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Macroeconomic Conditions and Successful Commercialization

Paul H. Jensen and Elizabeth Webster

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Paul H. Jensen and Elizabeth Webster*
Intellectual Property Research Institute of Australia, The University of Melbourne
Melbourne Institute of Applied Economic and Social Research,
The University of Melbourne

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Melbourne Institute of Applied Economic and Social Research
The University of Melbourne
Victoria 3010 Australia
***Telephone* (03) 8344 2100**
***Fax* (03) 8344 2111**
***Email* melb-inst@unimelb.edu.au**
***WWW Address* http://www.melbourneinstitute.com**

Abstract

The commercialization of inventions is an investment, similar to spending on plant and equipment, and accordingly we would expect it to be affected by macroeconomic conditions. Using data on the commercialization activity from over 4000 inventors, we find evidence that macroeconomic conditions have a pro-cyclical affect on commercialization activities. However, the magnitude of the supply-side effects – the cost of finance and level of public sector research – are estimated to be larger than the growth in aggregate or industry demand.

Keywords: Innovation; Commercialization; Invention; Appropriation;

JEL Classification: O31, O34

1. Introduction

The commercialization of inventions is an investment, similar to spending on plant and equipment, and accordingly we would expect it to be affected by macroeconomic conditions. However, comparatively little is known about this association, primarily, we believe, because of the paucity of good commercialization data. If the level of commercialization activity is adversely affected by recession and low growth, then long-term productivity will suffer. In this paper, we examine the effects of macroeconomic conditions on downstream commercialisation decisions using new data from a sample of 4000 Australian inventors.

Scholars who argue that innovation is pro-cyclical (Griliches 1990, Guellec and Ioannidis 1997, Fatás 2000, Piva and Vivarelli 2007) have suggested that a positive economic outlook provides the incentive to invest in innovative activities (Geroski and Walters 1995), while high profit levels provide the means (Himmelberg and Petersen 1994). However, some have questioned whether this pro-cyclical relationship holds across the whole innovation process, and in particular to activities further down the value chain. For example, Francois and Lloyd-Ellis (2003) argue that since official R&D data is biased towards measured efforts of Research, it typically excludes important entrepreneurial functions that occur during Development. They argue that if the complete set of innovative activities were accounted for – R&D, in-house managerial time, the withdrawal of labour from direct production, *inter alia* – observed innovation would actually be counter-cyclical (see also Saint-Paul 1997). Wälde and Woitek (2004) extend this line of argument by formally separating Research from Development. In the USA between 1953 and 1998, they found that the pro-cyclical nature of R&D was driven by the more 'entrepreneurially-orientated' development, while research was in fact weakly countercyclical.[1]

Our approach hones in on this issue and considers whether macroeconomic conditions have differing effects on Research as distinct from Development. To do so, we rely on survey responses from a sample of 4,000 Australian inventors who filed for a patent application between 1986 and 2005. In this survey, inventors were asked a range of questions relating to their experiences with commercialisation. In addition, we collected a set of inventor- and invention-specific characteristics. Following Palmberg (2006) and Nerkar and Shane (2007), we model the commercialisation decisions using duration analysis. We employ a multiple

[1] Francois and Lloyd-Ellis (2003) also do not find any correlation between applied research and GDP in the US from 1953 to 1999.

event model and define the 'event' as an attempt made at one of a number of distinct commercialisation stages: development, licensing, transferring to a spin-off company, 'make and sell', mass production and export.

We find strong evidence that macroeconomic conditions matter and are pro-cyclical. However, the magnitude of the supply-side effect is estimated to be larger than the growth in aggregate or industry demand. In particular, the overdraft rate was found to have the largest effect followed by the level of tax incentives for R&D and changes to the level of public sector R&D.

The outline of our paper is as follows. In Section 2, we summarise the determinants of commercialisation with particular emphasis on macroeconomic forces. We then outline the data collated from the Australian Inventor Survey and provide some descriptive statistics. In Section 4, we provide the estimating model and analyse the results. Section 5 presents some robustness checks based on a set of different assumptions relating to the timing of commercialisation decisions. Section 6 concludes.

2. Determinants of commercialisation

This study examines the determinants of decisions to commercialise an invention *conditional* upon the invention's creation. Our specific focus is on the role of macroeconomic conditions upon commercialization decisions. However, the study itself is microeconomic in nature and accordingly does not consider feedback from the state of the macro-economy to the decision to invent.[2] Both R&D and follow-on commercialisation activities are investments from the point of view of the firm, and we would expect the determinants of the commercialisation decision to parallel those for the decision to invest in plant and equipment.

Almost all theories of firm investment behaviour are pro-cyclical. The aggregate theories of (tangible) investment dating from Keynes (1936), and successors, Lundberg (1937), Samuelson (1939) and Harrod (1939), and their somewhat unconnected contemporaries, Schumpeter (1934, 1943) and Kalecki (1939, 1968), believed that the macro-economy had both a push and pull effect, both of which are pro-cyclical. Schumpeter and Kalecki modelled firm's investment demand as a function of both the capacity to finance (from retained earnings and external intermediaries) and the expectation of profits (as represented by current

[2] Studies that incorporate the complete innovation decision, such as Geroski and Walters (1995), endogenise both the decision to invent *and* the state of the macro-economy and are thus able to consider whether the innovations are caused by business cycle fluctuations or cause these fluctuations. The latter forms the basis of the 'real business cycle' theories of Lucas, Kydland and Prescott and (in a very different way) the evolutionary theories of Nelson and Winter (1982).

sales and exogenous embodied 'innovation').[3] Almost all of these theories comprised elements which are both endogenous to and exogenous from the macro-economy. In Kalecki's 1968 model, central banks' cash rate is the exogenous force determining the availability of external finance and the rate of exogenous 'innovation' (which we would call public sector scientific output) conditions the expectation of profits. Endogenous retained earnings are both the source of finance and are also the collateral against which banks extend credit. Endogenous (current) sales are the mainstay upon which firms base their future expectations of sales.

Since then, investment theories have expanded into the intangible realm and become more nuanced by distinguishing between the up- and down-stream stages of the innovation pathway (Wälde and Woitek 2004) and between product and process innovations (Brown and Eisenhardt 1995, Martinez-Ros 1999, Krishnan and Ulrich 2001). Consistent with other areas of applied economic research, the unit of analysis has shifted from the economy or industry to the individual firm or invention. Following Mansfield and Wagner (1975), many of these firm-level studies have focused on the role that technological and organisational characteristics play in shaping commercialization outcomes.

3. Data and descriptives

Data were drawn from the 2007 Australian Inventor Survey which was sent to every inventor who a submitted patent application to the Australian Patent Office between 1986 and 2005.[4] All inventors listed on the patent application were sent a survey. Moreover, inventors whose patent applications were unsuccessful were also surveyed. This is the major point of departure from other inventor surveys from around the world (such as the PatVal-EU survey). Thus, our data relate to a mix of patentable inventions, some of which passed the novelty and non-obviousness tests imposed by the patent office and some of which did not. One major advantage of this survey design is that it provides us with a unique cross-section of different commercialization pathways utilized by entrepreneurial inventors.

[3] Schumpeter goes further than Kalecki and assumes that firms' demand functions and existing conditions of markets are made malleable by firms' innovation decisions. Innovation is the prime weapon of competition. Furthermore, Schumpeter extends Kalecki's 'principal of increasing risk' (Kalecki 1939, Ch 4) to highlight the central role of retained earnings for highly uncertain investments such as innovation investments.

[4] An alternative strategy would be to send the survey to the assignee (rather than the inventor). However, we believe the inventor should have a more intimate knowledge of the lifecycle of the invention than his or her organization. Mattes *et al* (2006b) use a sample of 136 inventors to show a correlation between inventor and owners responses on patent outcomes of about 90%.

The questionnaire included a comprehensive set of inventor- and technology-specific characteristics and a range of outcomes at different stages of commercialization. Unlike other studies which use one indicator of commercialization success or another – such as break-even times (see Palmberg 2006) or duration of sales (Astebro and Michela 2005) – we have collected information on whether or not each of five different stages of the commercialization pathway – development; product development; make and sell; mass production; export and licensing and spin-off; – were attempted. This enables us to test for whether the same macroeconomic forces are at work across different aspects of the commercialization pathway. Note, however, that our measure of "success" is whether a commercialization stage was attempted, rather than the revenue generated.

In total, there were 43,200 inventor-application pairs in the population which had a complete address and inventor name. These applications related to 31,313 unique patent applications (i.e. inventions). On the basis of the number of surveys returned to us unopened (and a post enumeration survey of non-respondents), we estimate that there are 5,446 inventions with still valid addresses. Since we received completed questionnaires relating to 3,736 unique inventions, our response rate was 68.6 percent.[5] The inventors were asked a series of questions about the nature of the invention itself – for example, whether the invention was radical or incremental – and the stage of commercialization that was attempted. Survey responses came from inventors in a wide range of employment arrangements: the largest group of inventors were employed in an SME (36.4 percent); with the remainder coming from large companies (10.5 percent), public research organisations (6.6 percent). The residual (46.6 percent) were individual inventors.[6]

The inventions in the sample of survey respondents covered a broad cross-section of different technology areas, which were classified using the OST-IPC technology concordance.[7] The distribution by technology area was: electricity and electronics (10.4 percent), instruments (10.4 percent), chemicals and pharmaceuticals (9.9 percent), mechanical engineering (27.9 percent), process engineering (11.1 percent), and 'other' (30.3 percent). The sample also contains a mix of those applications that were granted a patent (54.9 percent) and those that were not (45.1 percent).

In order to consider any potential response bias, the population in-scope was compared with the sample of survey respondents by the following characteristics: year of application;

[5] More information on the population and the survey method is provided in the Appendix.
[6] Employment status was determined by the name of the applicant.
[7] OST refers to the UK Office of Science and Technology classification. IPC is the International Patent Classification.

organisation type; whether the patent was granted (at the end of 2007); and technology area. In all cases, the chi-squared test rejected the hypothesis of independence (at the 5 percent level) between those that did and did not respond to the survey. A thorough analysis of the response bias issue is presented in the Appendix.[8]

The survey was structured in a way that mirrors the commercialization pathway. In the first section, all respondents were asked general questions about the nature of the invention, whether they were aware of any copying and whether an attempt had been made to license the invention. After this, a specific question was asked about whether the invention had been developed (which covers proof of concept, testing and validation, prototype). If the respondent answered “No”, they were directed to the end of the survey. If they answered “Yes”, they were asked questions about the stages of development attempted and then moved on to the set of questions on whether the invention was manufactured (which covers gathering market intelligence, validating the commercial opportunity, trailing the manufacturing process and market launch). Similarly, if the respondent answered “No” to the question on whether the invention had been manufactured, they were directed to the end of the survey. Thus, the probability of reaching each sequential stage of the questionnaire was conditional on answering “Yes” to the previous stage. The survey also asked a number of other questions pertaining to: i) whether the invention was incremental or radical; ii) the inventor’s previous experience with patenting; and iii) the complexity of the final product (i.e. how many patents were required to produce the final product).

Table 1 presents some descriptive statistics on the sample of survey respondents used in the analysis presented here. The majority of inventions in the sample are radical (60.5 per cent) rather than incremental (31.3 per cent) improvements, relate to product (59.1 per cent) rather than process (27.4 per cent) inventions, and were single-patent products (66.8 per cent).

[8] Since there is the potential for non-response bias in our sample, we use a Heckman selection model in our estimations.

Table 1: Descriptive Statistics

Characteristic of invention	Freq.	Percent
Relative to state of art at time of application, the invention was…		
Incremental improvement	1,158	31.3
Radical improvement	2,240	60.5
Unsure	307	8.3
Did the invention underlying the patent relate to a new or improved...		
Good or product	2,189	59.1
Way of manufacture	1,016	27.4
Both	499	13.5
Number of other patents also used to develop product		
None	2,476	66.8
1 to 5	1,101	29.7
6 to 10	86	2.3
11 to 20	22	0.6
20+	23	0.6
Number of prior patent applications by organisation since 1986		
None	1,688	45.5
More than none to 10	1,349	36.4
More than 10 to 50	344	9.3
More than 50 to 100	68	1.8
More than 100	259	7.0
Total	3,736	100.0

Note: the sum of each section may not add to 3,736 if some observations are missing a reported characteristic.
Source: Australian Inventor Survey 2007

4. Estimation model and results

We model commercialisation using event history analysis and assume an attempt at each commercialisation stage is the 'event'. Our main data problem with this approach is that apart from the date of lodgement of a patent application, the data do not identify the year in which each commercialisation stage was attempted. Ideally, calendar year information would be used to match the attempted commercialisation stage with date-relevant industry and economy-wide variables. In order therefore to introduce these time-varying factors, we have made assumptions about the number of years between filing the patent application (for which we have a date) and subsequently attempting each of the five commercialisation stages. Specifically, we assume that attempts (if made) occur at one year after filing for the development stage; 2 years for the examination decision; 3 years for the decision to license; 4 years for the decision to transfer to a spin-off; 5 years for the make and sell stage; 7 years for mass production and 9 years for export. We vary these assumed time lags in order to conduct a check on the robustness of our results.

Time-related events are typically modelled as a hazard function. The hazard function defines the probability that an event occurs at time *t* conditional on the unit having survived up until time *t*.[9] Formally, the hazard, which is denoted as $h_i(t \mid \mathbf{x})$, can be written as:

$$h_i(t \mid \mathbf{x}) = h_0(t)\alpha_i \exp(\mathbf{x}_{it}'\boldsymbol{\beta}) \quad (4)$$

where $h_0(t)$ is the baseline-hazard function, α_i is the invention-specific effect (which is assumed here to be proportional unobserved heterogeneity), and $\mathbf{x}_i$ is a vector of explanatory variables which impose a proportional characteristic-specific shift on the baseline hazard. The hazard rate is defined with respect to time since the invention's patent application with the baseline hazard h_0 written as a flexible function. This avoids potential mis-specification bias resulting from choosing an inappropriate parametric specification for the baseline hazard. The proportional unobserved heterogeneity α_i is assumed to be gamma distributed.[10]

The vector **x** in our empirical model includes a range of time-varying explanatory variables relating to the factors affecting intent to commercialise. Similar to Guellec and Ioannidis (1997), we employ a simple model based on demand-side variables (growth in demand; business confidence) and supply-side variables (the cost of borrowing; business R&D subsidies; level of public sector R&D). In our specification, the growth in demand is measured by the annual rate of growth in either real wages[11] or industry value-added[12]; business confidence is measured by a quarterly business survey[13]; the cost of commercial borrowing is the variable small-business overdraft rate[14]; business R&D subsidies is denoted by either the annual change in the level of business R&D (BERD) matched by 2-digit industry and deflated by the GDP deflator[15] or the b-index[16]; the annual change in the level of public sector R&D is the official Government Expenditure on economic development R&D (GERD) deflated by the GDP deflator[17]. The b-index is the proportion of (before tax) R&D cost paid by the firm as a ratio of the proportion of (before tax) profit received by the firm (see Warda 2001, Guellec and van Pottelsberghe 2003, Falk 2006). It includes general

[9] The word hazard derives from its literal meaning of an obstacle or something which may potentially lead to failure. Hazard functions are typically used to model adverse events such as death and disease. However, in our context, we define event in a positive light.
[10] This choice is not only made for computational reasons. See Abbring and Van den Berg (2001) for a rationalisation for choosing the gamma distribution.
[11] IMF World Commodity Prices.
[12] 5206.0 Australian National Accounts: National Income, Expenditure and Product, Table 6. Gross Value Added by Industry, Australia: Chain volume measures.
[13] NAB business confidence index, Source G08HIST.xls Reserve Bank of Australia. Downloaded 7/08/2008.
[14] Small Business small Overdraft rate. Source F05HIST.xls Reserve Bank of Australia. Downloaded 7/08/2008.
[15] ABS Cat. 8104.0 Research and Experimental Development, Business, Australia, 2005-06.
[16] We thank Russell Thomson for his estimate of the Australian b-index.
[17] 81090DO003_200607 Research and Experimental Development, Government and Private Non-Profit Organisations, Australia, 2006-07 and cat 8109.0 various years. Downloaded 7/08/2008.

incentives available to all firms such as depreciation and allowable tax credits. It has been designed as a proxy for the cost of R&D.

In Table 2 we present alternative specifications of our rather parsimonious model. Essentially, it indicates that the state of the macro-economy does matter. Regardless of whether we use the growth of real wages or real industry output as a measure of demand, there appears to be a considerable ‘pull’ effect. The effect of more intangible business confidence is less clear. If we use BERD as a proxy for the costs of conducting business R&D then business confidence appears to have an additive effect on commercialisation success. However, if we use the b-index, it appears to have a detracting effect.

By contrast, the cost of doing business appears to have a fairly clear effect on the success rate. A rise in either the bank overdraft rate or the b-index lowers the success rate. The annual change in the level of industry BERD does not have a significant effect on the success rate. Finally, the annual change in the level of GERD (government R&D designed for economic development) had a positive and significant effect in all models estimated.

To give an estimate of the economic importance of the independent variables, in Table 3, we present the change to the estimated linear prediction of the hazard model if we change the each independent variable from being on the 25th percentile to the 75th while holding all other independent variables at their means. Table 3 uses the coefficients from the last Model 5. These estimates show that variation in the rate of interest has the largest effect on the propensity to achieve a ‘success’. The absolute magnitude, 0.282, is nearly twice the size for the cost of conducting R&D (the b-index) and the change in the level of government spending on R&D. The impact of the rate of growth of industry value added is about half as small as these variables again. These relative impacts remain even if we use relative real wage growth.

Table 2: Results from the estimated hazard of (multiple) 'success'

	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5
Annual rate of growth in real wages	0.0352***		0.0929***		
	(0.0130)		(0.0111)		
Annual rate of growth in industry value-added		0.493*		0.711***	0.647**
		(0.285)		(0.271)	(0.269)
Business confidence	0.0100***	0.0115***	-0.00305	-0.00508**	
	(0.00226)	(0.00225)	(0.00233)	(0.00248)	
Small business overdraft rate	-0.298***	-0.357***	-0.0539***	-0.0909***	-0.0735***
	(0.0265)	(0.0252)	(0.0138)	(0.0143)	(0.0115)
Change in the real level of business R&D	-0.0377	-0.0644			
	(0.0727)	(0.0796)			
b-index			-1.093***	-1.728***	-1.320***
			(0.338)	(0.355)	(0.292)
Change in the real level of government R&D	4.647***	4.621***	1.166***	1.571***	1.692***
	(0.436)	(0.426)	(0.338)	(0.344)	(0.338)
Observations	8431	7558	9528	8430	8430
Estimation method	Cox Hazard	Cox Hazard	Cox Hazard	Cox Hazard	Cox Hazard
No. of subjects	3424	3601	3124	3232	3232
No. of events ('successes')	8431	9528	7558	8430	6557
Log likelihood	-59305.702	-68425.769	-52374.723	-59683.119	-46213.884

Absolute value of z statistics in brackets + significant at 10%; * significant at 5%; ** significant at 1%

Table 3: Effect of a change in independent variable from 25th percentile to 75th percentile on the linear prediction $X\beta$

	Change in the linear prediction $X\beta$
Annual rate of growth in industry value-added	0.061
Small business overdraft rate	-0.282
b-index	-0.164
Change in the real level of government R&D	0.146

5. Robustness check and comparison with other studies

Logically our commercialisation stages are ordinal: development has to precede 'make and sell', 'make and sell' has to precede manufacture and so on. However, we do not know the actual real world time intervals between stages and our assumption that there is a year between each stage is based only upon anecdotal information. In addition, we have assumed in our estimations that the development stage had been undertaken if any of the four activities – proof of concept, testing or validation prototype or 'other' – had been conducted. We could have treated these as four separate events rather than combine them as one event. A similar issue arises for the 'make and sell' stage. To assess therefore how sensitive our results are to first, the assumption of the time interval between stages and secondly, whether we treat development and 'make and sell' as one or four events, we undertook a series of alternative estimations. These estimations were conducted in three successive stages – first, assuming 6 months between events; secondly, assuming there is 18 months between events and thirdly, assuming that development and 'make and sell' constitute four events each. The results (which we do not present here but are available on request from the authors) are very close to those given in Table 2 and therefore indicate that the results we have presented are not sensitive to our assumptions regarding the length of the real time intervals between events and the number of individual events.

While our results confirm the importance of macroeconomic conditions – from both the demand and supply-side – on the decision to commercialise inventions, the magnitude of the supply-side effect is estimated to be larger than the growth in aggregate or industry demand. In particular, the overdraft rate was found to have the largest effect followed by the level of tax incentives for R&D and changes to the level of public sector R&D. Our results support the earlier findings of Guellec and Ioannidis (1997) who use an 18 country dataset from 1972 to 1995 and find that measures of overall level of economic activity (GDP), public-sector funded research, long-term interest rates[18] have a significant (with an *a priori* consistent sign) effect on the level of R&D spending. While the effects of aggregate or industry demand are clearly significant, they are also pro-cyclical. There is no support for the views purported by Francois and Lloyd-Ellis (2003) or Saint-Paul (1997).

These findings should not be confused with those from studies based on industry-level data such as Schmookler (1962), Stoneman (1979), or firm-level studies such as Cainelli, Evangelista and Savona (2006), von Hippel (1978), Buenstorf (2003), Geroski and Walters (1995), Fontana and Guerzoni (2008).[19] In the latter, the research questions, which are quite different, consider the effects of organisational capabilities, managerial style and the firm's ability to create a market on innovation not the broader macroeconomic environment. The two issues are not correlated empirically nor do they have the same implications for policy. Although qualitatively different from macroeconomic studies, it is interesting to note that the

[18] The negative effect of interest rates on R&D was predominantly apparent for the G12 OECD countries (Australia, Austria, Belgium, Denmark, Finland, Iceland, Ireland, Netherlands, Norway, Spain, Sweden and Switzerland).

[19] For a critical review of earlier microeconomic studies see Mowery and Rosenberg (1979).

microeconomic studies which compare the contributions of demand and supply-side factors, tend to find supply-side effects to be the more important.[20]

6. Conclusions and policy implications

In many respects the question of whether demand- versus supply-side factors determine the level of commercialisation activity is a false dichotomy. Both factors are necessary but are not on their own sufficient. A new product or process would not be commercialised if it clearly had no market. Nor would it be commercialized if funding was unavailable. The real question for policy makers is what constitutes the short side of the market? That is, which factor is the bottleneck? This question is not as easily answered. While we have found that the cost of funds has the biggest impact on the commercialization decision, we are not able to say that a one standard deviation reduction in the rate of interest will have a greater impact than a one standard deviation rise in aggregate demand.

Nonetheless, our findings are consistent with previous work that concludes that the overall level of economic activity, wages, public-sector funded research, and long-term interest rates have a significant pro-cyclical effect on the level of R&D spending. Contrary to other studies (e.g. Thomson 2009), we also conclude that total R&D tax treatment does appear to influence commercialization decisions.

APPENDIX: AUSTRALIAN INVENTOR SURVEY

The Australian Inventor Survey was mailed out in two waves between July and December 2007 by the Melbourne Institute of Applied Economic and Social Research at the University of Melbourne. The recipients of the survey constituted the population of Australian inventors who filed a patent application at the Australian Patent office – IP Australia – during the period 1986-2005. The survey recipients were identified by the country of applicant (Australia) and their postal address.

The inventor-invention relationship is a many-to-many relationship. That is, one inventor can have many patent applications, and one patent application can have many inventors. In

[20] Cainelli, Evangelista and Savona (2006) use a 1995 cross-section of approximately 700 Italian firms and find support for positive effect of past firm productivity (but not sales growth) on process innovations (R&D, ICT development) in the service sector firms. Geroski and Walters (1995) use patent and (SPRU[20]) innovation count data and find that evidence that while change in sales stimulates investments into inventions and innovation, that unobserved supply-side determinants (from say, scientific breakthroughs) are more important. In their review of eight industry- and firm-level studies, Mowery and Rosenberg (1979) argue that the role of demand had been overplayed and that both demand and supply-side forces are important.

total, there were 43,200 inventor-application pairs in the population with a complete inventor name and address. Of the 31,313 applications, 76.2 per cent had only one inventor and almost all (99.3 per cent) had 5 or less inventors (see Table 4). Of the 31,947 inventors, the vast majority (82.5 per cent) had only filed one application between 1986 and 2005 (see Table 5). To avoid administrative burden, inventors were asked about each invention, up to a maximum of 5 patent applications.

Table 4: Number inventors per application, 1986 to 2005

Inventors per application	Number of applications	%
1	23,866	76.2
2-5	7,225	23.1
6-10	218	0.7
>10	4	0.0
Total applications	31,313	100.0

Table 5: Number of applications per inventor, 1986 to 2005

Applications per inventor	Number of inventors	%
1	26,360	82.5
2-10	5,506	17.2
11-20	66	0.2
>20	15	0.0
Total inventors	31,947	100.0

There was no initial screening of applications and 47.0 percent of surveys were returned to us (as "return to sender") unopened, presumably because the address was no longer valid. To estimate the number of non-responses which also had invalid addresses, we selected a random sample of 600 non-respondents and manually looked the applicant up by name and address in both the telephone book and internet. This search revealed that only 11.7 percent of the sample of non-respondents had a complete address and were still at the listed address (some had moved while others had apparently disappeared). Assuming that this is representative of all non-respondents, we can infer that we had a valid inventor address for 5,446 of our original population of inventions. Given we received completed questionnaires for 3,736 inventions, our effective response rate was 68.6 percent.

The following four tables show the pattern of survey response by year of application across various characteristics. According to Table 6, there is a clearly defined rise in the percentage of completions over time. Response rates also varied according to whether the inventor was employed by a large company (63.2 percent), SME (64.3 percent), public research organisation (71.2 percent), or filed as an individual (73.5 percent), as demonstrated in Table 7.

Table 6: Number of inventions with a complete survey response by year, patent applications 1986 to 2005

Year	Number of patent applications			
	Complete	Estimated non-complete[a]	Total	% Completed
1986-1990	254	245	499	50.9
1991-1995	553	385	938	58.9
1996-2000	1124	541	1665	67.5
2001-2005	1805	538	2343	77.0
Total	3736	1710	5446	68.6

Note: [a] Number of non-completes exclude surveys that were returned as ‘return to sender’ and the estimated 65.7% of non-responses which we estimated, through a post-enumeration survey, to have had an invalid address.

Table 7: Number of inventions with a complete survey response by organisation type, patent applications 1986 to 2005

Organisation	Number of patent applications			
	Complete	Estimated non-complete[a]	Total	% Completed
Large company[b]	391	228	619	63.2
SME[b]	1361	756	2117	64.3
Public sector research	247	100	347	71.2
Individual	1737	626	2363	73.5
Total	3736	1710	5446	68.6

Note: [a] Number of non-completes exclude surveys that were returned as ‘return to sender’ and the estimated 65.7% of non-responses which we estimated, though a post-enumeration survey to have had an invalid address.
[b] A company is ‘Large’ where it, or its highest Australian-located parent company, has a turnover greater than A$50m per annum. Otherwise the company is defined as an SME.

The grant rate (as of the end of 2007) for the entire population of applications lodged at the Australian Patent Office between 1989 and 2000 was 68.4 percent.[21] In Table 8, a simple comparison of the patent grant rates between those that completed the survey and the population in-scope is presented. This shows that the response rate was highest (81.2 percent) for pending patents (presumably because they are more recent), followed by granted (67.6 percent), rejected (61.9 percent) and withdrawn (63.3 percent) respectively.[22] Finally, Table 9 presents the response rate by technology area. It shows that there is a modest level of variation in the response rate across technology groups. There was a slightly lower response rate from the electricity and electronics area and ‘Other’.

[21] We exclude applications lodged between 1986 and 1988 as the high percentage of grants suggests that some non-granted applications are missing from the database.
[22] However, this is partly due to the fact that recent applications have not yet been examined. For applications lodged between 1989 and 2000, the response rate is 12.6 percent for non-grants and 18.6 percent for granted applications.

Table 8: Number of inventions with a complete survey response by patent grant status, patent applications 1986 to 2005

Patent grant status	**Number of patent applications**			
	Complete	Estimated non-complete[a]	Total	% Completed
Withdrawn	572	331	904	63.3
Pending	731	167	900	81.2
Rejected	382	232	617	61.9
Granted	2051	979	3034	67.6
Total	3736	1710	5446	68.6

Note: [a] Number of non-completes exclude surveys that were returned as 'return to sender' and the estimated 65.7% of non-responses which we estimated, though a post-enumeration survey to have had an invalid address.

Table 9: Number of inventions with a complete response by technology area, patent applications 1986 to 2005

OST technology area[b]	**Number of patent applications**			
	Complete	Estimated non-complete[a]	Total	% Completed
I Electricity and electronics	329	181	511	64.4
II Instruments	440	175	617	71.3
III Chemicals, pharmaceuticals	410	166	579	70.8
IV Process engineering	447	187	638	70.1
V Mechanical engineering	1061	476	1542	68.8
VI Other	1048	524	1578	66.4
Total	3736	1710	5446	68.6

Note: [a] Number of non-completes exclude surveys that were returned as 'return to sender' and the estimated 65.7% of non-responses which we estimated, though a post-enumeration survey to have had an invalid address.
[b] OST refers to the Office of Science and Technology classification which is based on the International Patent Classification system

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