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Do Patents Matter for Commercialization?

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Abstract

In this paper, we take another look at the role that patents play in determining successful commercialization. We address this issue using 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. This variation in patenting and commercialization outcomes enables us to address the question: do patents matter for commercialization? Our results suggest that while the receipt of a patent grant had a positive and significant effect on most commercialization stages, the magnitude of the effect is quite modest. In fact, the marginal increase in the probability of attempting a commercialization stage due to the presence of a patent varies from 2.0 (export) to 8.0 (mass production stage) percentage points.

1. Introduction

Empirical economists have found it difficult to find evidence supporting the theory that patents stimulate investment in innovation. In an important recent contribution to this literature, Arora *et al.* (2008) demonstrate that the average patent premium is small and positive in only a few industries. Such a result is consistent with earlier work by Levin *et al*. (1987) and Cohen *et al.* (2000) which highlighted the fact that patents' effectiveness in appropriating returns is highly industry-specific – a fact which can only be partly explained by the narrow industrial coverage of the patent system. Casting further doubt over the efficacy of patenting, Bessen and Meurer (2008, p.17) recently argued that "…the risk of patent litigation that firms faced in their capacity as technology adopters *outstripped the profits that they made by virtue of owning patents*".

In this paper, we take another look at the role that patents play in stimulating innovation. In contrast to Arora *et al.* (2008), we focus on the effect that patents play in determining successful commercialization. As such, our study draws upon the work of previous studies on the forces that shape successful commercialisation of new products and processes (including Mansfield and Wagner 1975; Cooper and Kleinschmidt 1987). Our contribution to this literature is that very few studies have considered the specific role that patents play in enhancing commercialization outcomes. We address this issue using 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. We compare the commercialization outcomes for inventions that were awarded a patent with those that were not. This enables us to address the question: do patents matter for commercialization? Since our study only includes inventions that are *potentially* patentable (as evidenced by the inventor's decision to apply for a patent), our results are not biased by the narrow industrial coverage of the patent system.

Our empirical model identifies five stages of commercialization: licensing or spin-off; development; make and sell; mass production; and export. To model the determinants of commercialization, we estimate five separate Heckman probit models (for each commercialization stage) in order to control for any selection bias associated with survey non-response. Our results suggest that while the receipt of a patent grant had a positive and significant effect on most commercialization stages, 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 commercialization stage due to the presence of a patent – varies from 2.0 (export) to 8.0 (mass production stage) percentage points. Although patents matter, they are hardly the powerful force that economic theory suggests.

We also find strong evidence of heterogeneity in the marginal patent value across different technology areas. For instance, in highly codifiable technologies, patents play a particularly important role in decisions to license or spin-off to another entity and manufacture. In fact, the presence of a patent increases the probability that an inventor in the chemical and pharmaceuticals industry will attempt to license or spin-off by 24.0 percentage points. Our contention is that this is a function of the fact that patents are most effective in highly codifiable technologies where an idea is easily reverse engineered and articulating the boundary of an idea is more precisely conveyed in written form. Our results also indicate that organisations – such as public research organisations, SMEs and individuals – that do not possess the complementary assets (e.g. marketing and distribution) typically required to commercialize an invention are much more likely to license or sell their technology. However, patents only play a modest role in aiding their licensing efforts, *ceteris paribus*.

A number of caveats to the results should be noted. First, disentangling the effect of a patent from the underlying commercial value of the invention is difficult to do. We rely on a range of variables – such as whether a PCT patent application was made and whether the invention is radical or incremental – to identify the additional value attributable to the patent (that is, the marginal patent value). However, we acknowledge that this is not without limitations. Second, the exact 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 difficult 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. Fourth, we are not able to account for the fact that one firm's commercialization decisions (or examination outcomes) may impact rival firms' decisions. Such externalities are clearly important, but cannot be addressed here.

This paper is structured as follows. In section 2, we discuss the main findings from the literature on factors governing successful commercialization of inventions and use these finding to formulate three hypotheses relating to appropriability, codifiability and complementary assets. In section 3, 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 five separate Heckman selection probit regression analyses. Finally, Section 6 concludes.

2. Background and Hypothesis Development

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 investing 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 make imitation costly, 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 (successful) 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 examination and renewal data (Schankerman 1998; Lanjouw 1998). The effect of the patent on the incentive to conduct R&D or to commercialize is inferred rather than directly measured. Other studies have sought to estimate the effect of the 'strength' of the patent regime on the level of innovative activity by use of economy-wide measures of patent strength and innovation (see Sakakibara and Branstetter 2001; Branstetter and 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.

Following Mansfield and Wagner (1975), the microeconomic literature in this field has focussed on the determinants of innovation success, usually using inventions, products or projects as the unit of analysis (not patent applications as used here). However, of the published studies, only Dechenaux *et al* (2005) and Palmberg (2006) use patent applications as the unit of analysis and are thus able to estimate the marginal patent value.[1] In other studies, the patent status is either not recorded or is invariant across the sample. Nonetheless, these latter studies are relevant for what they reveal about different measures of 'success', including whether a dollar of sales revenue was generated (Bizan 2003; Dechenaux *et al* 2005; Mattes *et al.* 2006; Nerkar and Shane 2007), the speed to market (Markman *et al*. 2005; Palmberg 2006), rate of return on or presence of profits from investment (Bizan 2003; Astebro 2003; Amesse *et al*. 1991) and duration of sales (Astebro and Michela 2005).

Due to data limitations, these studies typically use only one measure of 'success' 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 success is measured.[2] In contrast, we use five different measures of 'success' which relate to different commercialization stages: development, license or spin-off, make and sell (conditional on development completion), mass production (conditional on make and sell completion) or export (conditional on make and sell completion). In the following section, we develop three hypotheses relating to the role patents may play in the successful commercialization of inventions. These comprise theories relating to appropriability, the existence of complementary assets and codifiability.

2.1 Hypothesis 1: Appropriability

Our first hypothesis relates to the conjecture that the strength of appropriability conditions should shape successful commercialization. Although appropriability can be achieved through

[1] Palmberg (2006) does not find that possession of a patent reduces the speed to market.
[2] 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.

numerous mechanisms, patents are recognized (at least in theory) as an important way in which firms can recoup their investment in innovative activity. Of course, 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). Moreover, others (e.g. Dosi *et al*. 2006, p.897) 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." Nevertheless, we argue that the grant of a patent should increase the probability that a stage of the commercialization pathway 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*.

Since most examination decisions at the Australian Patent Office are known early in the commercialisation time scale (the median examination lag is approximately 28 months), a comparison of the group which was granted a patent with the group that was not, all other things considered, should give us an estimate of the marginal patent value in terms of its effect on the propensity to commercialise the invention. Furthermore, given that most of the financial and disclosure costs of acquiring a patent are sunk by the time of the examination decision, we expect that the examination decision will only affect revenues and thus the effect of the patent examination decision on the commercialization decision should be positive. Our first hypothesis can be stated as:

HYPOTHESIS 1: The existence of a patent increases the probability that successive commercialization stages will be attempted, ceteris paribus.

2.2 Hypothesis 2: Complementary Assets

Organisations that do not possess complementary commercialization assets (such as manufacturing capabilities, marketing capital and distribution networks) have a natural incentive to license the invention or sell outright (perhaps to a spin-off company) to an organization that does (Hall 2005; Teece 1986; Levin *et al*. 1987; Cohen *et al*. 2000; Gans *et* *al.* 2002; Hall and Ziedonis 2001). In other words, there are potential gains for buyers and sellers from trade in technology transfer. However, selling requires the owner to expose the idea to the potential buyers which – in the absence of the protection offered by a legal title – puts the owner at considerable risk of expropriation (Arrow 1962). Not only does the possession of a patent give legal protection to the seller but it gives the buyer of the intellectual capital additional confidence that his/her investment into the development and marketing of the invention will be free from imitation.

Since public research organisations, small-medium sized enterprises and individuals are less likely than companies to possess the complementary assets and are therefore more likely to depend on selling or licensing their intellectual capital, we expect that achieving a patent grant will boost the commercialization outcomes for these groups (Mazzoleni and Nelson 1998; Arora and Merges 2004; Orsi and Coriat 2005, Teece 1986; Arora and Ceccagnoli 2006). This leads to our second hypothesis:

HYPOTHESIS 2: Patents have a larger marginal effect on the licensing and outright sale decisions of public research organizations, SMEs and individuals, ceteris paribus.

2.3 Hypothesis 3: Codifiability

Other recent studies have focused on the role that technological characteristics – as opposed to the organisational characteristics – play in shaping commercialization outcomes. For instance, Nerkar and Shane (2007) find that the broader is the scope of the patent, the more the patent owner is able to deter rivals from investing in a similar technology space and the more likely the idea is to be commercialized. Continuing this line of thought, we also examine the role that technological characteristics have on the marginal patent value. The primary characteristic we consider in this regard is the degree of codifiability.

To the extent that highly codifiable technologies are easily reverse engineered (and are therefore provided less protection by non-patent forms of protection such as production complexity), they will benefit the most from patent protection. As a result, we expect that legal protection will be more effective the more codifiable is the underlying technology (Mansfield *et al.* 1981, Levin *et al.* 1987, Saviotti 1998, Cohen *et al.* 2000, Harabi 1995).

This conjecture is supported by the empirical work of Mansfield *et al.* (1981) who 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.[3] The work of Bessen and Meurer (2008) is also an important source of empirical information on the importance of technology area with regard to patent effectiveness. They argue that the "…average public firm outside chemicals and pharmaceuticals would be better off if patents did not exist" (p. 18). Given this background, our third hypothesis can be stated as:

HYPOTHESIS 3: Patents have a larger marginal effect on the probability of commercialization in highly codified technologies such as pharmaceuticals and chemicals compared with other technology areas, ceteris paribus.

3. 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 a survey including inventors with many applications. Since the survey was sent to the population of patent applicants, our sample includes a large number of inventors whose patent applications were unsuccessful. However, as will be shown below, many of the inventions underlying these unsuccessful patent applications were, in fact, successfully commercialized. This is the major point of departure from other inventor surveys from around the world, such as the PatVal-EU survey.[5] Our dataset includes a mix of *potentially* patentable inventions, some of which passed the novelty and non-obviousness tests imposed by the patent office and

[3] As a corollary, we expect that a higher percentage of inventions in codifiable technologies will be patented compared with less codified technologies. 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.

[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 percent.

[5] See Gonzalez (2006) and the special issue of *Research Policy* in 2007 for examples of applications of the PatVal-EU survey.

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.

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 – product development; make and sell; mass production; export; and licensing and spin-off – were attempted.[6] This enables us to examine whether the same forces are at work at different stages of the commercialization pathway.

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.[7] 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 (46.58 percent) were individual inventors.[8]

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.[9] The distribution by technology area was: electricity and electronics (10.4

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[6] Thus, as we noted previously, our measure of "success" is whether a commercialization stage was attempted rather than the revenue generated.
[7] More information on the population and the survey method is provided in the Appendix.
[8] Employment status was determined by the name of the applicant.
[9] OST refers to the UK Office of Science and Technology classification. IPC is the International Patent Classification.

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; 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.[10]

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 pervious 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 cross-tabulations on the percentage of inventions that achieve each commercialization milestone according to their patent grant status. To limit truncation bias,

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

we only present patent applications which were made between 1989 and 2002. The data show that a substantial proportion of inventions that were rejected by the patent office were commercialized (with varying degrees of success). At least at the prima facie level, this suggests that a patent may not be necessary for successful commercialization. For instance, whether or not a patent was granted appears to have only a small effect on whether or not to attempt develop the innovation: 86.6 percent of rejected applications proceeded to development compared with 92.1 percent of granted inventions. For the other commercialization stages, there was approximately a 5-20 percentage point difference between those with and without a granted patent.

These results are quite similar to other surveys of inventors. The Mattes *et al.* (2006a) survey of 177 Australian medical inventors who possessed a US patent between 1984 and 1994, found that three-quarters were involved in a development stage and 58 percent in a manufacturing stage. Both percentages are slightly lower that those reported in Table 1. In addition, the Amesse *et al*. (1991) 1986 survey of 374 individual Canadian inventors found that 43.3 percent received positive revenues from the invention (of which about half were profitable).

Table 1: Commercialization stage by patent grant status at April 2007, patent applications lodged between 1989-2002

Stage	Withdrawn (%)	Reject (%)	Grant (%)	Total (%)
License or spin-off	36.3	39.3	49.2	45.7
Development	86.6	86.9	92.1	90.5
Make and sell	65.2	64.3	76.3	72.8
Mass production	25.3	27.4	41.5	36.9
Export	13.9	13.1	26.0	22.3

Notes: Withdrawn includes those that lapse before an examination is requested and those that withdraw before an examination decision is made.
Source: Australian Inventor Survey 2007

4. 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 (or licensor) has a sequence of hurdles to overcome before attempting the next stage of the commercialization process. These decisions are made according to whether suitable finance can be obtained and expectations regarding the future revenue streams (based on current knowledge). The commercialization process is broken down into five different stages – product development; make and sell; mass production; export; and licensing and spin-off. Underlying the decision to attempt each successive stage of the commercialization process are estimates of the market for the final product or process, the costs of undertaking the commercialization stage and the appropriability of future revenue streams.

One of the difficulties in modelling the determinants of successful commercialization is that there is likely to be some sample response bias: perhaps, for example, those 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 commercialization success 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:

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

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:

$$\tilde{y} = Z_i\gamma + \xi_i > 0 \tag{2}$$

where Z_i is a set of selection variables and ξ_i is a random error term. If $\text{corr}\left(\varepsilon,\xi\right) = \rho \neq 0$ then there are significant selection effects and the standard probit equation will yield biased results. Assuming $\Pr(y{*}_i > 0 \mid X_i) = \left(\exp\left[X\right]_i\beta\right)/\left(1+\exp\left[X\right]_i\beta\right)$, 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, OST technology area dummy variables, three ownership variables (individual, public and company) and the number of years the patent was in-force.[11] We use the entire population of 31,313 inventions in our estimating sample.

Dependent variables

As discussed, there are five different commercialization stages which form the set of dependent variables in the estimating equations. *Development* was coded 1 if the inventor indicated that either proof of concept, testing and validation, prototype or another development activity had been attempted, and 0 otherwise. *License or spin-off* was coded 1 if the inventor said that there had been an attempt to licence, sell or transfer the patent to a spin-off company, and 0 otherwise. *Make and sell* was coded 1 if the inventor indicated that either gathering market intelligence, validate commercial opportunities, trialling the manufacturing process or 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, *Export* was coded 1 if the inventor indicated that the invention was exported and 0 otherwise.

Explanatory and control variables

The main explanatory variables relate to our three hypotheses. The key to Hypothesis 1 – which relates to the marginal value that a patent provides – is the explanatory variable *Grant* (=1 if the patent application was granted, =0 otherwise). Information on the status of the patent was extracted from the official patent office database in April 2007. Assuming that the patent applicant had some knowledge about whether the patent would be granted, the sign of the coefficient on the variable *Grant* informs us how the existence of a patent shapes the probability that each stage of the commercialization process will be attempted. It should be reinforced here that this is not a monetary interpretation of the value of a patent – rather, it is

[11] 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.

an attempt to capture the effect that a patent has on attempting various stages of commercialization.[12]

To capture the presence of complementary assets – which relates to Hypothesis 2 – we include dummy variables on the organisation type (*Large Company*[13], *Public Research Organization, SME* and *Individual*) which we interact with the *grant* variable. If a patent enhances technology transfer then the estimated coefficient should be significant and positive. Hypothesis 3 relates to the impact of codifiability. In order to ascertain how the codifiability of the technology shapes commercialization outcomes, the variable *Grant* is interacted with the technology dummy variable *Pharmaceuticals & Cosmetics*. If patents are especially effective in these highly codified technology areas, then the estimated coefficient on this interacted term should be significant and positive.

One of the difficulties 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 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 is also controlled for. The latter is controlled for by the variable *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).

[12] 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.
[13] 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.

5. Results

The estimated coefficients are shown in Table 2 and converted into marginal effects in Table 3. The marginal effects are calculated by estimating the predicted probabilities of attempting each commercialisation stage using the original data but at set values for one specific independent variable. What we have loosely called ‘invention quality’ is shown to have large, and with one exception, positive effects on the probability of attempting a commercialisation stage. In particular, we find that the *PCT* variable was positive and significant for all commercialization stages with the exception of mass production. Somewhat surprisingly, the size of the *PCT* coefficient was largest for the licensing and spin-off decision. Radical inventions were also much more likely to result in attempts at commercialization than incremental inventions. For instance, radical inventions increased the probability of attempting the ‘make and sell’ stage by 9.5 percentage points. The product complexity has also been found to be associated with a large effect on the probability of attempting each commercialisation stage, especially licensing and spinoff.

With respect to our hypotheses, we find positive support for Hypothesis 1 that the grant of the patent title has a positive effect on the probability of commercialization. The full effect of a patent grant is easiest to interpret by examining the marginal effects (Table 3). On average, over the whole sample, a patent grant increases the probability of attempting to licensing and spin-off by 3.6 percentage points. It increases the probability of attempting the development, make and sell, mass production and export stages by 2.5, 5.9, 8.0 and 2.0 percentage points respectively. The modest finding for export can be attributed to the fact that what matters for export decisions is not whether the invention is patented in Australia (which is what we observe), but whether the patent is granted in the overseas jurisdictions where the invention is intended to be sold. These overall patent grant results are broadly consistent with those found by Dechenaux *et al* (2005) and Arora et al. (2008) which concluded that the existence of patent has a small but modest impact on commercialization outcomes.

As anticipated by the literature, we find that invention owners who are less likely to have complementary assets (public research organisations, SMEs and individuals) are considerably more likely than large companies to attempt to license or sell to a spin-off company. The incremental percentages for these three entities were 44.3, 24.8 and 27.1 respectively. However, this result creates a puzzle: if licensing (or sale) is successful, the invention should also be manufactured and we should observe that these decisions are also strongly connected with attempts at subsequent commercialisation stages. However, the results shown in Table 3 reveal that this was not the case for public research organisations and individuals. This could be explained by a number of factors: licensing and spin-off companies have lower success rates than inventions developed in-house; that attempts to license or sell to a spin-off company are not successful; or that the commercialization process takes a long time.[14]

However, what matters for our question – do patents matter? – is whether the possession of a patent for these organisations was more influential than for large companies that did not regard the patent as a vehicle for technology transfer. The results imply a modest effect. According to Table 2, the coefficient on the interaction term between patenting and not belonging to either a public research organisation, an SME or an individual was only significant for the 'make and sell' stage. Although the marginal effects in Table 3 for the interaction between a patent grant and a public research organisation are non-trivial, they are statistically insignificant. This result is therefore inconsistent with Arora and Ceccagnoli (2006) who argue that that patent protection is most important for those inventors without specialised complementary assets.

The results do provide strong evidence for Hypothesis 3 that patents are more effective in pharmaceutical technologies than other technologies. However, we found that this was only true for the decision to attempt to license or transfer into a spin-off company. In fact, the presence of a patent in the pharmaceuticals industry increased the likelihood of licensing activity (or the creation of a spin-off company) by 24.0 percentage points. The incremental effect of the patent on the development, make and sell and mass production stages are more modest, and in the case of export, large and negative.

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 commercialization. This finding

[14] An alternative explanation is that inventors lose touch with what happens to their invention after it is licensed or sold. If this is the case, we have a biased picture of the manufacturing and export outcomes of licensed and sold patents.

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. In a similar light, Arora *et al.* (2008) find that when the costs of patenting are taken into account (filing and attorney fees, costs of disclosure and enforcement costs), patenting a typical invention is not profitable. That is, the patent premium is actually quite small. However, even though the average invention is not worth patenting, patents are very effective for a subset of inventions – increasing profits by about 50 percent – and can therefore be said to stimulate R&D spending.

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. One is that enforcement issues erode the value. For example, Lanjouw (1998) estimated that doubling 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. Another plausible explanation is 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 completely 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 whether radical 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 that attempting the development stage does not necessarily *cause* an organisation to attempt manufacture. Alternatively, it is possible that 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 may not be accurate.

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[15]). 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 commercialisation 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 2000; Scotchmer 1991; Heller and Eisenberg 1998; Cohen, Nelson and Walsh 2000; Gallini 2002; Hall and Ziedonis 2001), but unfortunately can not be addressed here.

[15] 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.

Table 2: Determinants of commercialization (ML estimation with sample selection), patent applications 1989-2005

	Explanatory variables	Commercialization stage attempted (dep. variables)				
		License or spin-off	Develop ment	Make and sell	Mass production	Export
Appropriability	Patent grant	0.227	0.561**	0.212	0.113	-0.058
		(0.150)	(0.218)	(0.150)	(0.130)	(0.115)
Invention Quality	Radical improvement	0.167***	0.329***	0.307***	0.0728*	0.0705*
		(0.0437)	(0.0609)	(0.0461)	(0.0417)	(0.0403)
	PCT	0.388***	0.12	0.153***	-0.0489	0.116**
		(0.0523)	(0.0749)	(0.0547)	(0.0463)	(0.0458)
	Complex	0.165***	0.142**	0.111***	0.0748**	0.0957***
		(0.0350)	(0.0562)	(0.0390)	(0.0329)	(0.0312)
Complementary Assets	Public research organisation	1.261***	-0.224	-0.749***	-0.834***	-0.748***
		(0.164)	(0.193)	(0.148)	(0.149)	(0.142)
	SME	0.674***	0.237	0.109	-0.0281	-0.125
		(0.125)	(0.155)	(0.118)	(0.103)	(0.0940)
	Individual	0.735***	-0.11	-0.179	-0.443***	-0.717***
		(0.139)	(0.163)	(0.126)	(0.106)	(0.0973)
	Patent grant * Public/SME/individual	-0.31	0.301	0.432**	0.0523	0.0156
		(0.198)	(0.313)	(0.209)	(0.209)	(0.195)
	Development[(a)]	0.400***				
		(0.0794)				
Codifiability	Pharmaceuticals&cosmetics	0.263*	0.195	-0.527***	-0.407**	-0.198
		(0.157)	(0.240)	(0.153)	(0.166)	(0.150)
	Patent grant * Pharmaceuticals&cosmetics	0.601**	-0.659**	-0.0859	-0.196	-0.437*
		(0.239)	(0.308)	(0.219)	(0.233)	(0.227)
Constant		-0.161	-0.411*	-0.0152	0.124	0.147
		(0.150)	(0.221)	(0.151)	(0.130)	(0.117)
	Total observations	31243	31243	31243	31243	31243
	Censored observations	27574	27574	27574	27574	27574
	Uncensored observations	3669	3669	3669	3669	3669
	Log likelihood	-13150.01	-11850.69	-12858.53	-13145.96	-12595.16
	LR test of indep. eqns. (rho = 0), Prob > chi2	0.1633	0.9260	0.8109	0.0222**	0.0000***

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). Includes a control variable on the length of time between the survey collected data and the patent application.

Table 3: Marginal effects on the probability of attempting each stage of commercialisation, patent applications 1989-2005

Explanatory variables	Change (from : to)	Effect of change in explanatory variable on the probability of attempting...				
		License or spin-off	Develop ment	Make and sell	Mass production	Export
Appropriability						
Patent grant	(no : yes)	3.6	2.5	5.9	8.0	2.0
Invention Quality						
Radical improvement	(no : yes)	6.1	5.5	9.5	2.7	2.5
PCT	(no : yes)	14.1	1.9	4.6	-1.8	4.1
Complex	(1 : 20+ other patents)	21.9	6.7	11.8	10.5	12.8
Complementary Assets						
Public research organisation	(no : yes)	41.2	-7.0	-26.5	-29.3	-24.2
SME	(no : yes)	21.7	0.7	2.8	1.3	-1.5
Individual	(no : yes)	23.9	-4.7	-5.7	-14.0	-23.0
Patent grant & public res. org.[a]	(public with grant : public without grant)	4.2	9.0	7.9	6.8	0.7
Development attempted[a]	(no : yes)	14.8				
Codifiability						
Patent grant & pharmaceuticals&cosmetics (IPC A61K)[c]	(pharma&cos with grant: pharma&cos without grant)	24.0	-1.9	4.8	-3.2	-18.3

Base case: all cases evaluated with independent variables held at actual values except for the variable defined in the row.
Notes: (a) both cases (with and without a grant) assume all applicants are public research organisation. (b) development was an optional stage only for licensing or spin-off.(c) both cases (with and without a grant) assume all applicants are in the pharmaceuticals & cosmetics technology class.

6. Conclusions

Our study of the commercialization outcomes for 3,736 Australian inventions has revealed two important results. First, patents play a modest role in the successful commercialization of inventions. Bearing in mind that all the inventions in the study are *potentially* patentable, possession of a patent raises the probability that the invention will be commercialised by between 2.0 and 8.0 percentage points. Second, we find that many unpatented innovations were successfully commercialized. Thus, we conclude that patents are neither a necessary nor sufficient condition for successful commercialization. However, we can not 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. In addition, we find support for the view that patents are more effective for highly-codified technologies but less support for the view that they aid in the technology transfer.

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 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.

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.[16] 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.[17] 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’.

[16] 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.

[17] 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 6: Number of patent applications with a complete survey response by year, 1986-2005

Year	Number of patent applications			
	Estimated non-complete[a]	Complete	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 excludes 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 patent applications with a complete survey response by organisation type, 1986-2005

Organisation	Number of patent applications			
	Estimated non-complete[a]	Complete	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

Notes: [a] Number of non-completes excludes 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.

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

Patent grant status	Number of patent applications			
	Estimated non-complete[a]	Complete	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 excludes 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 patent applications with a complete response by technology area, 1986-2005

OST technology area[b]	Number of patent applications			
	Estimated non-complete[a]	Complete	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

Notes: [a] Number of non-completes excludes 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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