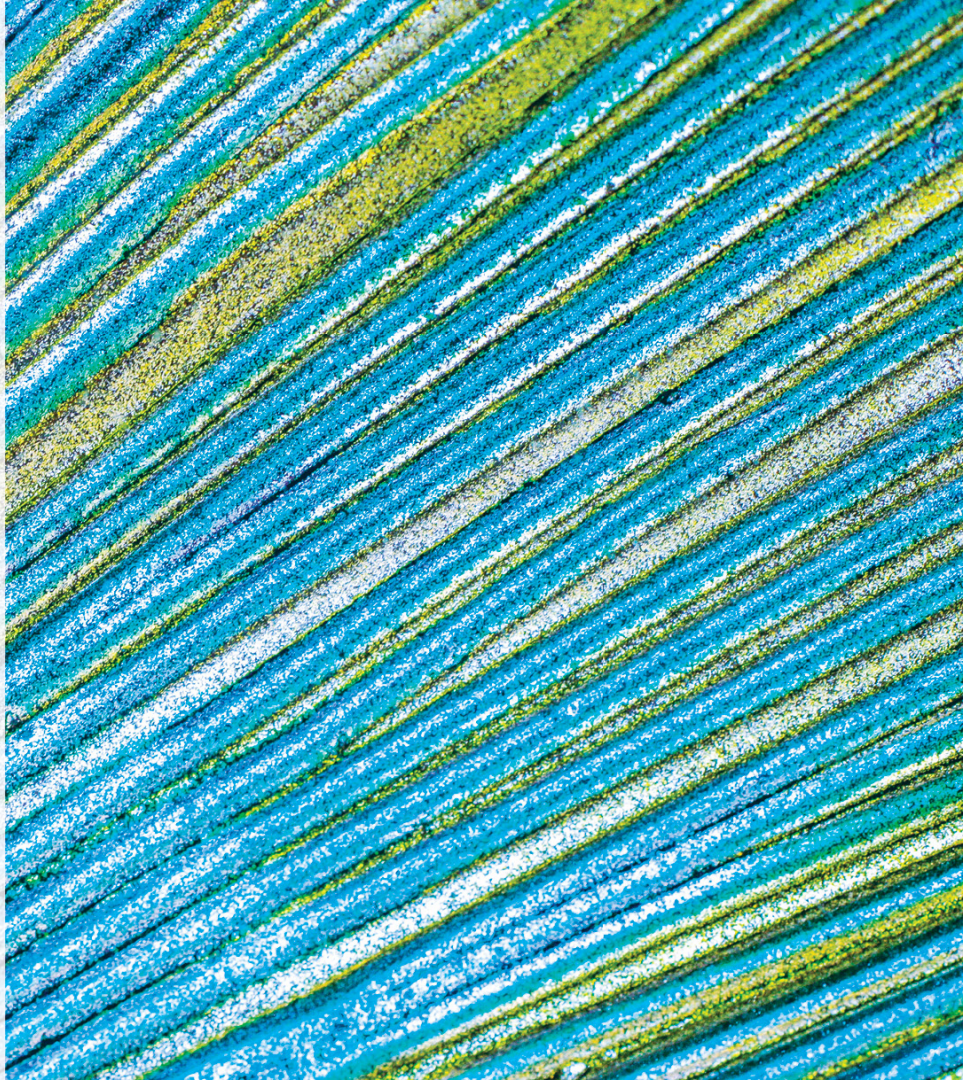
Thriving through innovation: Lessons from the top

How leading ASX firms outcompete

Methodological appendix



The University Of Queensland
AUSTRALIA

Thriving through innovation: lessons from the top

Acknowledgement

CSIRO acknowledges the Traditional Owners of the lands that we live and work on across Australia and pay their respect to Elders past, present and emerging. CSIRO recognises that Aboriginal and Torres Strait Islander peoples have made and will continue to make extraordinary contributions to all aspects of Australian life including culture, economy and science.

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Research design

1 Approach

In order to identify innovative behaviour associated with superior performance in Australian businesses, we searched for patterns of innovation activity across the three dimensions inspiring our investigation: (1) what are companies doing to innovate; (2) what processes are companies following to innovate; (3) what is the companies' attitude towards innovation.

We used multiple measures for each dimension, adopted from the most influential literature on innovation management from academia and practice.

While we relied on survey-based research to collect data on innovation activities from executives from Australian businesses, we also relied on secondary data in order to make robust observations about the performance effects of these innovation activities. The use of secondary data that measure performance in absolute terms represents an advancement over the typical survey research that collects relative performance data from the survey itself.

The analysis of the data and results are supported by cutting-edge methods including multiple statistical tests and predictive modelling.

2 Sampling

Publicly listed companies offer a proper setting to systematically investigate innovation management and strategy behaviour given the amount and type of company data available resulting from the obligations tied to public ownership. More data equals more powerful and robust insights. But also, public companies in Australia represent a diverse set of companies comprising successful world-class companies, influential players in the domestic scene, and mature companies that have been key to the economic stability of the nation. Taken together, the ASX is a top-performing group compared to other listed exchange groups in the world. This makes it an appropriate place to look for pockets of successful innovation activity and learn from them.

We took a snapshot of the ASX in November 2019 (which included 2,195 companies) and searched from financial data in large proprietary company financial datasets. After refining our sample to include those with available accounting data for at least three years, we obtained a final sample of 197 companies with complete survey results.

We analysed the representativeness of our sample compared to the entire population of ASX-listed companies, and the distributions across GICS (Global Industry Classification Standard) sectors and company size (by market capitalisation) for both sample and population are similar.

National survey

1 Design

The national survey was designed so that it captured the most relevant features of the innovation activities carried out by the companies in our sample.

The targeted respondents were c-suite executives, managing directors, vice-presidents, directors and managers from corporate units responsible for undertaking company-level innovation efforts.

We conducted a systematic review of the innovation literature and identified constructs that have been employed to capture innovation activities across our “pattern, process and attitudes” dimensions, and with evidence of positive associations with business performance.

We then identified a series of survey scales that have been designed, tested and successfully employed by leading academics and practitioners to measure our constructs of interest.

2 Development

The survey questions were carefully developed so that the responses could clearly reflect the constructs of interest. Some questions were presented in the form of Likert scale-type questions, others were presented as yes/no questions, while others were presented as closed-ended direct questions. We standardised the coding structure across questions to maintain consistency, particularly in the Likert scale questions.

The questions, scales and underlying constructs of interests were validated by a panel of experts from The University of Queensland. We also discussed the survey design with key managers from the Department of Industry, Science, Energy and Resources.

We then conducted internal survey assessments, where we checked for consistency, interpretability and duration. Lastly, we teamed up with a multinational market research firm, who conducted additional checks to the survey program via pilot-testing.

3 Administration

For the administration of the national survey, we partnered with a world-leading multinational market research and consulting firm. In addition, we worked with multiple vendors to source and validate the contact details of the potential respondents.

The survey asked 10 multi-item questions, with an average duration of 16 minutes. It was administered via phone calls to the targeted respondents. A snow-balling technique was used in cases where the specific respondent was unable to participate but the organisation was.

The survey remained active for 2 months, from late January 2020 to late March 2020. During this period, COVID-19 emerged as a global pandemic and disrupted the economic activities in Australia. Undoubtedly, an unprecedented situation like this had an effect on the responsiveness and willingness to participate. Despite this, we managed to obtain a substantial number of complete surveys on time.

Secondary data, integration and processing

Secondary data collection

We collected financial data and corporate details for our sample companies from Morningstar's DatAnalysis and S&P's Capital IQ, two of the most comprehensive financial data sources for listed companies in Australia.

We gathered corporate details such as location, industry of operation and listing date, as well as longitudinal data comprising a variety of financial indicators reflecting the financial performance of the companies.

Data storage, integration and processing

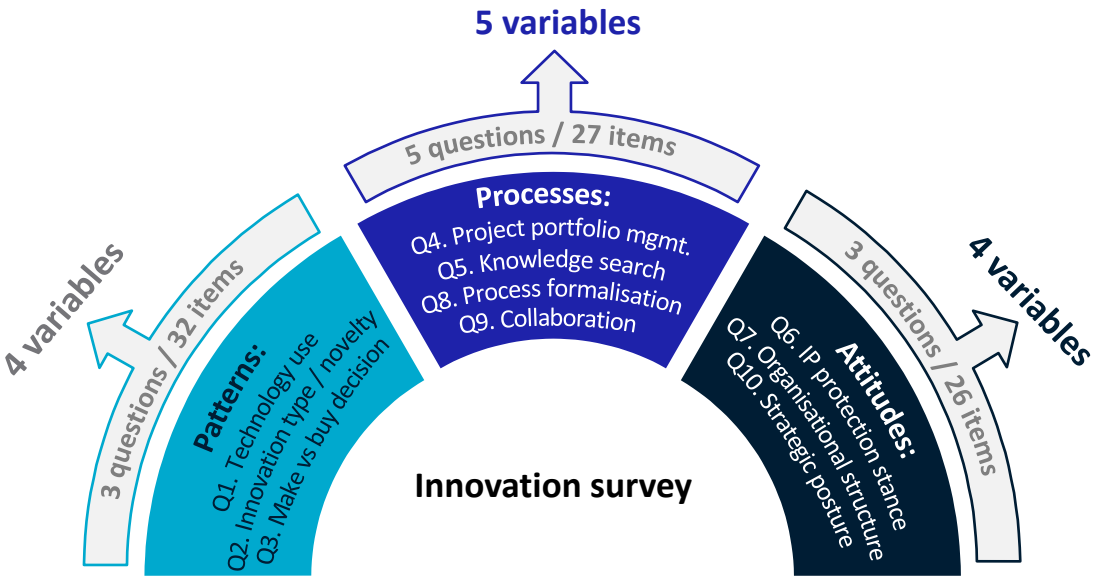
After pre-processing, primary (survey) data and secondary data were stored in robust relational databases purposefully designed for the study. For each company, primary and secondary data were integrated using the company ticker.

The data cleaning, processing, and analysis was conducted in R, one of the most comprehensive software environments for statistical computing and graphics.

Innovation variables (independent variables)

Each of the 10 main questions in the survey (comprising a total of 85 items) captured a particular aspect of the innovation activity in ASX companies. These aspects were directly associated to each of our three dimensions of analysis (innovation patterns, innovation processes and attitudes toward innovation).

A total of 13 innovation variables (and one self-assessed innovation performance variable) were constructed by aggregating multiple items. We employed different aggregation methods - ranging from sum to unweighted and weighted averages, and all variables were normalised. These procedures mirrored those indicated in the publications from which we sourced the scales. We checked the reliability and internal consistency among the items by conducting principal components analysis (PCA) and calculating Cronbach's alpha. The majority of the individual factors across the 13 variables had factor loadings greater than 0.5 (those below this number were discarded). All the 13 variables had a Cronbach's alpha of 0.7 or higher, values that are similar to those reported in the reference sources. See next slide for the full list of question, items and derived variables, with corresponding references.



Innovation variables (cont.)

Questions (with references)	Items	Scale	Variable
1. Is your business actively using the following technologies to create value for the business and/or for your customers?[1 2 3]	Robotic Hardware | Robotic Process Automation | Autonomous vehicles | Augmented / Virtual Reality | Internet of Things | Advanced data analytics | Artificial Intelligence | Cognitive computing | Conversational computing | Mobile computing | Cloud / edge computing | Blockchain | Digital twins | 3D printing | Advanced materials | Renewable energy | Energy storage | Carbon abatement | Space technologies | Advanced biotechnologies	Dichotomous (yes, no)	Breadth of technology use
2. In the last 3 years, has your business introduced any of the following types of innovation? For each one, what was the degree of novelty?[4]	Product innovation | business process innovation | business model innovation	Dichotomous (yes, no)	Innovation types
	New to the world | New to Australia | New to the industry within Australia	Dichotomous (yes, no)	Degree of novelty
3. Rate how well these activities have supported the introduction of new products and services in the past 3 year.[5]	Acquisition of R&D | Acquisition of machinery, equipment or software | Acquisition of external knowledge through intellectual property | Acquisition of knowledge from other organisations | Acquisition of knowledge through innovation contests | Participation in external innovation programs	5-point Likert scale	Degree of technology and innovation acquisition
	In-house R&D | Training of staff | Marketing | Design work	5-point Likert scale	Degree of in-house innovation activities

** Items dropped after internal consistency checks*

Patterns Processes Attitudes Alternative performance variable

Innovation variables (cont.)

Questions (with references)	Items	Scale	Variable
4. Please answer these questions about your innovation performance and management.[6 7]	Percentage of revenues from products and/or services that are new to the business in the past 3 years	Continuous	Innovation performance
	Number of innovation projects that have been funded in the past 3 years	Integer	Portfolio management strategy
	Number of innovation projects that have been stopped or discontinued in the past 3 years	Integer	
5. How important have these sources of information been for your innovation activities in the last 3 years?[6]	Other enterprises within your enterprise group* | Suppliers of equipment, materials, components, or software | Clients or customers from the private sector | Clients or customers from the public sector | Competitors or other companies in your sector | Consultants or commercial labs | Universities or other higher education institutes | Government, public or private research institutes	5-point Likert scale	Breadth of external knowledge search
6. Please rate the effectiveness of these mechanisms to protect and derive value from new products and services developed by your business.[6 8 9]	Patents | Design registration, such as trademarks, copyrights and servicemarks | Secrecy | Lead time | Complexity of product or design| Complementary service provision | Complementary marketing capabilities | Complementary production capabilities	5-point Likert scale	Strength of IP protection mechanisms
7. Please indicate how often each of the following items is employed when undertaking innovation activities.[11]	Employees are regularly rotated between jobs in our business | There is regular talk about possibilities for collaboration between units | Our business coordinates information sharing between units through a knowledge network | We have cross-functional teams to exchange knowledge between departments | Our business uses temporary workgroups for collaboration between units on a regular basis	5-point Likert scale	Use of cross-functional interfaces
	In our business, there is ample opportunity for informal "hall talk" among employees | In our business, employees from different departments feel comfortable calling each other when the need arises | People around here are quite accessible to each other | In our business, it is easy to talk with virtually anyone you need to, regardless of rank or position	5-point Likert scale	Use of network structures

** Items dropped after internal consistency checks*

Patterns Processes Attitudes Alternative performance variable

Innovation variables (cont.)

Questions (with references)	Items	Scale	Variable
8. Please rate how well the following statements describe the innovation initiatives in your business.[12]	Employees cooperate fully in generating and screening new ideas for new products and services (reversed)* | Top management has the exclusive task of establishing goals and priorities for our innovation strategies | The innovation process is heavily formalized through dedicated project teams and routinized procedures | In our business, we have a dedicated unit responsible for the innovation function	5-point Likert scale	Degree of process formalisation
9. Has your business cooperated on innovation activities with any of the following types of organisation in the last 3 years? [6]	Other enterprises within your enterprise group* | Suppliers of equipment, materials, components, or software | Clients or customers from the private sector | Clients or customers from the public sector | Competitors or other companies in your sector | Consultants or commercial labs | Universities or other higher education institutes | Government, public or private research institutes	Dichotomous (yes, no)	Breadth of collaboration
10. Please rate your business's strategic posture by rating the following statements [13]	In general, the top managers of my business favour a strong emphasis on R&D, technological leadership and innovation | We have very many new lines of products or services that have been marketed in the last 3 years | Changes in our product or services lines have usually been quite dramatic over the last 3 years | My business typically initiates actions which competitors then respond to | In dealing with competitors, my business is very often the first business to introduce new products/services, administrative techniques, operating technologies, etc. | My business typically adopts a very competitive "undo-the-competitors" posture | Our business has a strong proclivity for high-risk projects with chances of very high returns | In general, the top managers of our business engage in bold, wide ranging acts that are necessary to achieve our objectives | In uncertain times, my business typically adopts a bold aggressive posture in order to maximise the probability of exploiting potential opportunities.	5-point Likert scale	Degree of entrepreneurial strategic posture

** Items dropped after internal consistency checks*

Patterns Processes Attitudes Alternative performance variable

Performance variables

Performance variables (dependent variables and control variables)

For the financial performance measure (dependent variable), we chose a market-based measure of return instead of profitability ratios such as return on assets, given its forward-looking nature and capacity to capture the company's future performance potential.[14] This is particularly important in innovation studies, as the bottom-line effect of novel products and services take time to materialise. The way market-based measures such as market-to-book ratio and Tobin's Q reflect the value of the company's future earning and growth potential is by combining the tangible value of a company with the intangible value that is perceived by the market. Evidence suggests that the market is capable of evaluating innovative activity in firms reasonably well.[15] We adopted Morningstar's formula for calculating price-to-book value, computed as the closing share price on the last day of the financial year divided by shareholders equity per share. We then calculated the median of the price-to-book value for each company for the last three years. Our choice of performance variable and its calculation help us ensure that there is no significant correlation between the dependent variable and control variables used in the study, particularly firm size (measured by total assets).

In our models, we controlled for the differences in innovation activity across industries by introducing dummy variables for the two-digit GICS codes in which the company operates.[8] Given the potential effects of company size on innovation (in terms of resources available for innovation and complementarities between marketing and finance capabilities and innovation), we also employed a control variable for company size, calculated as the median of the natural logarithm of total assets for the last three years.[16]

For all variables, the three-year window helped us maintain consistency with the survey questions, which asked about the innovation activities performed in the last three years. Due to the presence of extreme outliers, the dependent variable was winsorised at 5% and 95%. Winsorisation is a technique used to treat highly skewed variables that may lead to biased results when conducting statistical analyses, and consists of replacing extreme observations by percentiles within the specified cut-off range.[17]

Final variables list

	Variable	Description and measurement	Source
		Survey variables	
Processes	**Degree of in-house innovation activities**	Degree of engagement in activities where tangible and intangible elements associated with innovation were developed in-house. Measured by the mean scores of activities conducted by and within the business that have supported the introduction of new products and services in the past 3 years (normalised).	5
	Portfolio management strategy	Whether the company follows a project portfolio management process in which innovation effort and resources are selectively allocated across a number of projects. This dichotomous variable takes to value of 1 (“selective”) if the number of both projects funded and stopped in the past 3 years are greater than 0, and 0 (“unselective”) otherwise.	7
	Breadth of external knowledge search	Degree of use of external sources of information and knowledge by the company in its innovative activities in the last 3 years. Measured by the sum of scores for each knowledge source (normalised).	6
	Degree of process formalisation	Extent to which the innovation processes are generated by managers, and formally structured through routines, frames and dedicated units across the company. Measured by the weighted mean of scores of the corresponding items, using the item factor loadings as weights (normalised).	12
	Breadth of collaboration	Degree to which the company has cooperated with different types of organisations as part of their innovation activities in the last 3 years. Measured by the sum of scores for each type of collaborator organisation (normalised).	6

Final variables list (cont.)

	Variable	Description and measurement	Source
		Survey variables	
Patterns	**Breadth of technology use**	Number of different types of technologies employed to create value for the company and its customers. Measured as the sum of the numbers of technologies used (normalised).	18
	Innovation types	Number of innovation types (i.e. product, process, business model) simultaneously introduced in the last 3 years. The possible values of this categorical variable are 1 type, 2 types, or 3 types.	19
	Degree of novelty	Average newness of the innovations introduced in the last 3 years, based on four levels of novelty: (1) new to the business, (2) new to the industry (within Australia), (3) new to Australia and (4) new to the world. Measured as the mean of the levels of novelty across the different types of innovation introduced (normalised).	20-21
	Degree of technology and innovation acquisition	Degree of engagement in activities where tangible and intangible elements associated with innovation were purchased or acquired from external parties. Measured by the mean scores of acquisition-based activities that have supported the introduction of new products and services in the past 3 years (normalised).	5

Final variables list (cont.)

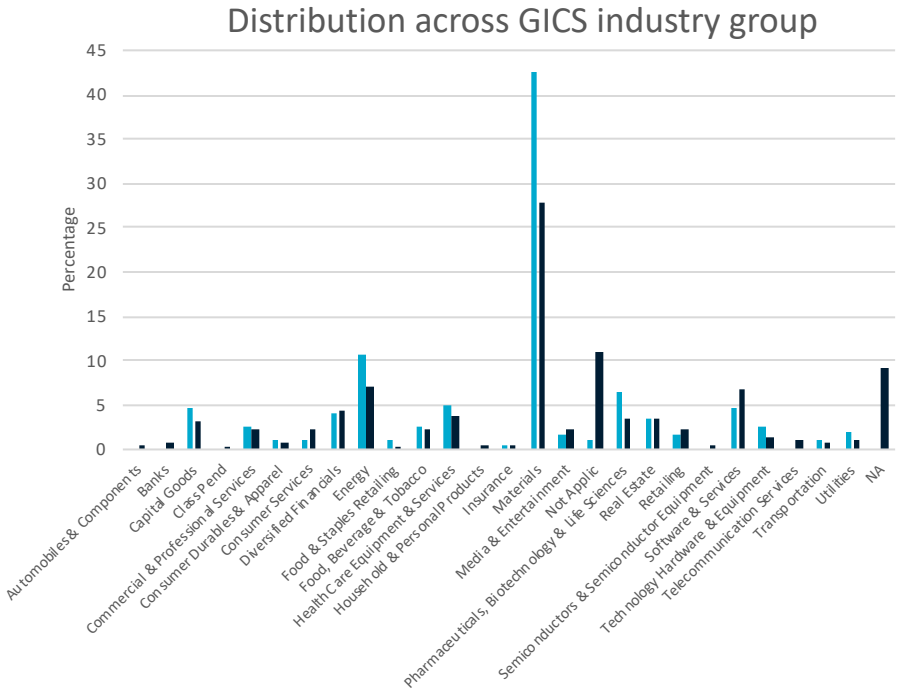
	Variable	Description and measurement	Source
		Survey variables	
Attitudes	**Strength of IP protection mechanisms**	Degree of use of informal and formal IP protection methods to derive value from the new products/services developed. Measured by the sum of scores for each IP protection method (normalised).	6,8-10
	Use of cross-functional interfaces	Degree of use of cross-functional integration mechanisms (such as cross-functional teams or projects) when innovating. It also reflects the degree of reliance on formal organisational structures to innovate. Measured by the weighted mean of scores of the corresponding items, using the item factor loadings as weights (normalised).	11
	Use of network structures	Degree of use of employee networks within the company as integration mechanism when innovating. It also reflects the degree of reliance on informal organisational structures to innovate. Measured by the weighted mean of scores of the corresponding items, using the item factor loadings as weights (normalised).	11
	Degree of entrepreneurial strategic posture	Extent to which the company's strategic posture is characterized by frequent technological and product innovation, an aggressive competitive orientation, and a strong risk-taking propensity by top management. Measured by the mean scores of the items of the three traits used to assess strategic posture: innovation tendency, proactiveness and risk-taking propensity (normalised).	13

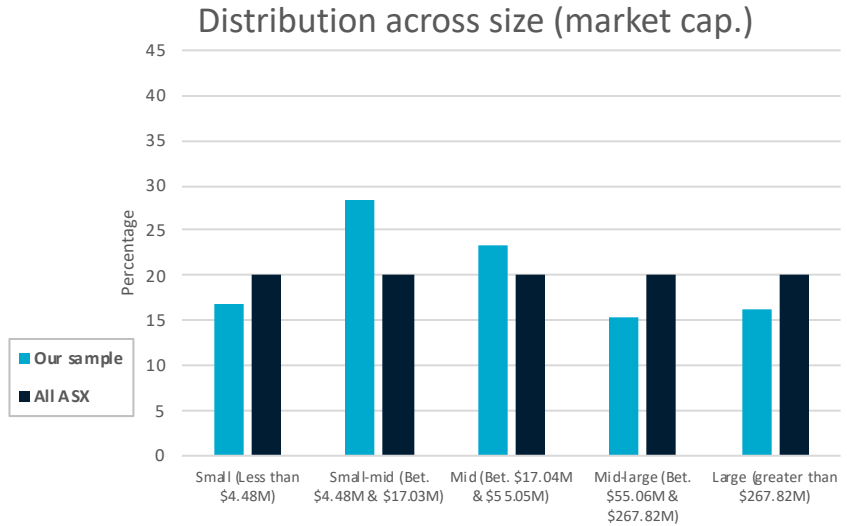
Final variables list (cont.)

	Variable	Description and measurement	Source
		Secondary data variables	
Financials and other	**Price-to-book value**	Market-based indicator of the long-term financial performance of the company. It integrates both the intangible and tangible value of the company, allowing to estimate future performance potential based on the present innovation activities. The measure is provide by Morningstar, and is calculated as the 3-year median of the closing share price on the last day of financial year divided by shareholders equity per share, over the last 3 years (winsorised at 5% and 95%)	15,24
	Total assets	Indicator of the size of the company using total assets. Measured by the 3-year median of the natural logs of the yearly total assets, over the last 3 years. Used in the models to control for the effects of size differences on performance	16,23
	GICS sector	Indicator of main industry of operation. Measured by taking the first two digits of the company GICS code. Used in the models to control for the effects of the industry conditions on performance.	8,23
	Innovation performance	Innovation output variable that reflects the company's capacity to translate innovation activities into products and services. Measured by the percentage of revenues from products and/or services new to the company in the last 3 years. Used for robustness checks to test the reliability of the estimations	6
	Market-to-book ratio	Alternative market-based indicator of financial performance. Measured by the 3-year median of the market capitalisation divided by total assets, over the last 3 years. Used for robustness checks the assess the effect of the choice of market-based performance measure as dependent variable	14
	Return on assets	Alternative profitability-based indicator of financial performance. Measured by the 3-year median of the fiscal year's earnings before interest divided by total assets, over the last 3 years. Used for robustness checks to assess the effect of the choice of performance measure as dependent variable	22

Sample of respondents and representativeness

The 197 companies that completed the survey were categorised by size (market capitalisation) and GICS industry group. The distribution across groups were compared with the distribution for the full list of more than 2000 ASX companies (taking the existing population on 5th March 2020 as baseline). Although the distributions are not identical, none of the categories are underrepresented or overrepresented by more than 8 percent point (excluding “NA” and “Not Applic”). The exception is “Materials” (over representation by 14.7 percent points). However, the industry dominance is of similar proportion in both sample groups. All in all, the distributions are moderately similar, thus, our sample seems to be a fair representation of the entire population.





Descriptive statistics and correlations

There are no systematic issues with missing values. Although “Degree of novelty” has missing values for 26% of the companies, these are cases were novelty could not be computed given the lack of innovations introduced in the last 3 years, and does not represent missing information.

Only two Spearman’s rank-order correlation coefficients are greater than +/- 0.5. For the first one, the correlation between ”Strength of IP protection mechanisms” and “Degree of in-house innov. activities” could be due that companies with high levels of R&D, marketing and design work are more likely to require stronger IP protection strategies. For the second one, an explanation of the correlation of “Degree of process formalisation” and “Strength of IP protection mechanisms” could be that a more formalised innovation process might result on a wider selection of IP protection methods, as there is more certainty about the type of innovation outputs and their needs in terms of appropriability mechanisms.

variable	n	mean	sd	median	min	max	skew	kurtosis	se
Breadth of technology use	197	0.26	0.19	0.25	0.00	0.85	0.80	0.27	0.01
Innovation types*	197								
Degree of novelty	145	0.71	0.28	0.75	0.25	1.00	-0.41	-1.26	0.02
Degree of in-house innov. act.	197	0.45	0.16	0.47	0.14	0.72	-0.23	-0.89	0.01
Degree of tech. and innov. acq.	197	0.31	0.12	0.31	0.12	0.64	0.27	-0.53	0.01
Innovation performance	184	0.20	0.32	0.00	0.00	1.00	1.53	0.88	0.02
Portfolio management strategy*	191								
Breadth of ext. knowledge search	196	0.52	0.16	0.50	0.14	0.91	0.31	-0.55	0.01
Strength of IP protection mech.	196	0.53	0.21	0.55	0.08	0.98	0.06	-0.89	0.02
Use of cross-functional interfaces	197	0.43	0.17	0.45	0.15	0.76	-0.21	-1.06	0.01
Use of network structures	197	0.70	0.15	0.75	0.17	0.84	-1.60	2.80	0.01
Degree of process formalisation	197	0.41	0.17	0.41	0.16	0.78	0.35	-0.70	0.01
Breadth of collaboration	197	0.54	0.29	0.57	0.00	1.00	-0.20	-0.96	0.02
Degree of entrep. strategic posture	197	0.60	0.18	0.60	0.20	0.98	-0.17	-0.64	0.01
Price-to-book value	197	2.92	3.32	1.83	-0.67	12.38	1.68	2.14	0.24
Total assets (log)	197	17.20	2.63	16.56	10.83	25.98	1.07	1.07	0.19
GICS sector*	197								

	variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Breadth of technology use	1.00													
2	Degree of novelty	-0.01	1.00												
3	Degree of in-house innov. act.	0.27	0.32	1.00											
4	Degree of tech. and innov. acq.	0.18	0.05	0.32	1.00										
5	Innovation performance	0.13	0.14	0.24	-0.04	1.00									
6	Breadth of ext. knowledge search	0.14	0.09	0.42	0.48	-0.02	1.00								
7	Strength of IP protection mech.	0.30	0.30	0.58	0.34	0.27	0.49	1.00							
8	Use of cross-functional interfaces	0.18	0.08	0.30	0.23	0.17	0.33	0.29	1.00						
9	Use of network structures	0.05	0.15	0.13	0.02	-0.05	0.13	0.05	0.37	1.00					
10	Degree of process formalisation	0.11	0.22	0.31	0.09	0.21	0.18	0.52	0.15	-0.08	1.00				
11	Breadth of collaboration	0.26	0.26	0.27	0.32	-0.01	0.48	0.30	0.26	0.12	0.16	1.00			
12	Degree of entrep. strategic posture	0.23	0.35	0.46	0.15	0.35	0.28	0.47	0.32	0.14	0.33	0.32	1.00		
13	Price-to-book value	-0.04	0.05	0.01	-0.04	0.22	0.03	0.07	0.08	0.00	0.09	0.05	0.16	1.00	
14	Total assets (log)	0.43	-0.21	0.02	0.06	-0.03	0.05	-0.03	0.01	-0.18	0.06	0.10	-0.13	-0.16	1.00

** Categorical variables*

Quantile regression analysis

After confirming that there were no significant correlations between the constructed variables, we estimated quantile regression models for each the 'pattern, process and attitudes' dimensions in our study. The dependent performance variable, price-to-book value, was regressed on each set of the innovation variables comprising the three dimensions (and controlling for size and industry), resulting in three separated models. We conducted separated analyses because we wanted to assess the performance effect of innovation patterns, processes, and attitudes irrespective of each other. Although we do not rule out the hypothesis that these three different innovation dimensions interact with each other to drive performance, assessing such interaction is out of the scope of this study and may unnecessary add complexity to our quantile regression models.

We chose quantile regressions over more traditional linear regressions for two reasons. Firstly, the dependent variable follows a non-normal and highly skewed distribution, which is problematic for traditional linear regression. Quantile regression is well equipped to deal with uneven distributions of the independent variables across the different quantiles of the dependent variable.[27] Secondly, we seek to understand the different ways in which innovation affects performance in companies across different performance levels – doing so maximises the likelihood of finding innovation behaviour that is far from average, generating insights that could encourage changes in the innovation behaviour of average companies in Australia. This is precisely the reason why quantile regression has been employed in influential innovation studies in the past.[15 25 26]

In our quantile regression analyses we make comparisons between the 90th and the 50th percentile. This comparison is meant to reflect the difference between the average ASX performer—what we term as mid-performers—and those at the top—i.e. the 90th percentile. This comparison is also a more conservative approach than comparing the top with the bottom performers. However, it represents a fairer comparison given that these companies may be in the lowest performance category for many other reasons outside of the study's scope, which could confound our analysis.

Quantile regression results

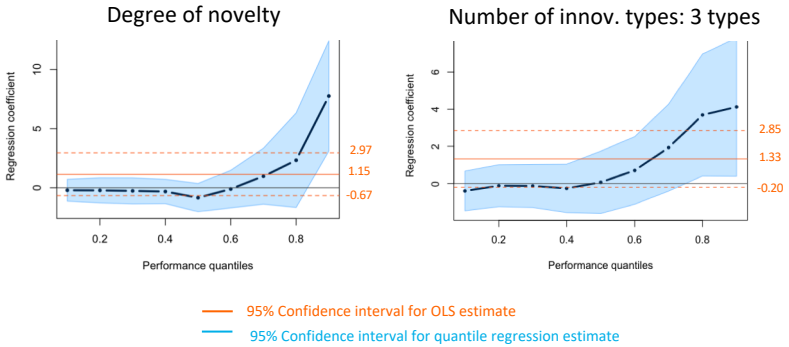
1 Patterns

Innovation patterns: Quantile regression results for 10th, 25th, 50th, 75th and 90th quantiles of the dependent variable

(Standard errors of coefficients in parentheses. Obtained using 200 bootstrap replications)

	Price-to-book value					
	OLS	*Quantile regression*				
		10th	25th	50th	75th	90th
Degree of novelty	1.15	-0.21	-0.19	**-0.84**	1.07	**7.76*****
	(1.10)	(0.55)	(0.64)	(0.76)	(1.97)	(2.93)
Number of innov. types: 2 types	0.01	-0.34	-0.39	-0.59	0.2	0.99
	(0.74)	(0.46)	(0.55)	(0.62)	(1.84)	(2.02)
Number of innov. types: 3 types	1.33	-0.4	-0.09	**0.07**	1.92	**4.12***
	(0.92)	(0.70)	(0.65)	(1.01)	(1.92)	(2.30)
Breadth of technology use	-0.84	-1.26	-0.21	1.62	-2.66	-5.84
	(1.93)	(1.21)	(1.31)	(1.76)	(3.36)	(4.44)
Degree of tech. & innov. acquisition	-1.13	0.35	-1.18	-0.07	0.28	-1.11
	(2.68)	(1.53)	(1.78)	(2.74)	(5.48)	(7.28)
Control variables:						
Company size (log total assets)	-0.04	0.18*	0.07	-0.1	0.01	-0.17
	(0.13)	(0.10)	(0.11)	(0.14)	(0.29)	(0.34)
GICS sector (dummies)	Included	Included	Included	Included	Included	Included
Constant	2.68	-2.63	0.05	3.38	5.26	3.31
	(3.42)	(2.87)	(2.60)	(3.01)	(5.79)	(7.24)
Observations	145	145	145	145	145	145
(Pseudo) R^2	0.11	0.31	0.25	0.28	0.32	0.46

*Note: *p<0.1; **p<0.05; ***p<0.01*



Results discussion:

The coefficient of degree of novelty at the 90th (top) percentile is positive, statistically significant and greater than the coefficient at the 50th (mid) percentile. For the average top performing firm, every percent increase in the degree of novelty of their innovations contributes to a 7.76 increase in price-to-book value, a significant jump from the negative contribution of -0.84 to price-to-book value for the average mid performer. As seen in the chart, in the top percentile, the coefficient estimate is significantly greater than estimations from OLS model (estimate and confidence interval in orange), providing confidence that the coefficients are indeed different.

A similar situation is seen for the innovation types variable. The effect of introducing three types of innovation (i.e. product, process and business model) among top performers is positive, statistically significant and greater than the effect seen among the mid performers. When the average top performer introduce the three types of innovation, the price to book value is like to increase by 4.12 percent, compared to an increase of 0.07 for the average mid performer. As per the chart, in the top percentile, the coefficient estimate is significantly greater than estimations from OLS model.

Quantile regression results

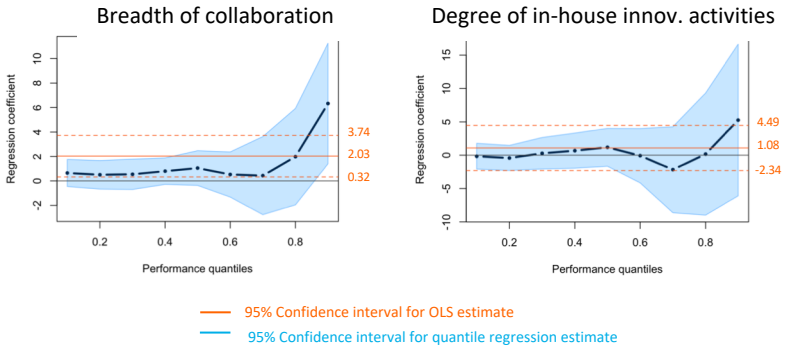
2 Processes

Innovation processes: Quantile regression results for 10th, 25th, 50th, 75th and 90th quantiles of the dependent variable

(Standard errors of coefficients in parentheses. Obtained using 200 bootstrap replications)

	Price-to-book value					
	OLS	*Quantile regression*				
		10th	25th	50th	75th	90th
Degree of process formalisation	1.14	0.81	0.44	0.05	-2.17	-0.08
	(1.68)	(0.92)	(0.97)	(1.28)	(3.13)	(4.82)
Breadth of ext. knowledge search	-1.99	0.07	0.55	-0.91	-0.54	-7.06
	(1.94)	(1.07)	(1.27)	(1.84)	(3.44)	(6.26)
Breadth of collaboration	2.03*	0.65	0.58	**1.05**	1.11	**6.33****
	(1.04)	(0.62)	(0.78)	(0.83)	(2.16)	(3.08)
Portfolio management. strategy	-0.37	-0.50*	-0.21	-0.11	-0.64	0.41
	(0.53)	(0.29)	(0.31)	(0.43)	(1.00)	(1.55)
Degree of in-house innov. activities	1.08	-0.17	0.02	**1.18**	-0.21	**5.26**
	(2.07)	(1.10)	(1.22)	(1.83)	(4.56)	(6.53)
Control variables:						
Company size (log total assets)	0.01	0.15**	0.06	-0.04	-0.01	0.01
	(0.11)	(0.06)	(0.07)	(0.10)	(0.24)	(0.35)
GICS sector (dummies)	Included	Included	Included	Included	Included	Included
Constant	1.4	-3.22	-1.18	1.18	6.46	1.81
	(2.98)	(2.18)	(2.34)	(2.77)	(4.47)	(7.29)
Observations	190	190	190	190	190	190
(Pseudo) R^2	0.11	0.12	0.06	0.08	0.09	0.25

*Note: *p<0.1; **p<0.05; ***p<0.01*



Results discussion:

The coefficient of breadth of collaboration at the 90th (top) percentile is positive, statistically significant and greater than the coefficient at the 50th (mid) percentile. For the average top performing firm, every percent increase in the breadth of collaboration on innovation activities contributes to a 6.33 increase in price-to-book value, a considerable jump from the contribution of 1.05 to price-to-book value for the average mid performer. As seen in the chart, in the top percentile, the coefficient estimate is significantly greater than estimations from OLS model (estimate and confidence interval in orange), providing confidence that the coefficients are indeed different.

A similar situation is seen for the degree of in-house innovation activities. Its coefficient at the top percentile is positive and greater than the coefficient at the mid percentile, although not statistically significant. In addition, the chart indicates that the coefficient estimate is barely different from the OLS estimations. Thus, the contribution of this variable to performance at the top percentile is not as evident as the contribution from breadth of collaboration.

Quantile regression results

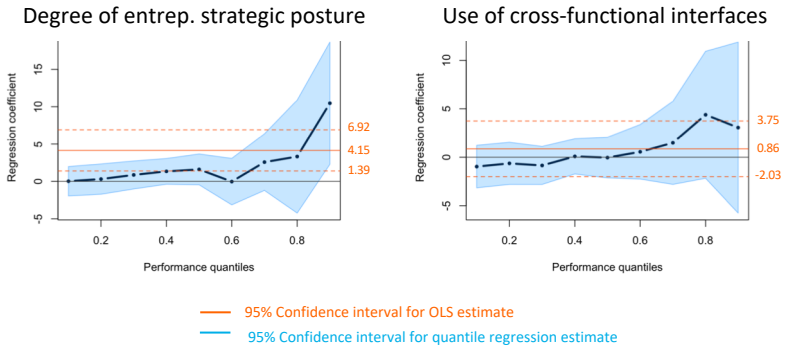
3 Attitudes

Innovation attitudes: Quantile regression results for 10th, 25th, 50th, 75th and 90th quantiles of the dependent variable

(Standard errors of coefficients in parentheses. Obtained using 200 bootstrap replications)

	Price-to-book value					
	OLS	*quantile regression*				
		10th	25th	50th	75th	90th
Strength of IP protection mech.	-1.12	0.91	0.17	-0.85	0.77	-2.65
	(1.44)	(0.76)	(0.72)	(1.24)	(2.60)	(3.42)
Use of cross-functional interfaces	0.86	-0.97	-0.76	**-0.04**	1.24	**3.06**
	(1.75)	(1.55)	(1.28)	(1.29)	(3.25)	(4.98)
Use of network structures	-0.03	-0.95	0.12	0.03	0.24	-1.24
	(1.77)	(1.05)	(0.87)	(1.50)	(2.22)	(3.68)
Degree of entrep. strategic posture	4.15**	0.03	0.24	**1.61**	3.29	**10.47****
	(1.67)	(1.22)	(1.18)	(1.45)	(3.76)	(4.97)
Control variables:						
Company size (log total assets)	0.01	0.14***	0.08	-0.001	-0.06	0.06
	(0.10)	(0.04)	(0.06)	(0.09)	(0.19)	(0.28)
GICS sector (dummies)	Included	Included	Included	Included	Included	Included
Constant	-0.51	-1.82	-0.99	0.72	2.42	-3.18
	(3.06)	(1.92)	(2.00)	(2.49)	(4.15)	(6.10)
Observations	196	196	196	196	196	196
(Pseudo) R^2	0.12	0.09	0.04	0.06	0.1	0.26

*Note: *p<0.1; **p<0.05; ***p<0.01*

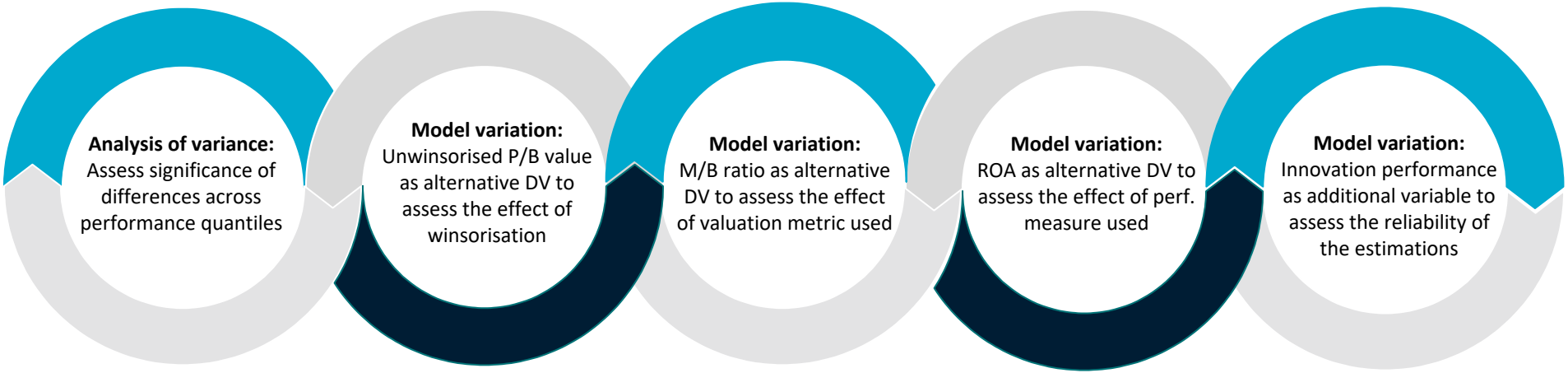


Results discussion:

The coefficient of degree of entrepreneurial strategic posture at the 90th (top) percentile is positive, statistically significant and greater than the coefficient at the 50th (mid) percentile. For the average top performing firm, every percent increase in the degree of entrepreneurial strategic posture contributes to a 10.47 increase in price-to-book value, a considerable jump from the contribution of 1.61 to price-to-book value for the average mid performer. As seen in the chart, in the top percentile, the coefficient estimate is significantly greater than estimations from OLS model (estimate and confidence interval in orange), providing confidence that the coefficients are indeed different.

A similar situation is seen for the use of cross-functional interfaces when innovating. Its coefficient at the top percentile is positive and greater than the coefficient at the mid percentile, although not statistically significant. Also, the chart indicates that the coefficient estimate is not significantly different from the OLS estimations. Thus, the contribution of this variable to performance at the top percentile is not as evident as the contribution from degree of entrepreneurial strategic posture.

Robustness tests and post-hoc analyses



We ran ANOVA tests between the coefficients estimated for the 90th and 50th percentile to assess the extent to which the coefficients are statistically significantly different across the performance groups. The test for all the key variables indicated that their coefficients at each percentile are significantly different at the $p < 0.05$ level. This supports our insights on the importance of key innovation variables for top performers compared to the average.

We developed supplementary models with the dependent variable (price-to-book value) in its original form (unwinsorised). The effect sizes, signs and significance of the key variables remain similar, confirming that our choice of winsorization did not influence the results

We also developed supplementary models with market to book ratio (an alternative market-based measure) as the dependent variable. The effect sizes, signs and significance of the key variables remain similar, confirming that our choice of market-based indicator did not influence the results.

We also ran supplementary models with ROA (profitability-based performance measure) as the dependent variable. Though the effect sizes and significance of key variables differed (as expected), the coefficient sizes for the 90th percentile remained greater (and positive) than the 50th percentile. This confirms our results on the importance of the key innovation variables for top performers compared to average performers.

We added innovation performance to our models, as it is a potential mediator of the innovation-financial performance relationship. For the four key variables, the signs and effect differences between 50th and 90th percentiles remained similar, confirming that innovation performance does not cause endogeneity issues biasing our estimations.

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