Do Patents Matter for Commercialization?*

Elizabeth Webster and Paul H. Jensen

Intellectual Property Research Institute of Australia, University of Melbourne and
Melbourne Institute of Applied Economic and Social Research, University of Melbourne

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Contact details:

Elizabeth Webster
Melbourne Institute of Applied Economic and Social Research
Level 7, Alan Gilbert Building
University of Melbourne Vic 3010
Australia
Email: e.webster@unimelb.edu.au

Paul Jensen
Melbourne Institute of Applied Economic and Social Research
Level 7, Alan Gilbert Building
University of Melbourne Vic 3010
Australia
Email: pjensen@unimelb.edu.au

ABSTRACT

This paper estimates the effects of a patent on the likelihood that an invention will proceed to a stage of manufacture using survey data on 3700 inventions. We found that about a third of all inventions, both with and without a patent, proceeded to the point of market launch and mass production. However, possession of a patent title only raises the probability of attempting pre-manufacturing activities by at most 3.9 percentage points and mass production by 8 percentage points. There was no evidence that the effect of patents was greater for more valuable inventions or for firms which lacked manufacturing capabilities.

Keywords: Innovation; Commercialization; Invention; Appropriation

JEL Classification: O31, O34

I. Introduction

Despite the fact that patents play a seminal theoretical role in stimulating innovation, empirical evidence supporting the theory has been hard to find. In this paper, we take another look at this issue. In particular, we focus on the effect that patents play in influencing the decision to manufacture. As such, our study draws upon the work of previous studies on the forces that shape the commercialisation of new products and processes (including Mansfield and Wagner 1975; Cooper and Kleinschmidt 1987). In order to re-examine this issue, we use survey data on 3,736 Australian inventions which were the subject of a patent application between 1986 and 2005. Although almost half of the survey respondents' patent applications were not granted, many still attempted to commercialize their inventions. By comparing the commercialization outcomes for inventions that were awarded a patent with those that were not, we are able to address the question: do patents matter for commercialization? Since our surveyed population are drawn from the set of inventions that have been the subject of a patent application, our results do not confound the decision to patent with the decision to commercialize. Nor do they confuse whether or not a technology is patentable with how effective patents are in protecting competitive advantage.

Our empirical model identifies three stages of the commercialization process: pre-manufacture (gathering market intelligence, validating commercial opportunity and trialling the manufacturing process); market launch; and mass production. To model these commercialization outcomes, we estimate separate probit models. In order to control for any selection bias associated with survey non-response we employ a ML selection estimation technique. Our results suggest that while the receipt of a patent grant had a positive and significant effect on attempting each stage of manufacture, the magnitude of the effect is quite modest. In fact, the marginal patent value – that is, the marginal increase in the probability of attempting a manufacturing stage due to the presence of a patent – varies from 3.9 (pre-manufacture) to 8.0 (mass production) percentage points. Although patents matter, they are hardly the powerful force that economic theory suggests.

A number of caveats should be noted. First, in order to disentangle the effect of a patent from the underlying commercial value of the invention, we rely on a range of self-reported variables – such as whether a PCT patent application was made and whether the invention is radical or incremental. This enables us to identify the marginal patent value, but we acknowledge that this approach is not without its limitations. Second, the timing of commercialization decisions is unknown. Thus, it is possible that commercialization decisions were made *before* the outcome of the patent examination was known. As a result, it is not possible to draw strong causal inferences about the effect of patents on commercialization outcomes. Third, the results of our survey are possibly subject to 'recall bias' since commercialization decisions may have occurred up to 20 years prior. However, we believe that any such bias is randomly distributed and is not systematically related to the patent examination outcome. Fourth, we are not able to account for the fact that one firm's commercialization decisions (or examination outcomes) may impact rival firms' commercialization decisions. Such externalities are clearly important, but cannot be addressed here.

This paper is structured as follows. In the next section we discuss the main findings from the literature on factors governing successful commercialization of inventions. In the third section we discuss the design of the Australian Inventor Survey 2007 and present some descriptive statistics on the dataset. Following this, we present our empirical model and the results from four separate Heckman selection probit regression analyses. Finally we conclude.

II. Background

One of the underlying themes of the literature on innovation is that knowledge goods are easily expropriated to the extent they are easily observed and replicable (see Nelson 1959; Arrow 1962). Without the means to appropriate the returns from investment in innovation, for-profit organisations will not invest in the first place. While 'natural' characteristics of the knowledge – such as whether it is tacit or codified – can increase the cost of imitation, it is widely believed that policy instruments such as patents are necessary to reinforce excludability and thus stimulate *ex ante* investment. Accordingly, obtaining a patent should give the owners greater confidence in their ability to appropriate profits and will therefore lead to more commercialization. However, little is known about how important patents actually are in the commercialization process.

Previous studies on the value of patent protection estimate it as a monetary amount using revenue estimates and/or renewal data (Schankerman 1998; Lanjouw 1998; Harhoff et al. 1999). The effect of the patent on the incentive to conduct R&D or to commercialize is inferred rather than directly measured. These studies reveal two interesting facts: first the combined value of the invention and patent is highly skewed with a small percentage of high value inventions and second, the *average* proportional value of the patent varies between 10 and 25 percent of the invention's value.

A related but distinct area of research has focussed on the determinants of commercialization activities undertaken. While early work on these issues was conducted by

Mansfield and Wagner (1975), it did not consider the marginal contribution of the patent per se. More recent microeconomic studies have considered the determinants of innovation success, usually using inventions, products or projects as the unit of analysis. Of these studies, only Dechenaux et al. (2008) and Palmberg (2006) use patent applications as the unit of analysis and are thus able to estimate the marginal patent value. Dechenaux et al. match data from the Yale Survey[1] on the stated strength of patents in each industry to their sample of university patents to find a positive relationship between 'strength' and the probability of commercialization. Palmberg, on the other hand, does not find that possession of a patent reduces the speed to market. Hanel (2008) does not use patent-level data but data from a firm-based innovation survey and finds, using a simultaneous equation model, a positive effect of patent use on commercialization but one that is smaller than single equation estimation would suggest. In other studies, the patent status is either not recorded or is invariant across the sample.[2] Due to data limitations, most of these studies typically use only one measure of commercialization with each metric having its relative strengths and weaknesses. One consequence of this is that it is unclear how robust analyses of commercialization are to the way in which it is measured.[3]

Macroeconomic studies of the marginal contribution of patent protection also exist. These studies regress estimates the effect of the 'strength' of the national patent regime on the level of national innovative activity (see Sakakibara and Branstetter 2001; Branstetter and

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[1] Levin et al. (1987).

[2] Nonetheless, these other studies are relevant for what they reveal about commercialization outcomes across different measures of 'success', including whether a dollar of sales revenue was generated (Bizan 2003; Dechenaux et al. 2008; Mattes, Stacey and Marinova 2006b; Nerkar and Shane 2007), the speed to market (Markman et al. 2005; Palmberg 2006), rate of return on investment or profits (Bizan 2003; Astebro 2003; Amesse et al. 1991) and duration of sales (Astebro and Michela 2005).

[3] An exception to this is the work of Shane (2002) who looked at commercialization outcomes across a number of different dimensions including patents licensed, patent licensing efforts, and royalties.

Nakamura 2003; Scherer and Weisburst 1995; Kanwar 2007; Kanwar and Evenson 2003; Schneider 2005; Varsakelis 2000; Allred and Park 2007; Qian 2007). In most of these studies, the measure of innovative activity used is limited to early stage invention (as measured by R&D and patenting). Despite extensive research, the general consensus amongst this literature is that the effects of patents are hard to find.

These findings are not necessarily unanticipated. Patents are less likely to be effective appropriation mechanisms in instances where firms can "invent around" the patent, if technology is moving very rapidly, or if the patents are difficult to enforce in a court of law (see Levin et al. 1987). Others are even less sanguine about the primacy of patents, arguing that: "…in most circumstances, appropriability conditions sufficient to justify private innovative efforts are in place with or without IPR protection…IPR themselves have only a limited importance as drivers of innovative efforts" (Dosi et al. 2006, p.897). Nevertheless, we argue that the grant of a patent should increase the probability that manufacturing will be attempted since the existence of a patent should increase the confidence a firm has that copying will be prevented and future revenue streams protected, ceteris paribus.

III. Data and Descriptive Statistics

Data for this study were drawn from the Australian Inventor Survey 2007, which involved sending a questionnaire 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

[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, Stacey and Marinova (2006b) use a sample of 136 inventors to show a correlation between inventor and owners responses on patent outcomes of about 90 percent.

a survey including inventors with many applications.[5] Since the survey was sent to the population of patent applicants, our sample includes a large number of inventors whose patent applications were not granted. However, as will be shown below, many of the inventions underlying these unsuccessful patent applications were commercialized. This is the major point of departure from other inventor surveys from around the world, such as the PatVal-EU survey, which only surveyed recipients of granted patents.[6] Our dataset contains only *potentially* patentable inventions, some of which passed the novelty and non-obviousness tests imposed by the patent office and some of which did not, some of which were withdrawn before examination and some whose examination outcome is still pending.[7] 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.

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 or another, we have information on whether or not a number of different manufacturing stages of the commercialization process were attempted. We have identified these stages as follows: pre-manufacture (gathering market intelligence, validating commercial opportunity and trialling the manufacturing process); market launch; and mass production. This enables us to examine whether the same forces are at work at different stages of the commercialization pathway.

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[5] Inventors with more than 5 applications were only sent questionnaires for 5 applications. These were randomly selected.
[6] See Gonzalez (2006) and the special issue of *Research Policy* in 2007 for examples of applications of the PatVal-EU survey.
[7] Most examination decisions at the Australian Patent Office are known early in the commercialisation process (the median examination lag is approximately 28 months).

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 two post enumeration surveys of non-respondents), we estimate that there were 5,446 inventions with still valid addresses. We received completed questionnaires relating to 3,736 unique inventions.[8] 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), and individual inventors (46.6 percent).[9]

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.[10] 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). To gauge how technologically representative our sample is of 'world' patents, in Table 1 we compare our survey sample with data from the full population of granted patents from the US patents office. This reveals that US patent office

[8] More information on the population, sample and survey method is provided in the Appendix.
[9] Ownership status was determined by the name of the applicant.
[10] OST refers to the UK Office of Science and Technology classification. IPC is the International Patent Classification.

patents are more heavily weighted towards electricity and electronics and less towards mechanical engineering and 'other' patents than Australian patent applicants.

TABLE 1—TECHNOLOGY GROUP OF US PATENT OFFICE AND AUSTRALIAN INVENTOR SURVEY RESPONDNENTS

Technology group (OST[a])	US patent office 1986-2005	Aust. Inventor survey 1986-2005
I Electricity and electronics	30.4	10.4
II Instruments	16.9	10.4
III Chemicals, pharmaceuticals	12.5	9.9
IV Process engineering	12.1	11.1
V Mechanical engineering	19.4	27.9
VI Other	8.8	30.3
Total	100.0	100.0

Note: [a] OST refers to the UK Office of Science and Technology classification.
Source: Australian Inventor Survey 2007 and NBER USPTO database, 1976-2006 from https://sites.google.com/site/patentdataproject/Home.

In order to consider any potential response bias, the survey population was compared with survey respondents according to the following characteristics: year of application; 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.[11]

Table 2 presents cross-tabulations on the percentage of inventions that achieved each commercialization milestone according to their patent grant status. To limit truncation bias, we only present patent applications which were made between 1989 and 2002. These data show that a substantial proportion of inventions that were rejected by the patent office were commercialized. At least at the prima facie level, this suggests that a patent may not be necessary for commercialization. For each commercialization stage, there was approximately a 12-16 percentage point difference between those with and without a granted patent.

[11] Since non-response bias is a potential problem, we use a Heckman selection model in our estimations.

These results are quite similar to other surveys of inventors. Mattes, Stacey and Marinova (2006a) surveyed 177 Australian medical inventors who possessed a US patent between 1984 and 1994, and found that three-quarters were involved in a development stage and 58 percent in a manufacturing stage. In addition, the Amesse et al. (1991) survey of 374 individual Canadian inventors found that 43.3 percent received positive revenues from the invention (of which about half were profitable). Nagaoka and Walsh (2009) surveyed 3700 triadic patent inventors and found that 60 percent were commercialized in the US and Japan.

TABLE 2—COMMERCIALIZATION STAGE BY PATENT GRANT STATUS AT APRIL 2007, PATENT APPLICATIONS LODGED BETWEEN 1989-2002

Stage	Withdrawn[a] (%)	Reject (%)	Grant (%)	Total (%)
Pre-manufacturing[b]	57.7	56.1	68.0	64.7
Market launch	25.8	25.0	41.2	36.5
Mass production	25.3	27.4	41.5	36.9

Notes: (a) Withdrawn includes those that lapse before an examination is requested and those that withdraw before an examination decision is made. (b) Comprises: gather market intelligence, validate commercial opportunity; and trial the manufacturing process.
Source: Australian Inventor Survey 2007

IV. Empirical Model

Our model of commercialization starts by assuming that once an invention has been created and a patent application has been filed, the owner must decide whether to attempt to commercialize the invention. This decision hinges on the availability of suitable finance, the costs of undertaking manufacturing, and expectations regarding the future revenue streams (based on current knowledge).

A concern when estimating the marginal effect of patents using cross-sectional data has been that the belief that decisions to apply for a patent and to start the commercialization process are jointly determined. Estimation has therefore required careful handling often by use of simultaneous estimation methods (Hanel 2008; Arora, Ceccagnoli and Cohen 2008).

The advantage of our dataset is that the decision to grant a patent title is exogenous to the applicant's commercialization decision given that all 'observations' in our dataset are the subject of a patent application. The grant decision then depends solely on the independent patent examination which is based solely on technological merit, not expected commercial value.

A complication however with our survey data is that there may be response bias: perhaps, for example, because inventors whose inventions were successfully commercialized are more likely to respond to the survey than those whose inventions were not. Without taking account of this, any estimates of commercialization determinants would be biased. To address this issue, we model the commercialization decision using a Heckman selection model.

We model the probability of the inventor of application *i* attempting commercialization stage *j* as a set of variables relating to the invention's technological characteristics and inventor characteristics. That is, if y_i is the attempt at a stage of commercialization, we model the outcome as:

$$y_i{*} = f\left(X_i;\beta\right)+\varepsilon_i \qquad (1)$$

where

$$y_i = \begin{cases} 1 \text{ if } y_i{*} > 0 \text{ (stage is attemped)} \\ 0 \text{ if } y_i{*} \le 0 \text{ (stage is not attempted)} \end{cases}$$

and β is the associated vector of parameters to be estimated, X_i includes the explanatory variables and a random error term, ε_i. However, $y_i\,*$ is only observed if:

$$\tilde{y} = Z_i\gamma + \xi_i > 0 \qquad (2)$$

where Z_i is a set of selection variables and ξ_i is a random error term. If $\text{corr}(\varepsilon, \xi) = \rho \neq 0$ then there are significant selection effects and the standard probit equation will yield biased results. Assuming $\Pr(y*_i > 0 \mid X_i) = (\exp[X]_i \beta)/(1 + \exp[X]_i \beta)$, equations (1) and (2) are jointly estimated as a Heckman probit model using Maximum Likelihood methods.

To control for response bias, we include year dummy variables, six technology area dummy variables, four ownership variables (large company, small and medium size enterprise [SME], public research organisation [PRO] and individual) and the number of years the patent was in-force.[12] We use the entire population of 31,313 inventions in our estimating sample.

Dependent variables

As discussed, there are three manufacturing stages which form the set of dependent variables in the estimating equations. *Pre-manufacturing* was coded 1 if the inventor indicated that attempts have been made to gather market intelligence, validate commercial opportunity or trial the manufacturing process and 0 otherwise. *Market launch* was coded 1 if the inventor indicated that a market launch had been attempted and 0 if otherwise. *Mass production* was coded 1 if the inventor indicated that an attempt had been made to mass produce the invention and 0 otherwise. Finally, we constructed a variable, *Any manufacturing*, as 1 if any of the above three activities had been attempted and 0 otherwise.

Explanatory and control variables

The key to our hypothesis that patents improve commercialization outcomes is the explanatory variable *Grant* (=1 if the patent application was granted; =0 otherwise).

[12] Patent years in-force is included to control for the fact that inventors with more valuable patents (as proxied by years in-force) may be more likely to respond to the survey. Although this variable will be right censored, this problem is attenuated by the inclusion of the year dummy variables.

Information on the status of the patent was extracted from the official patent office database in April 2007. The sign of the coefficient on the variable *Grant* informs us how the existence of a patent shapes the probability that each stage of commercialization will be attempted. It should be reinforced here that this is not a monetary interpretation of the value of a patent – rather, it is an attempt to capture the effect that a patent has on attempting various stages of manufacture.[13]

The major difficulty in identifying the role that patents play in shaping commercialization outcomes relates to disentangling the effect of the patent from the effect of the underlying quality of the invention. Given that invention quality is likely to influence both the likelihood of being granted a patent and the commercialization outcome, it is difficult to find a variable which effectively controls for invention quality. We tackle this issue through the use of a range of variables including whether or not the patent application was a Patent Cooperation Treaty (PCT) application (=1 if *PCT*). If the applicant is planning to file the application with four or more countries then it is cheaper to use the PCT route rather than the standard national route. Since there is likely to be a positive correlation between the number of countries an application is filed in and its economic value, we use the PCT variable as an indicator of underlying invention quality. Over and above this, we also include variables to control for whether the inventor described the invention as radical or incremental (=1 if *Radical*) and the complexity of the final product (*Complex*), which is based on the survey question on the number of complementary patents needed for manufacture (=1 if the final product requires 20+ patents).

[13] Since we do ask questions about the monetary value of a patent in the Australian Inventor Survey, we are exploring this issue in a separate paper.

Other control variables included dummy variables on the organisation type (*Large Company*[14], *SME, PRO* and *Individual*). These variables capture the financial power of the patent owner and their internal capability to undertake manufacturing activities. We expect that PROs and individuals will not possess the assets required to manufacture and market their inventions, which will pose an additional barrier to the commercialization of their inventions. Most individuals will also lack the financial resources to acquire these capabilities. In addition to these dummy variables, we include a count of the number of prior applications undertaken by each individual owner, which should capture their accumulated capabilities (*Prior applications 1986*). We also control for the invention's technology on the basis that commercial opportunities are likely to vary by technology. Finally, we include the number of years between application and the year of the survey (*Year*) since older inventions will have had greater opportunity to explore manufacturing options.

V. Results

The estimated coefficients are shown in Table 2 and converted into marginal effects in Table 3. Table 2 shows the progressive sequence of results as we move from a simple probit estimation with *Grant* as the only explanatory variable to a ML selection model with the full set of control variables. The marginal effects are calculated by estimating the predicted probabilities of attempting each commercialization stage using the original data but at set values for one specific independent variable. With respect to our hypothesis, we find the patent grant variable to be significant and positive each estimation. The full effect of a patent grant is easiest to interpret by examining the marginal effects (Table 3). On average, over the

[14] 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.

whole sample, a patent grant increases the probability of attempting the pre-manufacturing stage by 3.9 percentage points; market launch by 5.9 percentage points; and mass production by 8.0 percentage points. Overall, the marginal effect on any of the above manufacturing stage was 6.2 percentage points. These overall patent grant results are broadly consistent with those found by Dechenaux et al. (2008) which concluded that the existence of patent has a modest impact on commercialization outcomes.

What we have referred to as 'invention quality' is shown to have a large, and with one exception, positive effect on the probability of attempting a commercialization stage. In particular, radical inventions were statistically significant and positively associated with an increase in the probability of attempting pre-manufacturing (9.1 percentage points) and market launch (4.2 percentage points). We also find that the *PCT* variable was positive and significant for market launch and that product complexity is associated with a large effect on both the probability of attempting market launch and mass production. All in all, each of the three invention quality variables was significant in at least one case and all were significant and positive in 'any manufacturing'.

As anticipated by the literature, we find that individuals and PROs – who are less likely to have complementary assets such as manufacturing capabilities, marketing capital and distribution networks – are considerably less likely than companies, of any size, to attempt any of the manufacturing stages. Such organisations have a strong incentive to license the invention or sell outright (perhaps to a spin-off company) to an organization that does (Mazzoleni and Nelson 1998; Arora and Merges 2004; Orsi and Coriat 2005; Teece 1986; Arora and Ceccagnoli 2006; Gans, Hsu and Stern 2002). Interestingly, there was no statistically significant difference in the rate at which SMEs attempted each of the manufacturing stages compared with large companies, ceteris paribus. This stands in contrast to anecdotal evidence that the patent system does not work for SMEs (Cordes et al. 1999; Norman 2001; WIPO 2003; Macdonald 2004; Arundel and Kabla 1998) but is consistent elsewhere with evidence that SMEs use the patent system in equal proportion to large firms (Jensen and Webster 2006).

TABLE 3—DETERMINANTS OF COMMERCIALIZATION (PROBIT AND ML ESTIMATION WITH SAMPLE SELECTION), PATENT APPLICATIONS 1989-2005

	Explanatory variables	Commercialization stage attempted (dep. variables)							
		Pre-manufacturing(a)				Market launch			
Appropriability	Patent grant	0.230*** (0.0499)	0.316*** (0.0507)	0.254*** (0.0532)	0.323*** (0.0438)	0.169*** (0.0566)	0.150*** (0.0521)	0.252*** (0.0479)	0.126** (0.0573)
Invention qual[y]	Radical improvement			0.134*** (0.0451)		0.120*** (0.0412)	0.289*** (0.0442)		0.286*** (0.0442)
	PCT			0.0111 (0.0507)		-0.00537 (0.0458)	0.210*** (0.0520)		0.203*** (0.0523)
	Complex			0.00752 (0.0355)		0.00511 (0.0319)	0.134*** (0.0368)		0.132*** (0.0366)
Owner	PRO			-0.610*** (0.141)		-0.573*** (0.131)	-0.545*** (0.121)		-0.548*** (0.119)
	Individual			-0.385*** (0.0788)		-0.479*** (0.0731)	-0.189** (0.0797)		-0.235*** (0.0894)
	SME			0.0773 (0.0757)		0.0546 (0.0697)	0.05 (0.0776)		0.0439 (0.0770)
Owner exp[c]	Prior applications 1986			0.16 (0.229)		0.121 (0.206)	0.336* (0.194)		0.323* (0.193)
Technology	II Instruments			-0.0222 (0.0958)		-0.0916 (0.0892)	0.000696 (0.0967)		-0.0249 (0.0989)
	III Chemicals, pharma			-0.767*** (0.110)		-0.760*** (0.103)	-0.230** (0.102)		-0.253** (0.103)
	IV Process engineering			0.0816 (0.0942)		-0.00211 (0.0893)	0.157 (0.0965)		0.128 (0.100)
	V Mech engineering			0.0495 (0.0828)		0.00775 (0.0765)	0.0885 (0.0835)		0.0746 (0.0839)
	VI Other			0.107 (0.0835)		0.0846 (0.0767)	0.112 (0.0840)		0.107 (0.0834)
Age of applic[n]	Years	0.540*** (0.0660)	-0.471*** (0.0661)	-0.439*** (0.131)	-1.178*** (0.0963)	0.311 (0.236)	0.0772 (0.133)	0.0908 (0.165)	0.329 (0.279)
Constant		-0.155*** (0.0389)	-0.0414 (0.0392)	0.0138 (0.0415)	-0.177*** (0.0372)	0.132*** (0.0481)	-0.0852** (0.0408)	-0.228*** (0.0427)	-0.0394 (0.0610)
	Total observations	3736	3736	31309	31245	3736	3671	31309	31245
	Uncensored observations	3736	3636	3671	3669	3736	3671	3669	3669
	LR test of indep. Eqns. (rho = 0), Prob > chi2			0.0055***	0.3198			0.0000***	0.0022***
	Estimation method	Probit	Probit	ML Probit with selection	ML Probit with selection	Probit	Probit	ML Probit with selection	ML Probit with selection

Estimation method: ML Probit with selection. Standard errors in brackets * significant at 10%; ** significant at 5%; *** significant at 1%. Selection variables: year (5-year groups), OST technology (7 groups), organisational type (3 groups), patent grant status (grant, non-grant), number of years patent in-force (at end 2007). (a) Gather market intelligence, validate commercial opportunity, trial the manufacturing process.

TABLE 2 (CONTINUED)

	Explanatory variables	Commercialization stage attempted (dep. variables)							
		Mass production				Any manufacturing[(a)]			
Appropriability	Patent grant	0.316*** (0.0504)	0.266*** (0.0526)	0.329*** (0.0455)	0.167*** (0.0553)	0.293*** (0.0523)	0.218*** (0.0550)	0.309*** (0.0464)	0.212*** (0.0609)
Invention qual[y]	Radical improvement		0.0702 (0.0446)		0.0618 (0.0391)		0.294*** (0.0467)		0.294*** (0.0467)
	PCT		0.0265 (0.0504)		0.00636 (0.0443)		0.167*** (0.0561)		0.165*** (0.0564)
	Complex		0.0910*** (0.0350)		0.0775** (0.0311)		0.117*** (0.0396)		0.116*** (0.0396)
Owner	PRO		-0.651*** (0.136)		-0.597*** (0.125)		-0.662*** (0.124)		-0.664*** (0.124)
	Individual		-0.395*** (0.0777)		-0.495*** (0.0699)		-0.290*** (0.0855)		-0.303*** (0.0991)
	SME		0.0108 (0.0746)		-0.00821 (0.0667)		0.0327 (0.0837)		0.0312 (0.0839)
Owner exp[c]	Prior applications 1986		0.151 (0.217)		0.105 (0.190)		0.426** (0.201)		0.423** (0.202)
Technology	II Instruments		-0.0198 (0.0965)		-0.0971 (0.0876)		-0.00792 (0.103)		-0.0148 (0.106)
	III Chemicals, pharma		-0.482*** (0.106)		-0.501*** (0.0949)		-0.496*** (0.106)		-0.502*** (0.108)
	IV Process engineering		0.134 (0.0945)		0.034 (0.0882)		0.134 (0.103)		0.127 (0.107)
	V Mech engineering		0.176** (0.0830)		0.114 (0.0764)		0.14 (0.0889)		0.137 (0.0900)
	VI Other		0.243*** (0.0836)		0.199*** (0.0765)		0.13 (0.0894)		0.129 (0.0895)
Age of applic[n]	Years	-0.302*** (0.0654)	-0.422*** (0.131)	-0.936*** (0.124)	0.411* (0.221)	0.771*** (0.0695)	0.448*** (0.141)	-0.00146 (0.158)	0.517* (0.305)
Constant		-0.110*** (0.0390)	-0.0584 (0.0410)	-0.217*** (0.0386)	0.0817* (0.0481)	-0.156*** (0.0408)	-0.0940** (0.0432)	-0.269*** (0.0389)	-0.0813 (0.0663)
	Total observations	3736	3671	31309	31245	3736	3671	31309	31245
	Uncensored observations	3736	3671	3669	3669	3736	3671	3669	3669
	LR test of indep. Eqns. (rho = 0), Prob > chi2			0.0000***	0.0005***			0.0000***	0.8007
	Estimation method	Probit	Probit	ML Probit with selection	ML Probit with selection	Probit	Probit	ML Probit with selection	ML Probit with selection

Estimation method: ML Probit with selection. Standard errors in brackets * significant at 10%; ** significant at 5%; *** significant at 1%. Selection variables: year (5-year groups), OST technology (7 groups), organisational type (3 groups), patent grant status (grant, non-grant), number of years patent in-force (at end 2007). (a) Market launch, gather market intelligence, validate commercial opportunity, trial the manufacturing process, mass production.

TABLE 4—MARGINAL EFFECTS ON THE PROBABILITY OF ATTEMPTING EACH MANUFACTURING STAGE, PATENT APPLICATIONS 1989-2005

Explanatory variables	Change (from : to)	Effect of change in explanatory variable on the probability of attempting...			
		Pre-manufacture[(a)]	Market launch	Mass production	Any manufacturing
Appropriability					
Patent grant	(no : yes)	3.9	5.9	8.0	6.2
Invention Quality					
Radical improvement	(no : yes)	9.1	4.2	2.7	8.8
PCT	(no : yes)	6.2	-0.2	-1.8	4.7
Complex	(1 : 20+ other patents)	14.0	0.7	10.5	11.7
Owner					
SME	(no : yes)	1.4	1.9	1.3	0.9
PRO	(no : yes)	-19.1	-21.0	-29.3	-22.6
Individual	(no : yes)	-7.3	-16.4	-14.0	-8.8

Base case: Large company. All cases evaluated with independent variables held at actual values except for the variable defined in the row.
Note: (a) Gather market intelligence, validate commercial opportunity, trial the manufacturing process.

Taken together, our results suggest that patents are not quite the omnipotent force that one might expect after reading the theoretical literature on the economics of innovation. In fact, patents appear to have a small (but positive) effect on whether or not the invention proceeds to one or more manufacturing stages. This finding resonates with other empirical studies on the role that patents play in shaping commercialization outcomes. Sirilli (1987), for instance, surveyed 555 Italian inventors who had previously applied for a patent, and found that three-quarters claimed that the invention would have been achieved in the absence of the patent system. This effect was especially pronounced for inventors in large companies.

This raises the question: why is the average marginal patent value so small? Although this is outside the scope of the present study, there are a couple of plausible explanations. The most obvious explanation is that the reported coefficients and marginal values capture the *average* effects of patents. Given the available evidence that the value of the invention plus the value of the patent varies widely (see Harhoff et al. 1999; Gambardella, Harhoff and Verspagen 2007), it is quite possible that the *effect* of the patent is similarly skewed (for example, by technology area or organisation type). To the extent that highly codifiable technologies are easily reverse engineered (and are therefore offered weaker protection by non-patent forms of protection), they should benefit the most from patent protection (see Mansfield, Schwartz, and Wagner 1981; Levin et al. 1987; Saviotti 1998; Cohen, Nelson and Walsh 2000; Harabi 1995).[15] For instance, Mansfield, Schwartz and Wagner (1981) found that patents raised the costs of imitation by between 20-30 percentage points in drugs and chemicals compared with 7 percentage points in electronics. Arora, Ceccagnoli and Cohen (2008) appears to be the only recent paper to consider the dispersion of the marginal patent value but their estimated patent premia show little variation across technology areas. To examine this issue in our study, we included a technology area-patent grant interaction term into the Heckman selection equations shown in Table 2. However, the results (which are not presented here) did not support the conclusion that the effect of the patent varies by technology area. In no case was the interaction term significant.

Another plausible explanation is that investors may decide on a commercialization strategy prior to applying for a patent. If the patent application does not succeed, it may result in the project being downgraded or lowered in firm’s priority list, but it is not the death knell for the project. Another possibility is that unexpected enforcement issues erode the effectiveness of the granted patent. For example, Lanjouw (1998) estimated that doubling

[15] One might also expect that a higher percentage of inventions in codifiable technologies will be patented. A 1993 survey of 600 European manufacturing firms by Arundel and Kabla (1998) supports this. They found that patent propensity rates were as low as 8 percent in textile technologies. Only pharmaceuticals, chemicals, machinery and precision instruments industries apply for a patent for more than 50 percent of their innovations.

legal fees would result in a 20-30 per cent reduction in the mean value of patent protection in pharmaceuticals if patent enforcement is weak. It is also possible that patents are used as insurance. Since it is unknown ex ante whether the invention will have commercial value, inventors simply take out a patent as a piece of insurance. More recently, Bessen and Meurer (2008) have provided similar evidence that the net effect of patenting – that is, the increased profits generated through patenting minus the costs of dispute resolution – is negative in most industries in the United States. Our analysis provides supporting evidence of the same phenomenon from a different perspective.

A number of caveats are in order. The first is that disentangling the value of the patent from the value of the underlying invention is extremely difficult to achieve. This is a direct corollary of the fact that inventions are inherently heterogeneous. Despite the considerable lineage in devising measures of economic or technological value, it is impossible to know the magnitude of differences in value which remain unaccounted for. We attempt to identify the value of the invention using proxies such as whether or not it was the subject of a PCT patent application and whether it was radical and/or complex. However, we acknowledge that this is not without its limitations. To the extent that the unobserved portion of the invention's quality is greater for granted applications compared with non-granted applications, our estimates of the marginal patent value represent an upper bound.

Second, although we observe the date of the patent examination decision, we do not observe the timing of the commercialization decision. However, even if we did have precise dates, we would not be able to rigorously infer cause from effect based on precedence in time since investment decisions are based on the expectations of future events. If the expectation is realised, then the real 'cause' may be observed after the event. In relation to our analysis, this means commercialization decisions are made when a patent is still pending (and the inventor doesn't know whether it will be successful or not). Thus, our inference that granted patents create a small positive effect on commercialization decisions should be treated with caution.

Third, our data has been drawn from inventors' commercialization experiences which occurred up to 20 years ago. As such, the data will still be subject to errors of recall and incomplete knowledge. However, what matters most is whether these errors are random or not (Rossman and Sanders [1957] found that inventors tended to be more optimistic than owners about the eventual use of inventions[16]). As long as any recall bias is uncorrelated with other variables such as the patent grant decision (which we believe to be the case), our estimated coefficients will be unbiased. Biases will then only increase that size of the standard errors which then understates the level of statistical significance.

Fourth, we are not able to account for any externalities arising from other organization's examination and commercialization decisions. These spillover effects may affect the commercialization activities of the subject invention: for example, if rival firms fail to have their application granted, this may give the subject inventor greater freedom to operate which should improve their probability of commercialization success. The role of patent thickets in stifling innovation in the US is well documented (see Green and Scotchmer 1995; Bessen and Maskin 2009; Scotchmer 1991; Heller and Eisenberg 1998; Cohen, Nelson and Walsh 2000; Gallini 2002; Hall and Ziedonis 2001), but unfortunately can not be addressed here.

[16] Owners estimated that about 50 percent of patented inventions were 'used' and 40 percent of unpatented inventions were 'used'. Lack of market demand was the most cited reason for not 'using' the invention.

VI. Conclusions

Our study of the commercialization outcomes for 3,736 Australian inventions has revealed three results. First, patents play a positive but modest role in the decision to manufacture inventions. Bearing in mind that all the inventions in the study are *potentially* patentable, possession of a patent raises the probability that a manufacturing attempt will be made by between 3.9 and 8.0 percentage points. However, we cannot rule out the fact that unobserved differences in the underlying value of the invention may partly explain this result. If these are positively correlated with a patent grant, then the 'true' effect will be less than our estimates. Second, we find that many unpatented innovations were commercialized. Thus, we conclude that patents are neither a necessary nor sufficient condition for commercialization. Finally, we find no support for the view that the marginal effect of patents is higher the more valuable the underlying invention, for PROs, SMEs and individuals who lack manufacturing capabilities and for inventions in the highly codified chemical and pharmaceutical technologies.

Appendix 1: 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 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 5). Of the 31,947 inventors, the vast majority (82.5 per cent) had only filed one application between 1986 and 2005 (see Table 6). To avoid administrative burden, inventors were asked about each invention, up to a maximum of 5 patent applications.

TABLE 5: 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 6: 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. People with a valid telephone number were then called to confirm that they were the correct person. 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. We received completed questionnaires for 3,736 inventions.

The following four tables show the pattern of survey response by year of application across various characteristics. According to Table 7, 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), PRO (71.2 percent), or filed as an individual (73.5 percent), as demonstrated in Table 8.

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.[17] In Table 9, 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.[18] Finally, Table 10 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'.

[17] 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.

[18] 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 7: NUMBER OF PATENT APPLICATIONS WITH A COMPLETE SURVEY RESPONSE BY YEAR, 1986-2005

Year	Number of patent applications			
	Complete	Est. address valid[a] & not complete	Est. address not valid	Total
1986-1990	254	245	3,705	4,204
1991-1995	553	385	5,832	6,770
1996-2000	1,124	541	8,187	9,852
2001-2005	1,805	538	8,144	10,487
Total	3,736	1,710	25,867	31,313

Note: [a] Excludes surveys that were returned as 'return to sender' and the estimated 88.3% of non-responses which we estimated, through a post-enumeration survey, to have had an invalid address.

TABLE 8: NUMBER OF PATENT APPLICATIONS WITH A COMPLETE SURVEY RESPONSE BY ORGANIZATION TYPE, 1986-2005

Organization	Number of patent applications			
	Complete	Est. address valid[a] & not complete	Est. address not valid	Total
Large company[b]	391	228	3,446	4,065
SME[b]	1,361	756	11,439	13,556
Public sector research	247	100	1,515	1,862
Individual	1,737	626	9,467	11,830
Total	3,736	1,710	25,867	31,313

Notes: [a] Excludes surveys that were returned as 'return to sender' and the estimated 88.3% 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.

TABLE 9: NUMBER OF PATENT APPLICATIONS WITH A COMPLETE SURVEY RESPONSE BY PATENT GRANT STATUS, 1986-2005

Patent grant status	Number of patent applications			
	Complete	Est. address valid[a] & not complete	Est. address not valid	Total
Withdrawn	391	228	3,446	4,065
Pending	1,361	756	11,439	13,556
Rejected	247	100	1,515	1,862
Granted	1,737	626	9,467	11,830
Total	3,736	1,710	25,867	31,313

Note: [a] Excludes surveys that were returned as 'return to sender' and the estimated 88.3% of non-responses which we estimated, though a post-enumeration survey to have had an invalid address.

TABLE 10: NUMBER OF PATENT APPLICATIONS WITH A COMPLETE RESPONSE BY TECHNOLOGY AREA, 1986-2005

OST technology area[b]	Number of patent applications			
	Complete	Est. address valid[a] & not complete	Est. address not valid	Total
I Electricity and electronics	329	181	2,739	3,249
II Instruments	440	175	2,654	3,269
III Chemicals, pharmaceuticals	410	166	2,516	3,092
IV Process engineering	447	187	2,825	3,459
V Mechanical engineering	1,061	476	7,204	8,741
VI Other	1,048	524	7,927	9,499
Total	3,736	1,710	25,867	31,313

Notes: [a] Excludes surveys that were returned as 'return to sender' and the estimated 88.3% 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

TABLE 11: CHARACTERISTICS OF RESPONDENTS

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
PCT status		
Paris Convention (non-PCT)	2306	61.7
Patent Cooperation Treaty (PCT)	1,430	38.3
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.

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