047***
	Employment (FTE)	0.098***	0.087***	0.025	0.035***
	Turnover	0.159***	0.119***	0.073***	0.054***
	Gross output	0.114***	0.081***	0.011	0.039***
	Value added	0.091***	0.067***	–0.009	0.039***

Note: Model 1 treats persistence as a categorical/dummy variable while Model 2 uses one variable to capture the number of innovation years. Values are the percentage difference from the non-innovator control dummy. * $p<0.1$; ** $p<0.05$; *** $p<0.01$; Definitions of each growth indicator are at Table A3. Detailed regression outputs, including covariates, are found in Tables A7 to A11. FTE = full time equivalent.

Source: Australian Bureau of Statistics (2017) *Business Longitudinal Analysis Data Environment*, 2001–2 to 2013–14.

Discussion

The results of this paper are consistent with the current literature on innovation persistence reporting significant individual effects on growth in innovating firms, especially persistent innovators (Cefis and Ciccarelli, 2005; Deschryvere, 2014; Triguero *et al.*, 2014; Lhuillery, 2014; Baum *et al.*, 2015; Ciriaci *et al.*, 2015; Bartoloni and Baussola, 2015, 2016; Calvino and Virgillito, 2018; Bianchini and Pellegrino, 2019). Our data show that Australia follows many of the stylized facts on aggregate growth dynamics common to other countries examined to date. Sales, value-added output and employment growth in Australia are consistent with firm age and growth literature, with the added advantages that we included all economically active firms in our analysis including new and micro-sized firms from all sectors of the economy. High-growth firms in aggregate drive net positive economic and employment growth in the economy.

We used a randomized and stratified sub-sample of the Australian firm population to show that surviving, short-term persistent innovators had higher sales, value added, gross operating profit and employment growth than non-innovators and less frequent innovators. Persistent innovation also appears to affect positively net economic and employment growth dynamics as we found that annual growth is more likely to be net positive for persistent innovators than for non-innovators and less frequent innovators. Systematic innovation may therefore be one of the major mechanisms behind aggregate growth dynamics rates, particularly for the percentage contribution of SMEs and simple-structured large firms to aggregate economic and employment growth.

Our data also support the argument that persistent innovators are more likely to open new markets and increase demand for their products, reflecting the complementary or compounding benefits of several types of innovation being introduced together (Antonelli *et al.*, 2012; Goedhuys and Veugelers, 2012) and the importance of innovation novelty in capturing market share (Moreno and Coad, 2015; Coad, 2018). We argue that some of our results in different panels are consistent with Dachs *et al.* (2016) and Calvino and Virgillito (2018), who argue that the impact of innovation in all its forms can be both pro-cyclical during the growth phase of the business cycle and counter-cyclical during downturns.

Large mature high-growth firms made a significant per firm and aggregate contribution to net positive economic and employment growth in Australia over the period studied. Large firms have higher rates of innovation persistence than SMEs (Cefis and Orsenigo, 2001; Roper and Hewitt-Dundas, 2008; Máñez *et al.*, 2015). While the association between innovation and growth in these firms is apparent in turnover and profit, the positive association with innovation persistence is not as obvious in large complex-structured firms, except when viewed at the higher end of their growth distribution (Deschryvere, 2014). Other research suggests this phenomenon arises because large and/or mature firms are less agile and therefore able to leverage their innovations for competitive advantage (Coad *et al.*, 2018) or because the relationship between organizational/ management control and firm performance can be more opaque in complex structured firms (Le Bas and Scellato, 2014).

The results support the argument that older firms find it harder to adapt and take advantage of changing market conditions, despite more frequent innovation events than younger, smaller firms (Coad *et al.*, 2018). Firm ageing was often a significant negative factor influencing growth (Coad, 2018), and was particularly stark for profit and employment growth for large complex-structured firms. More than 90% of Australian firms reported innovating for profit reasons in 2012–13 (Australian Bureau of Statistics, 2014). It should be noted, however, that large Australian firms were significantly more likely to undertake innovation to address issues that do not necessarily capture market share. In 2012–13, large firms were almost three times more likely than micro firms to innovate in response to government regulations or to improve safety or working condition, and twice as likely to innovate to reduce environmental impacts or adhere to industry standards. Another compelling explanation is that, overall, Australian SMEs are more dependent on innovation for sustaining growth at their maximum desired size. Australian firms with 200+ employees report that innovation from new goods and services generates only 3% of their income. This was closer to 11% for firms with 5–199 employees and 21% in firms with 0–4 employees (Australian Bureau of Statistics, 2016).

Policy implications

The results of this paper clearly illustrate the risky nature of public and private investment in innovation. Figure A2 clearly shows the double-edged sword described by Moreno and Coad (2015).

The short-term growth percentile distributions in our study show that persistently innovating SMEs tend to be 'boom or bust' risk-takers: if they succeed, they grow faster, and if they fail, they fail harder than non-innovators. However, our results also show that innovation persistence helps create net-positive growth in sales, value-added, gross operating profit and employment. For large firms, persistent innovation has good betting odds. If they fail, they seem not to fail harder than non-innovators or less frequent innovators.

During the 2012–13 year, lack of access to additional funds was the most frequently identified barrier to innovative activity in Australian SMEs, at around 30% of firms reporting a barrier to innovation. Large firms were more likely to report cost of development or introduction/implementation over the same period (Australian Bureau of Statistics, 2014). Direct government financial support may therefore reduce the downside risk of innovation investment for young SMEs that are more exposed to the costs of failure than larger firms. However, policymakers need to understand, accept and communicate the inherent uncertainty of supporting the private sector in the search for innovation winners. Our results suggest that many government-supported firms may fail to grow or even exit the market. Our doubly robust regression results showed that, for all growth indicators, government financial assistance had no direct, positive impact on firm sales, value-added, profit and employment growth (though we note it did stimulate wage and salary growth).

Coad *et al.* (2018) argue that much of the dynamics we see are age-dependent and Guarascio and Tamagni (2019) provide some evidence that persistent innovation does not drive up growth in the long term after Spanish manufacturers cease their innovating. Even if in the long run growth and innovation persistence is essentially randomized and hard to predict in any single firm, short-term high-growth episodes in aggregate may deliver sustained economic, employment and wage growth in Australia, which we show is driven in part by short-run persistent innovation or innovation spells (Raymond *et al.*, 2010; Capasso *et al.*, 2013; Daunfeldt *et al.*, 2014; Bianchini and Pellegrino, 2019). So, while we agree with Moreno and Coad (2015) that targeting innovation policies to specific firms in the hope that they will drive high growth is impractical, we would argue that successive waves of firms experiencing short-term high-growth episodes, sustained perhaps by broad-based innovation policies, may be a pro-growth economic strategy consistent with the conclusions of Ciriaci *et al.* (2016). The aim of policymakers is not to support any one type of innovation in any one firm (or sector), but to encourage innovation-oriented cultures across all firms (Acemoglu *et al.*, 2018).

Innovation persistence literature suggests that helping firms develop an early innovation orientation or culture is more important to economic success than an ongoing subsidy of specific innovation activities, particularly in older firms that are more likely to shrink than to grow (Le Bas and Scellato, 2014; Navaretti *et al.*, 2014; Máñez *et al.*, 2015). The first five years of consecutive innovation seems to be the most critical to establishing an innovation culture (Triguero *et al.*, 2014). Coupling this with evidence that the most active growth phase of firms is their first five to seven years (Coad, 2018), our data suggest that economic and employment growth may be best served by supporting young SMEs (less than five years old) that are innovating for the first time. Beyond this period, government support may be less effective in stimulating growth via innovation in known persistent innovators or large and mature firms where innovation cultures and resources are already well-established (Peters, 2005).

Further research opportunities

No study to date has simultaneously observed whether different types of growth (sales or turnover, profit, value-added, productivity and employment) are supported by persistence in different types of innovation (product, process, organizational and marketing) at the same time as accounting for survivor bias. We could not control for survivor bias because of the limitations of our innovation survey and its confidentiality restrictions, but note that persistent Spanish product or process innovators have superior survival rates (Bianchini and Pellegrino, 2019). Survival bias could therefore be partly driving these results (Coad *et al.*, 2018).

While this study used many indicators to develop a propensity score, a number of our descriptive observations point to control variables that may further reduce omitted variable bias in future innovation persistence and growth studies. While the innovation persistence results are compelling, physical and intangible capital stock information is largely missing from the dataset, making it harder to claim growth is purely driven by sustained inter-firm competitive advantage (Denrell, 2004). Most studies (including this one) do not measure supply chain effects (where one firm's process innovation is another firm's product innovation (Calvino and Virgillito, 2018). Tavassoli and Karlsson (2017) also show that innovation persistence could be stimulated by external regional factors. While our choice of control variables was generally firm-level, some sectoral or market-specific proxy information, such as skill shortages, may account for some of this regional variation. Even strategic management capability which, when measured, accounts for significant variation in firm performance (Peters, 2005; Bloom *et al.*, 2014) could be reflected in variation in organizational and managerial innovation (Hendrickson *et al.*, 2016).

The higher likelihood of complementary and more novel innovations in persistent innovators found in our study also suggests that persistent innovators are more strategic or entrepreneurial than their less persistent counterparts. This would fit with the argument of Audretsch *et al.* (2014) that entrepreneurial firms that can be more adaptive and better exploit knowledge spill-overs will outperform other firms. The regression results showing a strong relationship between firm cooperation and growth support this argument and are consistent with Arranz *et al.* (2019). This further complicates a reverse causality argument. Firm innovation (persistence) may be our best current signal for a successful, strategic firm with higher levels of intangible capital, specifically managerial capital.

The impact of institutional factors on the innovation–growth relationship was not extensively examined in this paper though a number of indicators, such as firm cooperation and collaboration, skill shortages, market competition, foreign ownership and government assistance influenced firm growth rates, depending on the growth indicator studied (see Tavassoli and Karlsson, 2017). Future research could incorporate sequence analysis into our matching method to eliminate confounding patterns of innovation; for example, less frequent innovators who introduced innovations at different ends of the three-year time period (100 *vs* 001 patterns). Innovation-active firms, particularly persistent innovators, tended to be larger within their own size class compared with non-innovators. Other output measures such as annual turnover, are also correlated. Further research needs to include a more continuous variables in the PSM technique, particularly tighter turnover, output and employment ranges to account for these differences. This, along with more modern causal inference techniques that conserve sample size, such as causal forest modelling (see Wager and Athey, 2018), would improve the robustness of the results.

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The results presented here are based, in part, on tax data supplied by the Australian tax office (ATO) to the Australian bureau of statistics under the taxation administration act 1953, which requires that such data are used only for the purpose of administering the census and statistics act 1905. Any discussion of data limitations or weaknesses is in the context of using the data for statistical purposes, and is not related to the ability of the data to support the ATO's core operational requirements. Legislative requirements to ensure privacy and secrecy of this data have been adhered to.

In accordance with the census and statistics act 1905, the results presented are unlikely to enable identification of a particular person or organization.

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