Platforms for Technology: An Alternative to Markets for Know-how

Preliminary and Incomplete

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Abstract

This paper addresses recent failures in the market for know-how with regards to the development of complicated, integrated network technologies. The market failure is manifested in attempts to manipulate the market for patent rights, to extract higher royalties for the transfer of "must-have" technology. The observed manipulation is not the problem however, but a symptom of a system that is unable to provide the central planning and coordination required for technology integration. We argue that technology platforms in which the development and exchange of technology is centrally planned and governed by liability rules is a superior alternative.

1 Introduction

The United States, Europe and other developed economies rely on private inventors to acquire knowledge and know-how to develop useful technology. The acquisition is financed in a decentralized way by awarding patents or intellectual property rights *IPRs* to successful inventors who can then sell or license their technology to downstream innovators or end-use consumers. In effect a market for know-how is created in which patent-protected knowledge and technology are exchanged at whatever prices the "market will bear."[1] By most accounts, know-how markets have performed reasonably well, with the exception of some difficulties with patent examination and conflicts between IP and Antitrust. Recently however, this has changed with the increased demand for integrated network technologies in today's economy. Markets for know-how have become less competitive; to an increasing degree patents are bought and accumulated for strategic purposes to engage in *patent ambush* rather than to produce something.[2] A system that once was thought to facilitate competition for technology, now appears to have been manipulated by aggregaters of technology to extract higher prices.

This paper addresses the issue of whether there is a better venue for developing multi stage technologies than within conventional markets for know-how. Current reforms call for leaving the patent process in tact while requiring owners of technology to work with standard setting organizations SSO's to license their know-how ex-ante on terms that are "reasonable and non discriminatory."*RAND*[3] While proponents agree that *RAND* licenses are hard to define, and harder to implement, they hold out hope that there will be sufficient competition in the market to ensure *RAND* pricing or that prices can be set formulaically in advance of knowing the value of the technology. These reforms move in the right direction towards giving SSO's more leverage in coordinating technology acquisition and development. In the end, however, their solution to fixing broken markets for knowledge is to assume they aren't broken; either the markets are competitive enough to set the right prices, or they aren't, in which case one can set prices by formula without relying on the market.

These reforms are unlikely to make conventional markets for know-how workable, as we argue in section 2. The reason, as illustrated by some simple examples, is that patent ambush and hold up aren't the problems that need to be corrected; rather they are manifestations of the failure of decentralized markets for know-how to provide the central planning and

[1] The best process for developing, protecting and sharing intellectual property has been the subject of much debate among economists and lawyers. The consensus among most economists writing in the area, is that some form of markets for knowhow is necessary if inventors are to be compensated by the market value of their discovery. See Gallini and Scotchmer (2002), Shavell and van Ypersele (2001),Weyl and Tirole (2012) and Wright (1983) in support of this view, as well as Kremer (1998) for an opposing view.

[2] See Farrell et al (2007) and Schmalensee (2009)

[3] See Farrell et al (2007), Layne-Farrar (2007) et al, Lemley(2007), Lemley and Shapiro (2007), Schmalensee (2009) and Swanson and Baumol (2005)

coordination necessary to build an integrated technology. In particular we observe that cooperative investment to gather information, sharing and disclosure of planning information, and commitments to develop and to adopt complementary technologies can not be arranged in markets for know-how.

In section 3 we propose technology platforms as an alternative to markets for know-how. Technology platforms provide an organizational structure for planning, development and adoption of technology by intermediate and end use consumers which is a privately financed and governed by the platform members. The platform members share private information, make private investments in technology development and transfer technologies to each other under liability rules, that are supported and governed by the platform. We demonstrate the platform, in contrast to markets for know-how, provides a centralized network that selects the composition and order in which innovations are developed and shared. As a result platform development is more efficient; the difficult contracting issues manifested in patent ambush and hold up are avoided and end use consumers are able to control and adapt the technology to their needs by delegating decisions to independent developers.

The platform supports a process of sequential development and exchange leading to a final technology that is quite complicated and impossible to predict ex-ante. This suggests a possible rationale for why the development or procurement of a complicated technology consisting of several components parts is sometimes better done on a platform that throws all of the potential developers and consumers of the technology together to coordinate and share their information and innovations with each other.[4] The conventional wisdom that complicated projects are better staged in an open auction environment where substitute technologies compete for adoption, presumes that auctions will attract the "right "amount of competition, that the information required for efficient development will be generated and shared among the competing developers, and that the preferred technology configuration of the end user is known. Our findings suggest this is unlikely to be the case, and as a result

[4]This conclusion holds when there are orgainization and information leakage costs that result from an open auction format. Otherwise in the absence of these costs, auctions and market exchanges are typically preferred to sequential bilateral exchanges, even when the objects are complicated multiattribute products, for the reason that auctions promote more competition. See Asker and Cantillion (2010), Bulow and Klemperer (2006, 2009), and Che and Lewis (2007).

platforms for technology is a better alternative.

Section 4 concludes with a discussion of how platforms for technology may coexist along side of markets for know-how, the limitation of platform development and the transition from IPR to liability rules as a process for governing transfer of knowledge.

2 Model of Technology Development

To illustrate the issues of technology development in markets for know-how versus platforms, we consider the following simple model patterned after O'Donahue et al (1998) and Hopenhayn et al (2006).[5] There is a single good to be developed which is defined by the cumulative technology that it embodies. We assume that there is a sequence of independent developers $d_0, d_1, .., d_S$, who contribute incremental improvements to the technology. At any development stage s, the cumulative technology $\bar{\Delta}_s \equiv \Delta_0 + \Delta_1 + \Delta_2 ... + \Delta_s$, is the sum of the incremental innovations discovered, Δ_i for $i = 0, 1, 2, ...s$. Typically, it will be useful to regard d_0 as the developer of the basic technology and d_i, for $i = 1, ..., S$ as the follow-on innovator who embellish the basic technology with his improvement. For many applications d_S is the final developer who represents end-use consumers of the technology.[6]

The consumption value of the good is measured by its quality. The value (or quality) of technology $\bar{\Delta}_s$ is given by the a function $q\left(\bar{\Delta}_s\right)$ which is increasing in $\bar{\Delta}_s$ but is not necessarily concave. The cumulative technology is assembled so that separate innovations are complements or imperfect substitutes for each other. This assumption may reflect that there are increasing returns from innovation, or simply that the technology provides positive network externalities.[7] The *value* of the technology is imperfectly observed by the public and therefore not verifiable, meaning it is not possible to write contracts on its value. However,

[5] See Reinganum (1982, 1985)) for some of the first analysis of innovation and industry evolution in conventional markets for knowhow. A recent analyses of the effects of different RAND provisions on technology development under varying assumptions about the market for knowhow are Layne-Farrar et al (2007) and Schmalensee (2009).

[6] The assumption that there are a finite number of developers who make sequential improvements to the technology, while unnecessary, does simplify the exposition and helps to fix ideas.

[7] While we focus on complementary technologies here, most of our analysis and results pertain as well as to innovations that are substitues are substitutes for each other.

developers and consumers who contribute to the technology do know the value of $q\left(\bar{\Delta}_s\right)$.[8]

We model technology discovery as a sampling process.

ASSUMPTION 1 *Developers draw an innovation Δ_i at cost I_i from a stationary distribution $F_i\left(\Delta_i \mid I_i\right)$, with support in $\left[0, \hat{\Delta}\right]$. The greater the amount invested I_i the more draws are produced, the larger the innovation is on average. The distribution $F_i\left(\Delta_i \mid I_i\right)$ shifts to the right with greater I_i.*[9]

2.1 Markets for Know-how without RAND

Imagine there is a technology independently developed by d_0 and d_1. The value of the cumulative technology $\bar{\Delta}_1 = \left(\Delta_0 + \Delta_1\right)$, illustrated in Figure 1a and 1b, is

$$q\left(\bar{\Delta}_1\right) = \begin{cases} \left(\Delta_0 + \Delta_1\right)^2 & \text{for } \Delta_0, \Delta_1 > 0 \\ \\ 0 & \text{if } \Delta_1 = 0 \end{cases}$$

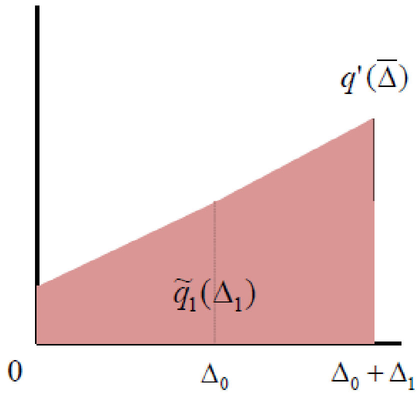
Product quality is strictly positive if both innovations are packaged together; otherwise the stand alone value of the technology without Δ_1 is zero. The idea is that the innovations are designed to be used together to produce a compatible technology.

Initially d_0 develops the basic technology Δ_0, expecting to eventually license it for a "reasonable" fee to a follow-on innovator who will complete the package. d_1 arrives later on and discloses his add-on innovation Δ_1. d_0 offers to license Δ_1 for a fee of $\tilde{q}\left(\Delta_0\right) = \lim_{\bar{\Delta}_1 \rightarrow \Delta_0} q\left(\bar{\Delta}_1\right)$, represented in Figure 1 by the area under the marginal quality curve labeled $q'\left(\bar{\Delta}\right)$, from 0 to Δ_0. He argues the offer is more than fair, it represents the *minimum* incremental value of Δ_0 to the package technology consisting of $\Delta_0 + \Delta_1$. d_1 counters: without his innovation Δ_1, the package technology has no value; therefore he offers to license Δ_0 for its stand alone value, zero. With that offer d_1 receives the entire surplus denoted by $\tilde{q}\left(\Delta_1\right)$ equal to $q\left(\Delta_0 + \Delta_1\right)$ as depicted in Figure 1a.[10]

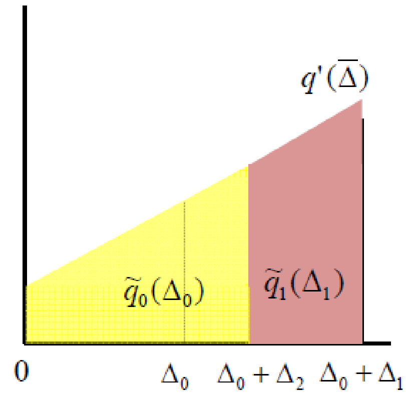
[8] For instance, consumers may know the *personal value* they attach to $q\left(\Delta_s\right)$. Suppliers may know their cost of producing an object with quallity $q\left(\Delta_s\right)$.

[9] The greater investment is, the more likely the technology exceeds a given value.

[10] Or alternatively, d_1 offers to license Δ_1 to d_0 at its incremental value $q\left(\Delta_0 + \Delta_1\right)$.



Surplus without RAND
Figure 1a



Surplus with RAND
Figure 1b

$d_1's$ take-or-leave-it offer may seem *unreasonable* or *unfair* as it extracts all of the development surplus. However, without more information, $d_1's$ offer is not necessarily illegal. Current law allows intellectual property right (IRP) holders to charge whatever the "market will bear." [11] So the offer may not only be legal, but it may be necessary for rewarding innovators when the value of invention can only be determined by the market.[12] The real concern over $d_1's$ take-or-leave-it offer is that it may eliminate $d_0's$ incentives to invest initially. And even though the scenario we've depicted is extreme in that d_1 has something to loose by refusing to bargain, and therefore would likely offer some strictly positive amount, there is no guarantee that the surplus d_0 retains from the transfer of his innovation will be sufficient to induce him to invest efficiently.[13]

2.2 Markets for Know-how with RAND

Responding to recent episodes of patent ambush, antitrust authorities have pushed standard setting organizations, to institute "reasonable and non discriminatory" $RAND$ licensing.

[11] More correctly, IRP holders can charge prices that don't extend beyond their exclusive rights to transfer their intellectual property. See Kovenkamp, Janis and Lemley (2006)

[12] See Weyl and Tirole (2012)

[13] Schwartz and Lewis (2016) argue that the inability of the banks to recoup their investments in loan quality led to a surge in subprime securities thus contributing to the collapse of the MBS market in 2008.

The meaning of *RAND* and its implementation is unclear, but the preferred recommendation appears to be the Efficient Component Pricing Rule, *ECPR*, put forward by Swanson and Baumol (2006). *ECPR* stipulates that innovators receive royalties equal to the marginal contribution of their invention to product value.

A possible difficulty with implementing *ECPR* is measuring the marginal contribution. However if two or more follow-on innovations compete for the license, the market can determine marginal contribution. With two follow-on developers available, say d_1 and d_2 , d_0 can hold an auction to license his innovation to the highest bidder. Assuming the auction is second-price, and $\Delta_1 > \Delta_2$, developer d_0 ends up receiving the surplus provided by the best substitute for the add-on innovation Δ_1. [14] The benefit from having competition in the follow on market is to allow d_0 to collect greater royalties for licensing its technology. Without a competing follow-on developer, d_0 would receive surplus of zero, as indicated in Figure 1a, whereas with competition, d_0 obtains a surplus of $\tilde{q}\left(\Delta_0\right) = q\left(\Delta_0 + \Delta_2\right)$ as indicated in Figure 1b.

Though helpful, *ECPR* is not a cure for all that plagues technology development in markets for know-how. The best case for *ECPR* presumes there is a market for add-ons with two or more developers. But the more competitive the add-on market is, the less add-on's will enter. There are no guarantees of sufficient competition in downstream markets to implement *ECPR*. Providing the right amount of competition is what markets are designed to do, not the reverse. Without follow-on competition, *ECPR* must be administered formulaically with ex-ante agreements to license. But without markets the value of the technology is difficult to know, because information is diffused among independent developers. A preferable licensing scheme would make it incentive compatible for informed parties to set royalties at the true value of the innovation. Such a process is possible when innovation is performed on a technology platform, as Section 3 demonstrates

[14]In theory, assuming there is no collustion, the type of auction that is held, first or second price sealed bid, doesn't matter by the Revenue Equivalence Theorem. Note in the second price auction each follow-on $i = 1, 2$ bids his value for the license $q\left(\Delta_0 + \Delta_i\right)$; the developer bidding the highest wins and pays the losing developer's bid. Hence d_0 ends up with a royalty equal to $q\left(\Delta_0 + \Delta_2\right)$.

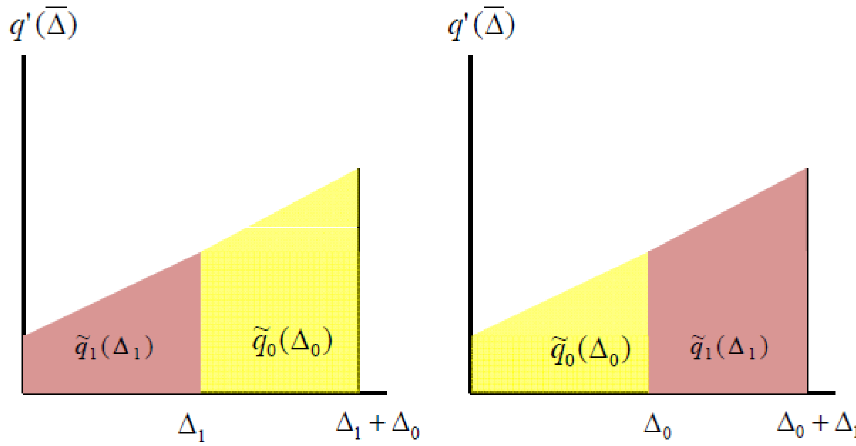


Figure 2a **Figure 2b**

2.3 Coordination Issues in Markets for Know-how

It is apparent that the order in which innovation occurs and the technology is assembled matters for efficient planning and for determining royalties. These issues are not directly addressed in the call for *RAND* licensing in general or in the recommendation for *ECPR* in particular. To illustrate the importance of staging for developers, notice in Figures 2a and 2b how the order in which innovations occur affects the developers' claims to royalties based on their marginal contributions. Assuming royalties are negotiated sequentially with the arrival of new innovation, the developer who innovates last has a greater claim on the marginal surplus created. If there is some latitude regarding the introduction of different stage technology, and if the development of the add-on technology precedes the development of the basic technology, the basic technology developer may command greater royalties than if the order of development was reversed. When developers can affect their royalties by timing innovation, there may strategic delay when innovations are strategic complements and strategic preemption when innovations are strategic substitutes.[15]

[15] Krasteva and Yildirim (2012) describe a similar phenomenia in sequential bargaining between a buyer and two sellers of complementary goods.

The previous observation also suggests that the order in which innovations are adopted to form a standard technology may be important from an efficiency standpoint. Since the value of developing a new innovation, depends on the technology that has previously been developed, the order in which technologies are developed should be a choice variable, if possible. For instance, if the value of creating an innovation Δ_o depends on the extent a preceding innovation Δ_1 has been developed, it is efficient to develop the innovations in sequence, to learn the value of one innovation, before developing the next one.[16] Which innovation should be developed first will depend on what the value of learning is with different sequences of innovation.[17]

To illustrate consider two developers d_o and d_1 who differ in their ability to predict the outcome of their investment. For an investment of $I_o = 1$ developer d_o draws innovation $\Delta_o \in \{0, 1\}$ with equal probability, $\frac{1}{2}$. At a cost of $I_1 = 2\Delta_1$ developer d_1 can select his innovation $\Delta_1 \in \{0, 1\}$ with certainty. The value of the cumulative technology for $\Delta_o, \Delta_1 > 0$ is $q(\Delta_o, \Delta_1) = (\Delta_0 + \Delta_1)^3$. This example is summarized below in Table 1.

Developer d_o :	$I_o =$	1	$\Delta_o \in \{0, 1\}$	*prob* $(1/2, 1/2)$
Developer d_1 :	$I_1 =$	$2\Delta_1$	$\Delta_1 \in \{0, 1\}$	*prob* (1)
Surplus of $V_{o,1}$	$=$	2		
Surplus of $V_{1,o}$	$=$	1		

Table 1

Development d_0/d_1: When d_o first invests $I_0 = 1$ and discovers $\Delta_o = 1$, d_1 follows by investing $I_1 = 2$,discovers $\Delta_1 = 1$, resulting in net surplus of $\mathbb{V}_{o,1}(1, 1) = (1 + 1)^3 - 1 - 2 =$

[16] However, if developers are anxious to bring their product to market, they may develop simultaneously without waiting to observe each other's investment.

[17] Similar timing issues arise when searching for the best alternative or a problem solution as in Weitzman (1979).

5. Otherwise if d_o first invests $I_0 = 1$ and discovers $\Delta_o = 0$, then d_1 follows by investing $I_1 = 0$, discovers $\Delta_1 = 0$, resulting in net surplus of $\mathbb{V}_{o,1}(0,1) = -1$. The expected surplus for this sequence of development is,

$$\mathbb{V}_{1,0} = \mathbb{E}q(\Delta_o, \Delta_1) - I_o - I_1(\Delta_o) = 2$$

<u>**Development** d_1/d_0</u>: Otherwise if d_1 moves first, invests $I_1 = 2$,discovers $\Delta_1 = 1$, then d_o may invest $I_o = 1$ and discover $\Delta_o = 1$ with probability 1/2, resulting in net surplus of $\mathbb{V}_{1,o}(1,1) = (1+1)^3 \ -1-2 \ = 5$. Alternatively she may discover $\Delta_o = 0$ with probability 1/2 resulting in net surplus of $\mathbb{V}_{1,o}(1,0) = -2$. The expected surplus of this development sequence is,

$$\mathbb{V}_{1,0} = \mathbb{E}q(\Delta_o, \Delta_1) - I_o(\Delta_1) - I_1 = 1$$

Both developers have the same expected return on investment of $\frac{1}{2}$, however, d_1' investment return is certain whereas d_o' return is variable. Our calculations show d_1 should observe d_o' s investment outcome to complement her effort with more investment if warranted. This example illustrates it is necessary to coordinate investment in complementary technologies. To invest efficiently, d_0 must know who are the add-on innovators and how valuable her technology will be to their development. Because markets for exchange can not provide this information, inventors rely on coordinated private development and capital networks to manage the development efficiently.[18]

3 Platform Development of Technology

Our discussion above reveals several reasons why markets for know-how are ill suited for developing platform technologies. As an alternative, we consider sequential development of the technology on a private commercial platform that provides the goods and services that end-users consume.[19] To illustrate how the platform would work, assume that is a finite

[18](ph) See Spulber and Choo (2003)

[19]For examples of network and platform development see Evans, Hagiu and Schmalensee (2005), Weyl(2010) and ,Spulber and Yoo (2003)

number of innovations to be discovered, $j = 0, ..., s$. To facilitate coordinated and collaborative development, the platform acts as a social planner by gathering together developers d_j of all of the innovations that are embodied by the technology. Under the platform's direction, each developer d_j acquires the previously developed technology; invests to improve that technology; transfers the augmented technology to the follow-on developer d_{j+1}, and so on.

To ensure the technology developed is of value requires end-use consumers to adapt the technology to their preferred use. Working backwards from the last stage s, d_s is the end use consumer of the technology. She derives surplus value denoted by $\mathbb{V}_s\left(\bar{\Delta}_s\right)$ from technology $\bar{\Delta}_s$. Assume the preceding developer d_{s-1} begins with technology $\bar{\Delta}_{s-1}$. The continuation value with acquired technology $\mathbb{V}_s\left(\bar{\Delta}_{s-1}\right)$[20] under the guidance of the platform is defined by,

$$\begin{aligned}\mathbb{V}_{s-1}\left(\bar{\Delta}_{s-1}\right) &: = \max_{I_{s-1}} \mathbb{E}q\left(\bar{\Delta}_{s-1} + \Delta_{s-1}\right) - I_{s-1} \\ &= \mathbb{E}\mathbb{V}_s\left(\bar{\Delta}_s\right) - I^*_{s-1}\left(\bar{\Delta}_{s-1}\right)\end{aligned}$$

The platform directs developer d_{S-1} to make a private investment I_{S-1} to complete the technology. $\mathbb{V}_s\left(\bar{\Delta}_{s-1}\right)$ is a derived value equal to consumers' value, net of the investment cost. While agents outside of the platform cannot observe this value, platform members developing and adapting the technology can.

Moving back to stage $s-2$, developer $d_{S-\ 2}$ is directed to acquire technology $\bar{\Delta}_{s-2}$ to prepare it for the next stage of development. Employing the argument above, we see the derived value of the acquired technology $\bar{\Delta}_{s-2}$ is defined by,

$$\mathbb{V}_{s-2}\left(\bar{\Delta}_{s-2}\right) := \mathbb{E}\mathbb{V}_{s-1}\left(\bar{\Delta}_{s-1}\right) - I^*_{s-2}\left(\bar{\Delta}_{s-2}\right)$$

Investment $I^*_{s-2}\left(\bar{\Delta}_{s-2}\right)$ is the efficient investment for d_{s-2} to develop the acquired technology $\bar{\Delta}_{s-2}$.

Extending the foregoing argument by backward induction, we are able to establish,[21] ,

[20] $\mathbb{V}_s\left(\bar{\Delta}_{s-1}\right)$ is referred to as the continuation value in dynamic programming.

[21] See Stokey and Lucas (1989 Recursive Methods in Economic Dynamics)

PROPOSITION 1: *Given ASSUMPTION 1 there exists a surplus maximizing technology development for stages $j = 0, ..., s$ defined recursively by,*

$$\mathbb{V}_{s-j}\left(\bar{\Delta}_{s-j}\right) = \mathbb{E}\mathbb{V}_{s-(j+1)}\left(\bar{\Delta}_{s-(j+1)}\right) - I_{s-j}\left(\bar{\Delta}_{s-j}\right)$$

Proposition 1 shows the ease with which the technology is developed with a sequence of innovations that build off each other. The process is deceivingly simple, because of the appearance of an omniscient, all powerful and well intentioned planner who directs the independent developers to invest efficiently. The developers are obedient and therefore the efficient technology is created.

3.1 Implementation

For the platform to implement the process requires that successive innovators transfer their technology to the follow on developer at a price that induces efficient, mutually beneficial investment in development. It also requires that the innovator completely disclose all of the intellectual property associated with her innovation. This allows the follow-on developer to invest in complementary innovations to maximize the value of the technology.[22] Under the conditions of the transfer, the platform ensures that the acquiring developer is buying the exclusive right to own and develop the technology, for eventual transfer to the next developer or consumer in line.[23] The technology has been designed for use by end use consumers on platform. As a result the value of the technology for use outside the platform is difficult to verify because the investments and the values of the innovations are specific to the platform technology that is produced, which is known and observed by the member of the platforms, but not by outsiders. Consequently the platform can develop the technology more efficiently than if it were developed in decentralized markets for know-how.

We now demonstrate that the efficient development process characterized in Proposition 1 may be implemented in a relatively decentralized means by the platform that specifies

[22] (ph) See Agrawal and Henderson (1992) for a discussion of the effects of partial disclosure of intellectural property on technology transfer.

[23] In general applications, the innovator may retain some control rights to her property, when it is not practical for her to transfer all of the knowhow to a succeeding developer.

a sequence of technology transfer prices $\left\{L_j\left(\bar{\Delta}_j\right)\right\}_{j=0}^{s}$. Whenever developer d_{j-1} transfers technology $\bar{\Delta}_j$ to developer $d_{j.}$ she is paid a transfer price $L_j\left(\bar{\Delta}_j\right)$ by developer d_j. Next developer $d_{j.}$ invests in innovation that grows the technology from $\bar{\Delta}_j$ to $\bar{\Delta}_{j+1}$. At this point d_j transfers $\bar{\Delta}'_{j+1}$, that is no greater than $\bar{\Delta}_{j+1}$ to d_{j+1} at price $L_{j+1}\left(\bar{\Delta}'_{j+1}\right)$.(The option of holding back some of the technology for private use, is common in technology transfer, though it is inefficient to do so.)[24] Developer d_{j+1} repeats the investment process to growing the technology to $\bar{\Delta}_{j+2}$ which he delivers to d_{j+2} at price $L_{j+2}\left(\bar{\Delta}_{j+2}\right)$, and so on.

The expected profit each developer earns with platform transfer prices is,

$$\Pi_j\left(I_j,\Delta'_j\right) = \max_{\left\langle I_j,\Delta'_j\right\rangle} \mathbb{E}L_{j+1}\left(\bar{\Delta}_j + \Delta'_j\left(\Delta_j\right)\right) - I_j\left(\bar{\Delta}_j, L_{j+1}\right) - L_j\left(\bar{\Delta}_j\right)$$

Prices $\left\{L_j\left(\bar{\Delta}_j\right)\right\}_{j=0}^{s}$ are said to implement the efficient technology development provided ,

$$\begin{array}{llll} (A) & I_j\left(\bar{\Delta}_j, L_{j+1}\right) & = \left\langle I_j^*\left(\bar{\Delta}_j\right)\right\rangle & \text{efficient investment} \\ & \Delta'_j\left(\Delta_j\right) & = \Delta_j & \text{complete disclosure} \\ & & & \\ (B) & \Pi_j\left(I_j^*,\Delta_j\right) & \geq 0 & \text{voluntary participation} \end{array}$$

Condition A requires the developers to select the efficient investment and to disclose their entire innovation. This is needed for efficient development. However this is difficult to impose because the developers' choice of investment and the amount of her innovation she discloses is not publicly observed, by the platform. Condition (B) is a necessary and sufficient condition for developers to participate without coercion.

In this section we consider the case where there is a single developer for each stage j. The network transactions are self financed and the transfers between successive developers must be balanced.

PROPOSITION 2 *Let* $\left\{L\left(\bar{\Delta}_j\right)\right\}_{j=1}^{s}$ *be the transfer prices that govern technology development. Then* $L\left(\bar{\Delta}_j\right) = V\left(\bar{\Delta}_j\right)$ *for all* j *implements the efficient development with full disclosure* .

Proposition describes a process whereby the platform provides for surplus maximizing sequential development of cumulative technology. To accomplish this the platform must induce

[24] (ph)See Agrawal and Henderson (1992).

efficient investment and transfer of innovation across a sequence of independent developers and users of the technologies. The key to their success is solving the measurement problem and determining the value of new innovation. This is crucial to compensating innovators for their effort and for directing new technology to its highest valued use. Only developers and users of the technology can assess its value. Processes that rely on third party verification or the market test to establish value are likely to fail, for the reasons mentioned above in Section 2. However, a platform consisting of the developers, intermediate and end users of the technology can collectively determine the value of innovation by measuring the marginal increase in user surplus the innovation provides. Once the value is determined, the efficient investment in and transfer of innovation requires that innovations be licensed at a price equal to its marginal value.[25] The platform implements this licensing procedure with a provision, similar to a liability rule, that permits follow-on developers and consumers use the innovation provided they pay innovators the marginal value as measured by the increased surplus it yields.[26]

4 Extensions

The preceding analysis lays out the advantages of platform development of technology. As is well known platforms are organized to exploit positive network externalities and minimize the impact of negative ones. In the case of technology the platform coordinates investment activity, facilitates the sharing of information and know-how and funds innovation with a non distortionary tax on users through liability rules. The platform accomplishes this by delegating these activities to its membership which, ideally consists of all the developers, intermediate and end- users consumers of the technology. The more inclusive the membership is, the greater are the network externalities and the more surplus the technology generates.

Whereas the strength of platform development lies in its all-inclusive membership, therein lies its weakness as well. As a practical matter it is not always possible to cover all of the patented innovations making up the ideal technology under one platform. This is particularly

[25] See Chakravarty and MacLeod (2009) and Lewis and Schwartz (2012) for similar analysis, applied to the design of complete contracts.

[26] The transfer price implementation is similar to liability rules as in Calabresi and Melamed (1972)

true given the proliferations of innovations that qualify for patent protection, many of which are dubious, yet may be useful in completing a cumulative technology.

It's inevitable that the platform membership will exclude some contributors, This raise several interesting questions. What should be the response of the platform whose membership is missing a potential contributor? Does the platform subsidize the developer's membership to increase its representation, wait to see what the developer discloses before responding, or plan around the developer to complete its technology from existing members? The last option of excluding a potential developer who is not known at the time the platform forms, may have the beneficial effect of forcing innovators to disclose their intentions to contribute from the outset, instead of ambushing the platform with a patent claim later on. Speculating further, could a two tiered system of rights, those that are privately granted and governed by private platforms and those that are granted by the US Patent Office eventually materialize ? And, if this were to occur, would the platform be required to license all or part its technology to other outside developers or perhaps to a competing platform?

Finally, this raises the question, of whether consumers are better served by a few large proprietary platforms that offer differentiated technologies, or by a market for know-how that governs the development and diffusion of technology. The advantage of the former is that it enables planning and development of technology to be done more efficiently by a discrete number of joint ventures between developers, intermediate and end user consumers. The disadvantage would be the exclusion of some interest groups from the process; though this shouldn't be cause for concern to the extent platforms are designed around and motivated by consumer interests. The alternative, markets for know-how, attempts to provide access to innovation on equal terms. This may be good for competition, but it is bad for efficiency. The development of network technology requires a coordinated and collaborative investment process that organizations, not markets, can provide.

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6 Appendix

PROPOSITION 2 *Let* $\left\{L\left(\bar{\Delta}_j\right)\right\}_{j=1}^{s}$ *be the transfer prices that govern technology development. Then* $L\left(\bar{\Delta}_j\right) = V\left(\bar{\Delta}_j\right) + k$ *for all* j *implements the efficient development with full disclosure*

Proof of Proposition 2

Let $\left\{L_j\left(\bar{\Delta}_j\right)\right\}_{j=1}^{s} = \left\{\mathbb{V}_j\left(\bar{\Delta}_j\right)\right\}_{j=1}^{s}$ for all j. Consequently

$$\begin{aligned}\Pi_j(\cdot) &= \mathbb{E}[\mathbb{V}_j\left(\bar{\Delta}_{j-i} + \Delta_j'\left(\Delta_j\right)\right)] - I_{j-1}\left(\bar{\Delta}_{j-1}, \mathbb{V}_j\left(\bar{\Delta}_j\right)\right) - [\mathbb{V}_j\left(\bar{\Delta}_{j-1}\right)] \\ &= \mathbb{E}[\mathbb{V}_j\left(\bar{\Delta}_{j-i} + \Delta_j\right) - I_{j-1}^{*}\left(\bar{\Delta}_{j-1}\right) - [\mathbb{V}_j\left(\bar{\Delta}_{j-1}\right)] \geq 0\end{aligned}$$

The second line follows from the first line after recognizing $I_{j-1} = I_{j-1}^{*}\left(\bar{\Delta}_{j-1}\right)$ and recalling that $\mathbb{V}_j$ is increasing in $\bar{\Delta}_j$. This proves that (A) and (B) are satisfied for $\left\{L_j\left(\bar{\Delta}_j\right)\right\}_{j=1}^{s} = \left\{\mathbb{V}_j\left(\bar{\Delta}_j\right)\right\}_{j=1}^{s}$.■