Patents, Buyouts and Venture Capital in Sequential Innovation

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Abstract

In a world of patent thickets and complex technologies many small entrant firms can be accused of developing ideas that infringe on existing patents owned by larger incumbents, an accusation that, if substantiated in court, may peril an entrant's existence. Nonetheless, as this paper shows, a fined tuned legal system can lead to a positive bargaining surplus, in the form of a management buyout offer (an out of court settlement) that allows both entrant and incumbent to profit. Such an outcome effectively creates a secondary market for ideas, on top of the stock market, offering entrant entrepreneur innovators and venture capitalists an extra option for reaping the benefits of their inventions.

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1 Introduction

For some years now the US has experienced a growth rate reminiscent of the post WWII years, contrasting the EU, which has remained largely an observer. It seems that the backbone of US growth is its technological superiority, which, as many commentators argue, has been backed and protected by an attitude towards intellectual property that finds no equivalent in the EU. Specifically, the Central Appellate Court for the Federal Circuit (CAFC) and its strict protection mechanism, the existence of software and business method patents, as well as the easiness that new inventive ideas can obtain a patent, is not matched by any EU economy.

Concentrating on the CAFC, since its creation in the early 1980s, it has, with no doubt, shifted the table well in support of strong patent protection, consistently arguing in favor of intellectual property owners and against infringers. This protection has come with a non-trivial cost, in the form of sizable legal fees, which arguably crowd out useful R&D funds. Our aim in this paper is to explain how a patent protection apparatus (similar to the CAFC), if fine-tuned, can help reverse this crowding out, attracting R&D funds increasing innovative output. Focusing on a patent dispute between an incumbent firm and an entrant (who is accused of infringing on the incumbent's patents), we examine how courts can help generate a secondary market for ideas on top of NASDAQ, offering entrant entrepreneur innovators (and venture capitalists) an extra option for reaping the benefits of their inventions. As we argue, depending on the incumbent's probability of successfully defending her patent in court, there may be a positive bargaining surplus, in the form of a Management Buyout (MBO) offer, an out of court settlement, that allows both parties to profit.

Specifically, in modern hi-tech industries where technology is complex and cumulative, a patentable new innovation is likely to infringe on existing patents. Therefore, an entrant innovator is likely to face the threat of litigation from a competing incumbent patent holder of significantly larger size. However, if IP protection is strong, and the courts do not take a lenient view on alleged infringement, arguing in favor of the incumbent patent holder, there would be no incentive for entrant entrepreneur innovators to innovate; see Bessen and Maskin (2004). However, even when IP protection is limited, and the courts have broader views regarding alleged infringement, entrant entrepreneur innovators may still choose to abstain from innovating. This is because their innovation will not be adequately protected from the incumbent, who is, in any case, endowed with a superior marketing capability that allows her greater bargaining power in case of an MBO. On the other hand, when IP protection is moderate, allowing the courts a more bal-

anced approach towards alleged infringement, the benefit of an MBO for the incumbent goes beyond commercializing the new innovation. This dynamic effect is the result of the increase in the incumbent's patent portfolio (as she incorporates the entrant's patented ideas), which allows her to better barricade her technological territory, strengthening her bargaining position in future MBO deals with other entrant innovations. Realizing this added value for the incumbent, the entrant entrepreneur innovator should anticipate a sufficient reward in terms of an MBO, which justifies her investment in innovation activities.

In brief, IP protection needs to be sufficiently strong so that the incumbent's added value has a significant impact on the entrant's share of the MBO. By contrast, excessive IP protection would accumulate the incumbent's bargaining power too quickly; killing off the innovation incentives for startups prematurely. This reasoning suggest that the optimal IP protection appears to be at an intermediate level, where there may be a positive bargaining surplus that allows both parties to gain.

The paper continues as follows, in section two we review the literature on patent litigation, while in section three we provide an economic model that outlines the bargaining process. In section four we elaborate on the model's results and provide some comparative statics, we offer some empirical backing for our theoretical proposal in section five, which is followed by the conclusions in section six.

2 A Closer Look at the Patent System

Patents are state monopoly-grants that hold for a limited time period; 20 years. During this period no one, part the patent holder, may freely make use of the technology embodied in the patent's claims. Nevertheless, occasionally new ideas arrive, whose technological domain may well rest in a technological territory vaguely entrenched by the patent's claims, in which case the issue of possible infringement arises, frequently accompanied by a counter claim of validity. This infringement differs from a direct copying and re-branding of one's patented ideas, in as much as it progresses the prior art. The question of how and by how much the novel idea progresses prior art finds no equivalent in other forms of material-property. This is because, asserting property rights on one's ideas is far from simple. An idea, contrasting land, can never be fully barricaded or entrenched. Therefore, the issue of infringement is largely a subjective one, resting on the decision of courts. As Judge Markey notes (Roper Corp. v. Litton Systems, Inc. 757 F2d 1266 Federal Circuit 1993), *"A patent is born valid and remains valid until a challenger proves it was*

stillborn or had birth defects"; therefore it is up to the innovator, through litigation, to prove the merits of her innovation. In other words, patents convey imperfect property rights to technologies, rights that can only be asserted by courts. It has thus been argued that patents can be thought of as lotteries that carry some probability of being verified by a court; Lemley and Shapiro (2005).

Two factors indisputably increase the enforcement probability of a patent. The first one is the scope of the patent, describing, through the claims that the patent office allows the patent holder to include, the patent's technological territory. The more the claims the more powerful a patent is, for it is harder to bypass it by innovating around it (or passed it), developing a better and more advanced technology. Nonetheless, the claims of the patent convey information but lack the ability to self enforce. This power is invested in courts, which are the ultimate judges of the patents' merits. Therefore, the courts attitude towards infringement is also a key component on patent validity.

The above two factors are far from static, in fact, as far as the US is concerned, we have seen a drastic change in the past 20 years, both in court attitudes as well as patent scope. In detail, a) in 1980 Congress passed the Patent and Trademark Laws Amendment (Bayh-Dole); allowing universities to patent any innovations they had created with government funding. b) In 1980 the US Supreme Court extended patentability to genetically engineered bacteria (Diamond v. Chakrabarty). c) In 1981 the Supreme Court held that software that was part of a manufacturing system or process was patentable (Diamond v. Diehr). d) In 1982 Congress passed the Federal Courts Improvements Act. This Act allowed for the formation of a centralized appellate court, the Court of Appeals of the Federal Circuit (CAFC). The CAFC raised the evidentiary standards required to challenge patent validity and broadened the interpretation of patent scope; Merges (1997). Furthermore, the court relaxed the requirement that patents be granted only for inventions that are not obvious to practitioners skilled in the art.[1] The above changes lead to a higher plaintiff success rate. e) In 1984 Congress passed the Semiconductor Chip Protection Act, to protect microchip design. f) In 1998 the CAFC upheld a patent on a software system that performs real-time accounting calculations and reporting, which was to be used by mutual fund companies (State Street Bank & Trust Company v. Signature Financial Group). This decision allowed the patentability of business methods. To the above one should also add the Drug Price Competition and Patent Restoration Act (Hatch-Waxman Act), and The First American Inventors

[1] See Cooley (1994), Dunner et al (1995) and Lunney (2001).

Protection Act of 1999.

The above changes have tilted the table towards patents, making it easier to assert infringement. The data is revealing. Federico (1964) provided validity and infringement data for litigated patents during the years 1925-1954. He found that courts upheld the validity of patents in only about 30-40% of the cases in which validity was an issue.[2] In a later study by Koenig (1980), with data from 1953-1978, district and circuit courts found patents valid about 35% of time.[3] The above pattern was to drastically change with the introduction of the CAFC, leading to a higher plaintiff success rate. Specifically, Harmon (1991) finds that from 1982 to 1990, the CAFC affirmed 90% of district court decisions holding patents to be valid and infringed, and reversed 28% of the judgments of invalidity and non-infringement. As a result the overall probability that a litigated patent will be held to be valid has risen to 54%, see Allison and Lemley (1998).[4] Subsequently, as Siegelman and Waldfogel (1999) note, the implied average expected likelihood that the plaintiff will prevail is about 35% for all patent cases, which is higher than all of the other categories except contracts.

This pro patent stance is not cost free. Merges (1999) points out, the expenses of a patent infringement court case can cost from 1$ million to several millions. In detail, direct legal costs of a typical patent lawsuit are estimated to be $4 million US (AIPLA 2003), although Farrell and Merges (2004) show that, as more money is at risk in the suit, litigation cost rise sharply –mostly driven by discretionary spending. Another estimate puts the cost in patent litigation at $500,000 US per claim at issue, per side; Barton (2000). If one is to take a closer look at the total cost of patent litigation then the numbers are roughly one fourth of basic research expenses. Specifically, Lerner

[2]He also concluded that prior art before the courts was often better than used by the PTO in issuing the patent, based on his observation that accused infringers were generally more successful in convincing courts to invalidate patents on the basis of incited prior art than on the basis of cited prior art.

[3]Koening collected all patent cases reported in the US PTO in the years 1953-1978 to produce an array of descriptive statistics. She also selected a random sample of 150 patents from the years 1953-1967 for more in-depth study. In addition to finding that most courts held patents invalid, and noting the wide disparity of validity rates across regional circuits, she also found that obviousness was the most frequent used basis for judicial invalidation of patents.

[4]Allison and Lemley find that the probability of validity does not vary significantly by technology field, or the nationality of the inventor. They also note that the average final validity finding occurs about 9 years after the patent was granted and about 12 years after the application date. However, Waldfogel (1998) finds that cases that resolve in 3 months are won by the patentee 84% of the time and cases resolved within a year are won 61% of the time. This suggests that the fact that only half of cases carried to conclusion are won by the patentee greatly understates the likelihood that a random patent can be enforced.

(1994) reports that, from July 1989 to June 1990, 1318 patent related suits were initiated in the US Federal Court and approximately 3900 procedures within the US Patents and Trademarks Office (PTO). He estimates, based on historical costs, that these cases will involve legal expenditures of about one billion 1991 dollars, which should be compared with expenditure on basic research of 3.7 billion by US firms in 1991 (i.e. 27% of expenditures on basic research by firms that year).[5]

It seems that litigation is an easier and less costly path to follow for large firms; with large patent portfolios. For example, Lanjouw and Schankerman (2004) find that having a larger portfolio of patents reduces the probability of filling a suit on any individual patent in the portfolio. As they note, *"for a (small) domestic unlisted company with a small portfolio of 100 patents, the average probability of litigating a given patent is 2%. For a company with a similar profile but with a moderate portfolio of 500 patents the figure drops to 0.5%. Thus, it is easier (less costly) to protect any given patent when that patent is part of a larger portfolio of patents".* Furthermore, as their research indicates, large firms (with large patent portfolios) have the experience and the ability to settle disputes by pooling or trading intellectual property. Therefore, if imperfect capital markets limit the capacity of smaller firms to finance litigation, larger firms may be able to extract better terms because they pose more credible litigation threats in confronting smaller firms.

The latter point is emphasized by Bhagat, Brickley and Coles (1994), who examine the market reaction to the filing of 20 patent infringement suits reported in the Wall Street Journal during the 1981-1983 period. They find that in the two-day window ending on the day the story appears in the Journal, the combined market-adjusted value of the firms fell on average of 3.1%. Research by Lerner (1995), using data on 26 patents suits between biotechnology firms, supports the above results. Lerner finds that on average the combined market-adjusted value drops by 2%. This represents a median loss of shareholder wealth of 20$ million. Such drop in market value heavily handicaps small firms, for if a defendant is unable to raise capital to finance litigation through external capital markets, he may be forced to settle the dispute, no matter what the ultimate merits of his case are.

The above are restrictive to the US, which stands alone among industrial economies in its strong attitude towards intellectual property. On the other side of the Atlantic, the European Patent Office (EPO) was created by the European Patent Convention of 1973, which in turn builds on the Patent Convention of Strasbourg in 1963, and ultimately on the Paris Convention

[5]To the above cost one should add damages awards, which have increased since the formation of the CAFC, Merges (1997), Kortum and Lerner (1999).

for the Protection of Industrial Property of 1883. The EPO is a centralized patent office in which innovators from the signatory member states can apply for a patent.[6] This patent in turn applies in all the member states. Even though the EPO grants patents using similar requirements as its US equivalent, such as novelty, non-obviousness and industrial applicability, contrary to the PTO it does not account for usefulness. In addition, the EPO largely diversifies from the PTO in three aspects. Primarily, it does not grand software and business method patents. To this one should also add that the EPO is stricter than the PTO in granting a patent. For example, as Graham and Harhoff (2005) suggest, even the most valuable US patents, those that are inviting costly litigation in US courts, are not being granted EPO patent protection in about 20% of cases. Another point worth noting is that, contrasting the PTO, 18 months after the filling date a patent is published, allowing any interested party to centrally challenge it at the EPO (up until 9 months after the patent grand), through a post grand opposition mechanism. In fact, 8.2% of all EPO patents are challenged, and about one third are revoked; Harhoff and Reitzig (2004). This centralized procedure does not undermine the power of the member states' courts, and if an opposing party, having lost its EPO opposition, wants to pursue its case at a national level it is free to do so, at a cost of anything between 50,000€ and 500,000€, depending on the country and the complexity of the case; see Ropski (1995). Overall, limiting the technological area, not accounting for usefulness, applying stricter rules, and allowing for post grand opposition proceedings limits the scope of EPO patents, in comparison to their PTO counterparts, and reduces costly legal opposition.

3 A Single-Innovation Model

Consider an industry consisting of two asymmetric firms: Firm 1 is the dominant firm (e.g., Microsoft) and Firm 2 is a startup. Firm 2 can engage in R&D at a cost $C > 0$, which will result in an innovation.[7] The value of the innovation is $V > C$ if firm 2 commercializes it, whereas it is worth more,

[6] Contrary to US and European patent systems the Japanese one is relatively recent. The JPO, up until 1988, issued very narrow patents, typically with only one claim and, since the judges frequently exerted pressure for settlements, patent litigation was lengthier than in Europe and the US. Due to US pressure, in 1989 Japan initiated the Structural Impediments Initiative, which led Japan (in 1994) to allow foreign applicants to file patent application in English, to request accelerated patent examinations, and to stop threatening firms that refused to license their patents to rivals.

[7] We focus on the case that the R&D resulted in an innovation, although it may happen with less than certainty.

say $V^* > V$, if firm 1 does.

Due to the sequential nature, the new innovation builds on previous technology owned/patented by firm 1. If firm 1 litigates, firm 2 loses the case with probability p: In this case the new technology is freely available to anyone, lowering its actual value to firm 1 down to bV^*, $b \in (0,1)$. For now we assume its values to firm 2 is negligible (i.e., 0) in this case. In case firm 2 wins the case (with probability $1-p$), firm 2 gets a patented ownership of the innovation and captures the full value V. A stronger IP protection is captured by higher p. A litigation incurs costs of $c_i \geq 0$ to firm i, $i = 1,2$, although we assume $c_1 = c_2 = 0$ for now.

Instead of litigation, firm 1 can negotiate a buyout deal with firm 2. We model this process as a Nash bargaining as follows. Should they fail to reach a deal, they will end up in a court. Hence, the disagreement/threat points of the firms are the respective expected surpluses from litigation, i.e.,

$$d_1 := pbV^* \qquad \text{and} \qquad d_2 := (1-p)V.$$

Since V^* is the maximum value of the technology, the Nash bargaining set is defined as

$$B := \{(u_1, u_2) \in \Re^2_+ \mid u_1 + u_2 \leq V^*\}.$$

Since B is compact and convex, there is a unique Nash bargaining outcome (s_1, s_2) that solves

$$\max_{(s,s') \in B} (s - d_1)(s' - d_2),$$

i.e., as functions of p,

$$s_1(p) = \frac{V^* + d_1 - d_2}{2} = \frac{1 + p(b+r) - r}{2} V^* \qquad \text{and} \qquad (1)$$

$$s_2(p) = \frac{V^* - d_1 + d_2}{2} = \frac{1 - p(b+r) + r}{2} V^* \qquad (2)$$

where $r := V/V^* \in (0,1)$. These will be the equilibrium outcome of the single-innovation model. Hence, we have

Proposition 1: In the single-innovation model the firms would reach an equilibrium buyout deal that splits V^* into $s_1(p)$ and $s_2(p)$ above, hence firm 2 will invest in R&D if and only if $s_2(p) \geq C$. Stronger IP protection decreases (increases) the share of firm 2 (firm 1) via weakening (strengthening) its bargaining position and thereby, reduces the innovation incentives of the startup firm.

4 A Sequential Model

We follow Bessen and Maskin (2004) closely in enriching the model to accommodate sequential innovation. There are an infinite periods indexed by $t = 1, 2, \cdots$, in each period of which firm 2, if invested in R&D, succeeds in an innovation that has commercial values of V^* and V to firms 1 and 2, respectively. Here, firm 2 is a new firm that arrives in each period while firm 1 is long-lived. To avoid the so-called *replacement effect,* we also suppose that these values are incremental values.

Then the following seems to make sense: If no IP protection, future is independent of the present, hence the two firms bargain over V^*. With a positive level of IP protection, the value of owning the innovation to firm 1 is V^* (present value) plus the increment in future bargaining share due to strengthened bargaining position via an enlarged patent portfolio (which pushes up future p), possibly leading to larger surplus for firm 2. This could mean the optimal level of IP protection is positive. To capture this, we need to define p as a function of both the degree of IP protection and the size of patent portfolio $L = 0, 1, 2, \cdots$.

We model the level of IP protection by a parameter $z \in [0, 1/2]$ in the following manner. Since $L = 0$ means no IP to protect, $p_z(0) = 0$ for all z, where the argument of p_z is L. Then, the k-th patent added to firm 1's portfolio increases p by z^k: $p_z(1) = z$, $p_z(2) = z + z^2$, and

$$p_z(L) = \sum_{k=1}^{L} z^k.$$

If $z = 0$, every period is separate as explained earlier, and the buyout deal would be the same as in Section 2 with $p = 0$, in particular, each period the surplus of the startup firm that undertook R&D is $s_2(0) := (1 - r)V^*/2$. Depending on the size of R&D cost C, either there will be innovation by startup in every period, or there will be none at all. For each of these two cases, we examine the effects of positive levels of IP protection, i.e., $z > 0$.

4.1 The case of innovation when $z = 0$

If $s_2(0) > C$ there will be innovation without IP protection in every period. So, IP protection ($z > 0$) does not induce innovation that would not have been possible without it. Nonetheless, we examine the innovation incentives in this case, for it might help understand the analysis in the other case.

Let $\hat{z}$ be such that $s_2(p_{\hat{z}}(\infty)) = C$. Then,

[A] for any $z < \hat{z}$, firm 2 produces innovation in every period.

This is because, in each period i) firms 1 and 2 bargain over a total surplus exceeding V^*, ii) $p < p_{\hat{z}}(\infty)$, iii) the disagreement points are the same as when there was no future[8] (because once they go to the court, the future share of firm 1 does not change) and, consequently, the Nash bargaining outcome for firm 2 is larger than $s_2(p_{\hat{z}}(\infty))$.

If $z > \hat{z}$, on the other hand, for large enough L firm 2 would not find it profitable to invest in R&D, because the total surplus to bargain over becomes arbitrarily close to V^* and so do the disagreement points to those in the absence of future, while p exceeds $p_{\hat{z}}(\infty)$, hence the Nash bargaining outcome for firm 2 goes below $s_2(p_{\hat{z}}(\infty))$, i.e., it would not recover the R&D cost. Let L^* denote the largest portfolio size for which R&D takes place. For any $L < L^*$, R&D takes place as well because, relative to L^*, the total surplus to bargain over is larger and p is lower (and the disagreement points are the same as when there was no future). That is,

[B] if $z > \hat{z}$, firm 2 produces innovation until firm 1's portfolio reaches a certain size, then no more R&D takes place.

4.2 The case of no innovation when $z = 0$

It seems plausible to anticipate that IP protection can promote innovation in early stages of technology development, i.e., for low L, by enlarging the total surplus to bargain over. The innovation process, though, would inevitably stop eventually, because the total surplus to bargain will converge back to V^* as the value of an additional patent dwindles to nil. However, in the last period that R&D is supposed to happen, firm 2 would not have such an incentive because it will bargain with firm 1 over V^* and has a worse bargaining position than when $z = 0$. This implies that, unlike the anticipation above, innovation never takes place in equilibrium.

This result, however, is an artifact of the simplifying assumption that all startups have the same cost of carrying out their R&D. Hence, we relax this assumption minimally as follows:

(α) In each period there is some chance, a probability $\eta > 0$, that the R&D cost is small, normalized to 0, instead of C. The realized R&D cost in each period becomes common knowledge at the beginning of that period.

Note that firm 2 will engage in R&D if cost is 0 in any period, hence an innovation will come forth with at least probability η in every future

[8] This means that the bargaining position of firm 2 is better than that in the single-innovation case for $p_{\hat{z}}(\infty)$.

period. The case we currently consider is one in which firm 2 will not invest in R&D if cost is C when there is no IP protection ($z = 0$). Now, return to check the presumed equilibrium above in this section. Again, the innovation process would inevitably stop eventually by the same reason. Consider the last period L^* that firm 2 would invest in R&D regardless of its cost. Since innovations will come forth with probability η in each future period, firm 1 would extract more surplus in the future if it had patent on the current innovation. Therefore, the total surplus to bargain over is larger than V^* by at least a certain amount, and firm 2 may still have an incentive to invest C in R&D even if its bargaining position is worse than when $z = 0$ (i.e., even if $p > 0$). This last period is one in which the next patent will render firm 1's bargaining position strong enough that firm 2's share of the next pie (which will be smaller than the current pie) does not recover C. Indeed such last period can exist in equilibrium. Furthermore, R&D tales place in any previous period because the pie is larger and firm 2 has a better bargaining position.

One interesting question is the level of IP protection (z) that maximizes L^*. It is straightforward to see that higher z is not always better, because p will get high very quickly and the incremental value of additional patent for firm 1 dwindles quickly, both of which are detrimental for firm 2's bargaining outcome. Hence, the optimal IP protection would be an intermediate level such that the value of the first patent is large enough (i.e., the pie in the first period to bargain is large enough) to drive up the innovation process via motivating the early-arriving high cost startups, but not too large to give excessive bargaining power to firm 1 that will discourage R&D investment.

4.3 Simulation/Calibration

Let $X(L)$ denote the value of firm 1 at the beginning of a period with a portfolio size L, that will accrue to firm 1 from deals surrounding innovations not yet realized, conditional on only low cost startups will innovate from the current period onwards. Then,

$$X(L) = (1-\eta)\delta X(L) + \eta(s_1(L) + \delta X(L+1)), \tag{3}$$

where $s_1(L)$ is the Nash bargaining share of firm 1 with a portfolio size L.

Suppose there is an innovation in some period when firm 1's portfolio size is L. The total extra surplus that this innovation can generate to the two firms is maximized when firm 1 commercializes it and add it to its patent portfolio. The total extra surplus in this case is $V^* + \delta(X(L+1) - X(L))$, which is the size of the pie on the bargaining table. The threat points

are the court outcomes $d_1 = p_z(L)bV^*$ and $d_2 = (1 - p_z(L))V$. Since the Nash bargaining set in this case is $B(L) = \{(u_1, u_2) \in \Re^2_+ \mid u_1 + u_2 \leq V^* + \delta(X(L+1) - X(L))\}$, the Nash bargaining outcome (s_1, s_2) that solves $\max_{(s,s') \in B(L)}(s - d_1)(s' - d_2)$ is calculated as

$$s_1(L) = \frac{1 + p_z(L)(b + r) - r}{2} V^* + \frac{\delta(X(L+1) - X(L))}{2};$$

$$s_2(L) = \frac{1 - p_z(L)(b + r) + r}{2} V^* + \frac{\delta(X(L+1) - X(L))}{2}$$

where $r := V/V^* \in (0, 1)$. Plugging $s_1(L)$ back into (3), we get a difference equation that characterizes an sequence $X(1), X(2), \cdots$. Since the value of additional patent diminishes to 0 as $L \to \infty$, it turns out that this sequence increases and converges, as formalized in the next result.

Proposition 2: The sequence $\{X(L)\}$ increases monotonically and converges to

$$X(\infty) = \frac{1 - r + p_z(\infty)(b + r)}{2(1 - d)} V^* \eta.$$

Proof: First of all, note that $X(L)$ is bounded below (by 0) and above because maximum surplus in each period is bounded and $\delta < 1$. Plugging the formula of $s_1(L)$ above into (3) and rearranging, we get

$$X(L+1) - X(L) = \frac{2(1 - \delta)}{3\delta\eta} X(L) - \frac{1 + p_z(L)(b + r) - r}{3\delta} V^*. \qquad (4)$$

If $X(L+1) < X(L)$ for some $L \geq 0$, then the right hand side of (4) is negative and, furthermore, its value decreases when evaluated for $L+1$ because $X(L+1) < X(L)$ and $p_z(L+1) > p_z(L)$. This means that $X(L+2) - X(L+1) < X(L+1) - X(L) < 0$. Applying the same argument repeatedly, we deduce that if $X(L+1) < X(L)$ then the sequence should decrease forever at an increasing rate after L, which is a contradiction because the sequence is bounded below. Hence, we conclude that $X(L+1) \geq X(L)$ for all L. Since the sequence is bounded above, it further follows that it must converge. The limit value, $X(\infty)$, is obtained by setting $X(L+1) = X(L)$ and $p_z(L) = p_z(\infty)$ in the equation (4) and solving for $X(L)$. *Q.E.D.*

Once a sequence is generated consistent with the difference equation (3) and the limit $X(\infty)$, then we can calculate the sequences of bargaining shares, $s_1(1), s_1(2), \cdots$, and $s_2(1), s_2(2), \cdots$. We now find the largest portfolio size, denoted by L^*, under which a high cost startup innovates. It must be the case that $s_2(L^* + 1) < C$. Identify the smallest L^* that satisfies this inequality,

and check whether a high cost startup would invest when $L = L^*$. Supposing it would, the value of firm 1 at the beginning of a period with a portfolio size L^*, denoted by $\hat{X}(L^*)$, is

$$\hat{X}(L^*) = \hat{s}_1(L^*) + \delta X(L^* + 1) \tag{5}$$

where $\hat{s}_1(L^*)$ is firm 1's bargaining share in this period. The total extra surplus to bargain over in this case is $V^* + \delta(X(L^*+1) - \hat{X}(L^*))$. The threat points are the court outcomes $d_1 = p_z(L^*)bV^*$ and $d_2 = (1 - p_z(L^*))V$, and the Nash bargaining outcome is calculated as

$$\hat{s}_1(L^*) = \frac{1 + p_z(L^*)(b+r) - r}{2} V^* + \frac{\delta(X(L^*+1) - \hat{X}(L^*))}{2};$$

$$\hat{s}_2(L^*) = \frac{1 - p_z(L^*)(b+r) + r}{2} V^* + \frac{\delta(X(L^*+1) - \hat{X}(L^*))}{2}.$$

Plugging $\hat{s}_1(L^*)$ back into (5), we express the value of $\hat{X}(L^*)$ in terms of the generated value of $X(L^*+1)$ as follows:

$$\hat{X}(L^*) = \left[1 + \frac{\delta}{2}\right]^{-1} \cdot \left[\frac{3\delta}{2} X(L^*+1) + \frac{1 + p_z(L^*)(b+r) - r}{2} V^*\right].$$

Rearranging (4), on the other hand, we get

$$X(L^*) = \left[1 - \delta + \frac{3\delta\eta}{2}\right]^{-1} \cdot \left[\frac{3\delta}{2} X(L^*+1) + \frac{1 + p_z(L^*)(b+r) - r}{2} V^*\right] \eta.$$

Since $1 - \delta + \frac{3\delta\eta}{2} > (1-\delta)\eta + \frac{3\delta\eta}{2} = (1 + \frac{\delta}{2})\eta$, it follows that

$$\hat{X}(L^*) > X(L^*), \text{ hence } \hat{s}_2(L^*) < s_2(L^*). \tag{6}$$

Therefore, $\hat{s}_2(L^*)$ is not guaranteed to exceed C even though $s_2(L^*) > C$. If $\hat{s}_2(L^*) \geq C$ then there can be an equilibrium such that a high cost startup invests until $L \leq L^*$, and not if $L > L^*$. (Note that L^* is the largest possible L for such equilibrium, because $\hat{s}_2(L) < s_2(L)$ for all $L > L^*$ by the same argument that leads to $\hat{s}_2(L^*) < s_2(L^*)$.) To ensure such an equilibrium, it further needs to be checked that a high cost startup would indeed innovate for all $L < L^*$, given the common knowledge that it will if and only if $L \leq L^*$.

If $\hat{s}_2(L^*) < C$, on the other hand, there cannot be such an equilibrium. As long as $\hat{s}_2(L^*) > s_2(L^*+1)$, though, there exist a range of C for which such equilibrium exists. For various values of C, we can find the optimal range of z for which such equilibrium exists and the associated L^* is largest. Through simulations using we identified some parameter values for which such equilibrium indeed exists

5 Empirical facts

Using data from the US statistical abstracts we have created a data set of PTO patents that spans from 1980 to 2003. This data set contains the value and the number of all US leveraged buyouts (divestitures and mergers), where all values are in 1980's dollars. In addition, for the same time period, we have amassed data for the number of patents issued, the number of patents issued to US corporations, the number of patents issued to foreign corporations, the number of patents issued to individuals, the number of patents awarded to inventions, as well as the number of patents awarded to US and foreign nationals.

Our theory suggests that as the number of patents increases there should be, up to a certain point, an increase in the surplus that the two parties can share, leading to a management buyout deal. In short, in macroeconomic terms, we should expect that the number of patents should be positively correlated to the number of buyouts, or the value of buyouts. The correlation statistics for all the above values, which are listed in figure one, seem to support this claim. Moreover, running a simple OLS regression between the number (or value) of leveraged buyouts and the number of patents issued provides positive and significant results. A similar OLS regression using fist differences provides similar results, although the level of significance drops.

Insert figure one here

6 Conclusions

Bearing in mind that startup firms are more innovative, but established incumbents are more experienced in creating final marketable goods an economy would benefit if it allowed incumbents and startups to solemnly concentrate on what they do best. Subsequently, when an incumbent offers a management buyout (MBO) deal to a startup firm this goal is achieved, as it allows the startup to develop and sell its technology to the incumbent, creating a secondary market for innovative startup firms on top of the stock market. Such MBOs are frequently used by major US firms in acquiring valuable technology, a practise that has yet to gain momentum in the EU. Commentators argue that the entrepreneurial attitude of US innovators may be the culprit behind this dissimilarity. We propose an alternative institutional explanation, which rests on differences in legal attitudes.

Specifically, we focus on how two firms of dissimilar size and expertise (an incumbent and a startup firm), locked in a legal dispute over alleged infringement by the startup, can negotiate an out of court settlement that

leads to a management buyout (MBO). We concentrate on two parameters whose importance is highlighted by recent economic research. The first one is the courts' attitude towards infringement. The second one focuses on the role of a large patent portfolio, held by the incumbent, upon the outcome of the trial. Since the role of large patent portfolios is to barricade one's technological territory from infringers, a large patent portfolio makes it hard for the startup firm to avoid using the incumbent's prior art. This is highlighted when innovation is sequential and the startup's innovation must build on prior art that is owned by the incumbent.

We find that litigation (where infringement is established) is not a blessing for either party. By contrast, an MBO may benefit both litigants. However, a prerequisite for this argument is a fine-tuned legal system; not openly benefiting any party. This legal apparatus is absent from the EU, where questions of enforcement, validity, and revocation are dealt with by national courts that have varying attitudes/experience towards infringement. By contrast, in the US the Central Appellate Court for the Federal Circuit that is responsible for patent disputes, takes a more balanced view, with win rates close to sixty percent; not openly favouring either party.

The EU Commission has been advocating the creation of a central patent dispute court, in the hope of simplifying the EU intellectual property framework. Our argument endorses the Commission's initiative suggesting that, provided the court keeps a balanced approach, it can unintentionally spur innovative activity and create benefits for startups and incumbents alike.

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