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Reflections on "Profiting from Innovation"

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Abstract

How innovators capture value from innovation is an enduring question. Two decades ago an effort was made in "Profiting from Innovation" to unlock this conundrum. This paper reflects on the framework offered, identifies and reviews the analytical foundations of the theory, and recognizes subsequent contributions and advancements. Linkages are also made to the strategic management literature on "resources" and "dynamic capabilities". Elements of a Schumpeterian theory of the firm are outlined, along with a framework to assist management in designing technology commercialization strategies.

Keywords: Appropriability; Complementary assets; Intangible assets; Standards; Technological innovation; Dynamic capabilities

1. Introduction

Twenty years after the publication of "Profiting from Innovation" (PFI) in this journal (Teece, 1986), the question asked therein continues to capture the interests of scholars and managers alike. The positive reception the paper has received[1] is no doubt in part because the

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[1] The paper has been extensively cited. In addition, it has been reprinted or translated in one form or another in many places. Reprints include: Freeman, C. (Ed.), The Economics of Industrial Innovation, 3rd ed. (Edward Elgar Publishing, U.K., 1997); Scott Shane (Ed.), The Foundations of Entrepreneurship (Edward Elgar Publishing, London, 2001); Richard N. Langlois, Tony Fu-Lai Yu, Paul L. Robertson (Eds.), Alternative Theories of the Firm (Cheltenham, Edward Elgar, UK, 2001); Burgelman, R., Madique, M., Wheelwright, S. (Eds.), Strategic Management of Technology and Innovation (McGraw-Hill, 1995, 1998, 2001); Essays in Technology Management and Policy: Selected Papers of David J. Teece (World Scientific, 2003). Intellectual Property in Business Organizations: Cases and Materials (Mathew Bender & Company, 2006); Arcangeli, F., David, P.A., Dosi, G. (Eds.), Modern Patterns in Introducing and Adopting Innovations (Oxford University Press, Oxford, 1989); Rhodes, E., Wield, D. (Eds.), Implementing New Technologies: Innovation and the Management of Technology (Basil Blackwell, Oxford/Cambridge, MA, 1994), 129–140; Michael L. Tushman, Philip Anderson, Managing Strategic Innovation and Change (Oxford University Press, New York/Oxford, 1997), 287–306; Strategy, Technology and Public Policy: The Selected Papers of David J. Teece, vol. II (Edward Elgar, Cheltenham, UK/Northampton, MA, 1998); Abstracted in The Journal of Product Innovation Management, 5:1 (March 1988). Slightly revised versions of the paper can be found in "Capturing Value from Technological Innovation: Integration, Strategic Partnering, and Licensing Decisions," Interfaces, 18:3 (May/June 1988), 46–61; Bruce R. Guile, Brooks, H. (Eds.), Technology and Global Industry (National Academy Press, Washington, DC, 1987), 65–95; Strategies for Capturing Value from Technological Innovation," Thai-American Business (May–June 1990), 30–38; "Capturing Value from Innovation," Les Nouvelles, 26:1 (March 1991), 21–26; "Capturing and Retaining Value from Innovation," Technology Strategies (August 1991), 8–10; Strategies for Capturing the Financial Benefits from Technological Innovation" in Technology and the Wealth of Nations. In: Rosenberg, N., Landau, R., David Mowery (Eds.) (Stanford University Press, 1992); Firm Boundaries, Technological Innovation, and Strategic Management. In: Thomas, L.G. (Ed.), Economics of Strategic Planning (Lexington Books, Lexington, MA, 1986), 187–199. Capturing Value Through Corporate Technology Strategies. In: John de la Mothe, Louis M. DuCharme (Eds.), Science, Technology and Free Trade (Pinter Publishing, London/NY, 1990), 69–84; Translations include: Ricerche Economiche, 4 (October/December 1986), 607–643; "Innovazione Technologica e Successo Imprenditoriale," L'Industria, 7:4 (October/December 1986), 605–643; Translated

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questions posed are seminal. Another reason may be because it joined the analysis of innovation and the field of business strategy, providing a parsimonious framework for explicating known conundrums about innovation, market entry timing, and subsequent marketplace success and failure. At a more abstract level, the article outlined key elements of a Schumpeterian theory of the business enterprise and innovation. In this paper, an effort is made to identify and evaluate the conceptual foundations of PFI, to suggest refinements and extensions, while making connections to subsequent developments in the literature on strategy and innovation.

2. A post-Schumpeterian theory of the firm

2.1. Determinants of the rate of direction of technological advance

Economists had long theorized about the factors that drive technological innovation. The central focus, at least since Schumpeter (1950), has been rather narrowly on the role of market structure and firm size as determinants of enterprise innovation. As Sidney Winter points out in his contribution to this special issue, Schumpeter highlighted the contradiction between perfectly competitive market structures and innovation. He saw perfect competition as incompatible with innovation because perfect competition does not provide the innovator with a sufficient watershed to appropriate enough of the returns from innovation to justify investment in R&D. At least in Capitalism, Socialism, and Democracy (1950), Schumpeter saw the large enterprise with large market shares as the solution to the appropriability problem, as a significant market presence would facilitate capture of the returns from innovation. However, other than quite general references to the ability of large organizations to finance innovation, absorb risk, and earn monopoly profits, Schumpeter did not give the particulars about what it is about larger enterprises that might assist with appropriability. Nor did he explore the mechanisms by which incumbency might serve as a disadvantage to innovative activity.

Subsequent theoretical work in the Schumpeterian tradition fixated on market structure as a proxy for market power, as if that was all that mattered. A whole panoply of empirical studies followed as industrial organization scholars focused on exploring the relationship between market structure and innovation.[2] Unfortunately, few of these studies broke out of the Schumpeterian mold and looked much beyond market structure and firm size as drivers of innovation. Not surprisingly, these studies were inconclusive. Mansfield (1968) summarized them adequately almost a half a century ago; and the evidence today is not substantially different:

> "Contrary to the allegations of Galbraith, Schumpeter, and others, there is little evidence that industrial giants are needed in all or even most industries to ensure rapid technological change and rapid utilization of new techniques. Moreover, there is no statistically significant relationship between the extent of concentration in an industry and the industry's rate of technological change . . ."

The PFI framework represented a strong break with the received industrial organization tradition. PFI hypothesized that appropriability, and success at innovation more generally, is related not so much to the innovator's exante market share, but to the (complementary) asset structure of the innovator, management's market entry timing decisions, and the contractual structures employed to access missing complementary assets. Choices with respect to the latter should depend on the asset positioning of other market participants, and on the intellectual property protection available. The PFI framework enveloped a far wider panoply of factors than had hitherto been addressed in the economic analysis of innovation.

While occasionally cited favorably by industrial organization theorists, the PFI framework has not been universally embraced by industrial organizational scholars. One reason may be that it is implicitly hostile to received theory. However, with respect to antitrust policy, the Department of Justice, Federal Trade Commission Guidelines on joint ventures makes use of some of the ideas in PFI, especially the idea of complementary assets[3]; but there is not a cite to PFI.

In any event, in developing the PFI framework, I was conscious of the extensive but moribund literature in industrial organization surrounding the innovation-

into Japanese: The Competitive Challenge: Strategies for Industrial Innovation Renewal, Chapter 9. In: David J. Teece (Ed.), Japanese Translation rights arranged with Harper & Row New York through Tuttle-Mori Agency Inc., Tokyo, 1987. Translated into Russian and published in Vestnik Leningradskogo Universiteta, 1991. Seria Economics, 4, 38–47.

[2] For a concise review, see Scherer and Ross (1990), p. 630–637.

[3] The document refers to "complementary factors", but it is clear that the concept is identical to what in PFI is defined as complementary assets. See United States Department of Justice and the Federal Trade Commission, Guidelines on Joint Ventures, 1995, p. 5.

market structure nexus.[4] It was clear that mainstream industrial organization was intellectually conservative and would not likely embrace a framework that eschewed market structure as the principal determinant of enterprise level innovative performance. Accordingly, I chose to direct the article to innovation studies and strategy scholars. As Sidney Winter points out, the market structure–conduct–performance paradigm from industrial organization economics has not turned out to be analytically all that helpful in the study of innovation. The promise of the PFI framework, based as it is on contracting and strategizing, is that it has more to offer to both strategists and economic theorists alike.

2.2. Foundations

PFI endeavors to explicate how managerial choices, the nature of knowledge, intellectual property protection, and the asset structure of the firm impact the business enterprise's ability to capture value from innovation. It is both a predictive and a normative theory of strategy, with testable hypotheses. It not only provides a contingency theory with respect to a key element of strategy – such as whether to license or not to license – but it also predicts how the profits from innovation are likely to be distributed as between customer, innovator, imitator, suppliers and the owner's of complementary assets. It might be thought of as a nascent neo Schumpeterian theory of the firm. The success of the article is in part due to the fact that it was built upon and around what are now recognized as important conceptual building blocks in our understanding of innovation processes and competitive strategy. I briefly identify these below.

2.2.1. Dominant design, entry, timing, and learning

Abernathy and Utterback (1978) were amongst the first to hypothesize that the nature of competition amongst technologies alters with the emergence of a "dominant design". This was an important insight. Over the past two decades, considerable additional evidence has been assembled supporting the emergence of dominant designs [e.g. Klepper and Graddy (1990), Utterback and Suarez (1993) and Utterback (1994)]. There is also considerable research focusing on why certain product designs became dominant. David (1985) and Arthur (1989) rely on dynamic increasing returns as a key explanatory variable. Under such conditions, those that get ahead tend to stay ahead. The more a technology is employed, the greater its attraction relative to the alternatives. This phenomenon can be fueled by the cumulative nature of technical advance, by learning (both producer and consumer), and by network externalities. When the basis of competition shifts (from product to process) with the emergence of a dominant design there are clear managerial implications. The PFI framework recognizes that pioneers frequently fail in the marketplace, particularly (but not only) when they lack intellectual property protection. First mover advantages and path dependencies are very important to the Arthur and David contributions.

PFI offered new insights with respect to market entry timing. One clear implication is that there is no one right answer, such as it is always good to be the first mover. Timing depends on what assets you have got (Mitchell, 1989). The framework identified several classes of contingency factors including the innovators ready and cost effective access to complementary assets, and the point at which the dominant design emerges. Both classes of factors should impact entry-timing decisions.

The discussion in PFI of timing with respect to the emergence of a dominant design also has embedded within it recognition of the importance of learning and experimentation. As noted in Teece (1986) "at some point in time, and after considerable trial and error in the marketplace, one design or a narrow class of designs begins to emerge as the more promising. Such a design must be able to meet a whole set of user needs in a relatively complete fashion" (p. 288). In this way, the framework recognized the importance of experimentation and learning, although this was not a theme developed in any depth. In some cases the innovator is able to improve upon its own initial market entry, e.g. Xerox's initial model A Xerographic printer was messy, hard-to-use, and slow. It was not a serious challenge to carbon paper; but the Xerox model 914 introduced 10 years later transformed the business office and "secretarial" work. Sometimes learning is serendipitous—the Pfizer drug Sildenfil was first tested in humans in 1991 for effectiveness for angina. Male patients reported erections as a side effect, and Pfizer initiated a program to test the compound for erectile dysfunction, culminating in 1998 in the successful launch of Viagra, which has subsequently become a blockbuster drug. This of course does not mean we should venerate failure for itself; but it is important to recognize that having a bias for action and willingness to risk failure are important components of learning. The VCR example cited in PFI where Ampex was the first into the market (but failed to sustain the multiple rounds of product improvement necessary to bring the product down to the price points and the physical size required to

[4] In Chapter 2 of Teece (2000), I explain some of the limitations of the market structure-innovation framework.

break open a mass market) demonstrates the importance of management having the vision, and the enterprise having the financial and organizational resources, to "stay in the game" until the dominant design emerges.

2.2.2. Appropriability regime

Until the publication of "Profiting from Innovation", there were only very limited efforts in the strategy literature to study notions of imitability, and to explicitly consider how intellectual property and the nature of knowledge impacts appropriability and technology commercialization strategies. This has now changed. A key insight in PFI was that imitability is a function of both legal impediments (patents, copyrights, trade secrets, trade marks) and the inherent replicability of the technology,[5] which depends in part on whether the know-how is tacit or codified. The "appropriability regime" has become a recognized concept in strategy, and PFI was where it was first introduced into the field. PFI was also where tacit knowledge itself first entered the management/strategy literature,[6] with Nonaka and colleagues at Hitotsubashi University and elsewhere subsequently extending and leveraging the concept of tacit knowledge to explain knowledge creation and knowledge management.

Another feature of PFI is that it underscores, and helps explain, how an innovator's intellectual property protection ought impact strategic decisions. The PFI framework also makes it abundantly clear that the enterprise's intellectual property portfolio cannot be managed independent of its business strategy, and that business strategy formulation requires an appreciation of intellectual property issues. However, in PFI, there was limited development of intellectual property strategy itself.[7] Importantly, intellectual property protection is represented as just one amongst many barriers to imitation. The nature of knowledge (especially the degree to which it is tacit) and its inherent replicability is another. Although PFI highlighted the role of dominant designs, it did not fully develop the role of standards, and standard setting bodies, on the innovation process. Nor did it explore the interaction between standards and intellectual property protection. In particular, a useful technology can sometimes take on additional value if it becomes formally or informally selected as a standard. I have explored some of these issues in subsequent research (Sherry and Teece, 2003).

2.2.3. Complementary assets and cospecialization

Perhaps the most important contribution of PFI is that it defined and developed a taxonomy around complementary assets and technologies: specialized, cospecialized, and generic. The extant literature in economics and strategy at the time made no mention of complementary assets. Economic historians had recognized the importance of complementarities, but their analysis was rather loose. As discussed earlier, Schumpeter (1950) had a visceral sense that there was something about the large enterprise that helped it appropriate returns from innovation, but his explanation was limited to market level monopoly power issues. The PFI framework zeroed in on the asset structure of the firm itself, and specialized complementary assets in particular. Market "power" analysis was done at the asset rather than the market level, and centered on availability of alternatives and/or ease of replicability. This in turn is likely to depend on whether the "asset" is generic (in which it is likely to be available in competitive supply) or specialized.

Clearly, control of an asset does not imply control of a market, unless the asset somehow defines a "relevant market".[8] If the asset is specialized, it is more likely to be difficult to replicate. This will affect the distribution of returns from innovation. The services it provides is likely to face competition, which will hold down the economic returns on the assets. Owners of such assets cannot expect any special benefit from innovation, even when innovation increases demand for the services of the complementary assets. This more granular supply side approach to assessing competition is what sets the PFI framework apart from the Schumpeterian framework. Clearly, incumbency is viewed in a dramatically different manner in PFI than in Schumpeter, and in the economics literature more generally. The complementary assets notion has also found applicability in applied frameworks (Sullivan, 2000; Harrison and Sullivan, 2006).

The evidence with respect to the importance of complementary assets to innovation outcomes has evolved beyond PFI. Helfat (1997) found that firms with more complementary assets in the form of coal reserves undertook greater amounts of R&D in synthetic fuels derived from coal. In generic pharmaceuticals, Scott Morton

[5] The discussion of legal impediments was static, when in fact intellectual property protection is dynamic. Patents, for instance, can undergo a life cycle (Sherry and Teece, 2004).

[6] More general applications were found in Nelson and Winter (1982) and Teece (1981).

[7] This topic was advanced further in Grindley and Teece (1997) and Teece (2000).

[8] I am using "relevant market" in the antitrust sense. For a discussion of relevant markets, see Hartman et al. (1993).

(1999) found that the proclivity to enter new markets was greater where there was similarity in manufacturing, distribution, and marketing. Tripsas (2001) observed that when computer technology began to take on a key role in typesetting, the new entrants were often established computer companies. Helfat and Raubitschek's (2000) analysis of the Japanese electronics industry showed that business firms repeatedly built on their pre-entry core technology and complementary assets to introduce new products in new subfields.

In Teece et al. (1997) and in Teece (2006b) the role that complementary assets play in shaping evolutionary paths, and potentially fueling anti-cannibalization biases, has also been developed. Put differently, complementary assets do not just play a role in appropriability; they also potentially shape going forward enterprise strategy, sometimes positively (in terms of returns to innovation) and sometimes negatively.

The distinctions made between specialized and generic complementary assets have also been built on and extended by others, included Chatterjee and Wernerfelt (1991) and Helfat and Lieberman (2002). The latter correctly note that there is a continuum between resources that are specialized to a particular setting and generalized resources that can be applied more broadly in many environmental settings. They also make a useful distinction (their Table 4) between core and complementary resources, which fits snuggly within PFI.

The contracting/strategy framework advanced in PFI builds on transactions cost economics (TCE). However, it also embraces imitability/replicability issues. Such analysis is also the essential domain of the resource-based theory of the firm, which is explored in Section 5.

There have been other attempts to develop strategy frameworks which highlight complements. A decade after PFI, Brandenberg and Nalebuff (1996) published Co-opetition. Their framework emphasized the importance of complements in competitive analysis. They discussed the universality of the principle, although most of their examples were demand side (e.g. computer hardware and software as complements). They highlight the strategic exposure firms have when they are missing certain complementary assets (p. 14), and rightfully stress that "thinking complements is a different way of thinking about business" (p. 14). However, they do not use the taxonomy found in PFI, with its distinction between specific and generic complementary assets (see Fig. 1). Nor do they employ a contracting framework. Hence, they cannot address make versus buy decision very well. As a result, their treatment does not help explain the distribution of returns to innovation.

It should also be recognized that the distribution of returns from innovation depends, interalia, on the innovator's relative positioning in specialized complementary assets Fig. 11 in Teece (1986). This figure is reproduced more elegantly here as Fig. 2.

Furthermore, as discussed in Section 5, the development of contracting/strategizing concepts around complementary assets has embedded within it the core component of an economic theory of management, which I have subsequently outlined in Teece (2006a,b). The essence of the idea is that a core economic function of managers in the economy is to create value by figuring out and organizing asset combinations that yield economies of scale and scope as well as appropriability benefits. When complementary assets are idiosyncratic and cannot be obtained through marketplace transactions, some form of internal organization is required instead. I harbor the belief that this is a fundamental post Chandlerian concept.[9]

Developing a theory of management based on PFI is central to my going forward research program. In economic theory, managers are banished from the economic system. There is simply no role for them to play in making markets work or organizing economic activity. PFI is one small step in the direction of a Schumpeterian theory of management and the firm. In PFI, managers/executives play a critical asset orchestration role inside the firm. The flow diagram (Fig. 10) in PFI outlines the strategic choices that managers are advised to make.[10] Then of course they must execute on the strategy, and do so proficiently.

2.2.4. *The market for know-how*

Embedded in the PFI framework is also a recognition that intellectual property rights lubricate the market for know-how. The contracting framework recognizes that strong intellectual property rights facilitate (licensing) transactions in the market for know-how; and that absent intellectual property rights, the market for know-how will be less efficient. This is of course a very "Coasian" notion.[11] Other scholars including Arora et al. (2001) have taken these ideas beyond where they were left in PFI. The existence of fabless semi-conductor companies is testament to the fact that exclusive reliance on intellectual property licensing can be a viable business model, although the travails that Rambus has encountered recently in securing its intellectual property, and

[9] See Chandler (1990) and my review (Teece, 1993).
[10] Fig. 3 in this paper is derived from Fig. 10 in PFI.
[11] See Coase (1937).

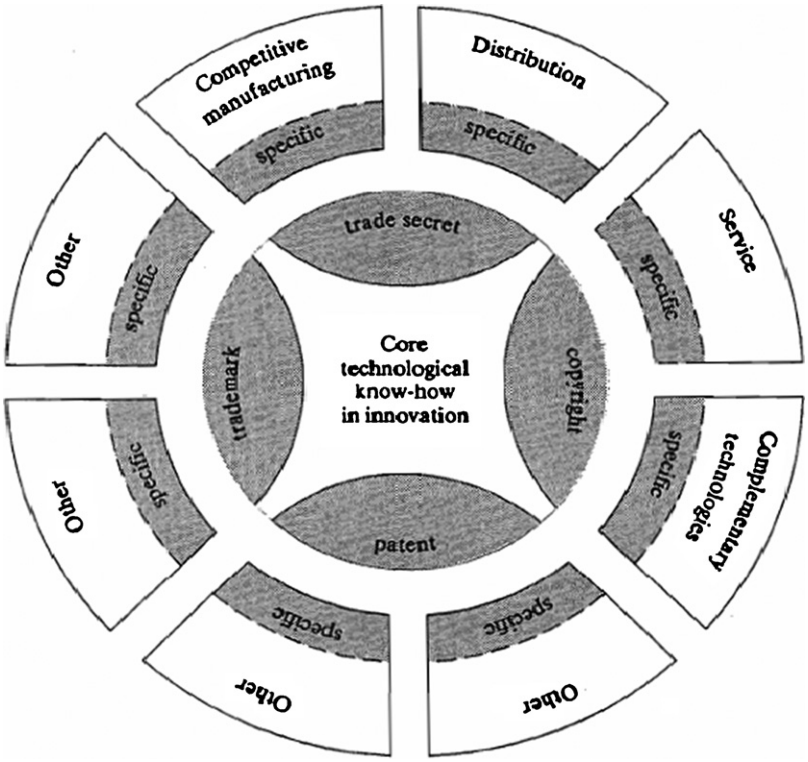

Fig. 1. Representative complementary assets needed to commercialize an innovation-shaded area represents the less imitable portion of the value chain. Outer segments represent complementary assets; inner circle segments represent know-how (Fig. 7.1 in Teece (1992b). This is adapted from Fig. 5 in Teece (1986)).

getting infringers to pay royalties, speaks to the risks of relying exclusively on contractual (licensing) modes.

3. Analytical design

3.1. Problem selection

One important feature of PFI was that it framed an important strategic question, and it did so in a way that was tractable. A good research question is one that, if answered, yields important insights and is refutable (i.e. in the Popperian sense, it is at least conceivably falsifiable). The research question in PFI was not framed as "understanding the foundations of innovative success". Such a question would be too broad, and the answer would require a three-volume treatise. The PFI framework was less ambitious. Its purpose was to understand the factors that impact success at commercialisation, i.e. not success at invention itself, not success in terms of who was first-to-market, and not success in terms of understanding the long run profitability of the enterprise. Rather, PFI focused more narrowly on success in terms of which entities ultimately capture significant shares of the available profits from a particular innovation. This was, and remains, one of the most important enterprise level questions one could ask. Yet no one had asked it before, and ironically, no one has asked it since (in the sense that no one has tried to displace the PFI framework).

By posing the question in terms of understanding success at commercialization, one critical observation and several important questions were explicitly and/or implicitly posed. The question drew attention to a phenomenon, which was well understood in industry and in policy circles, but had not been addressed fully by academics. This question was this: why is it that innovators (i.e. firms that succeed in bringing innovative products and processes to market) commonly fail to capture value from their investments. In the prior literature it was well recognized that inventors might be denied commercial rewards if their invention lacked commercial utility. However, that was not the same as explaining why it is that even when an inventor actually gets the product into the market, the inventor may still fail to reap rewards.

Complicating matters is the fact that innovation is not a well-defined homogenous activity with a start date and an end date. Most innovations evolve through some kind

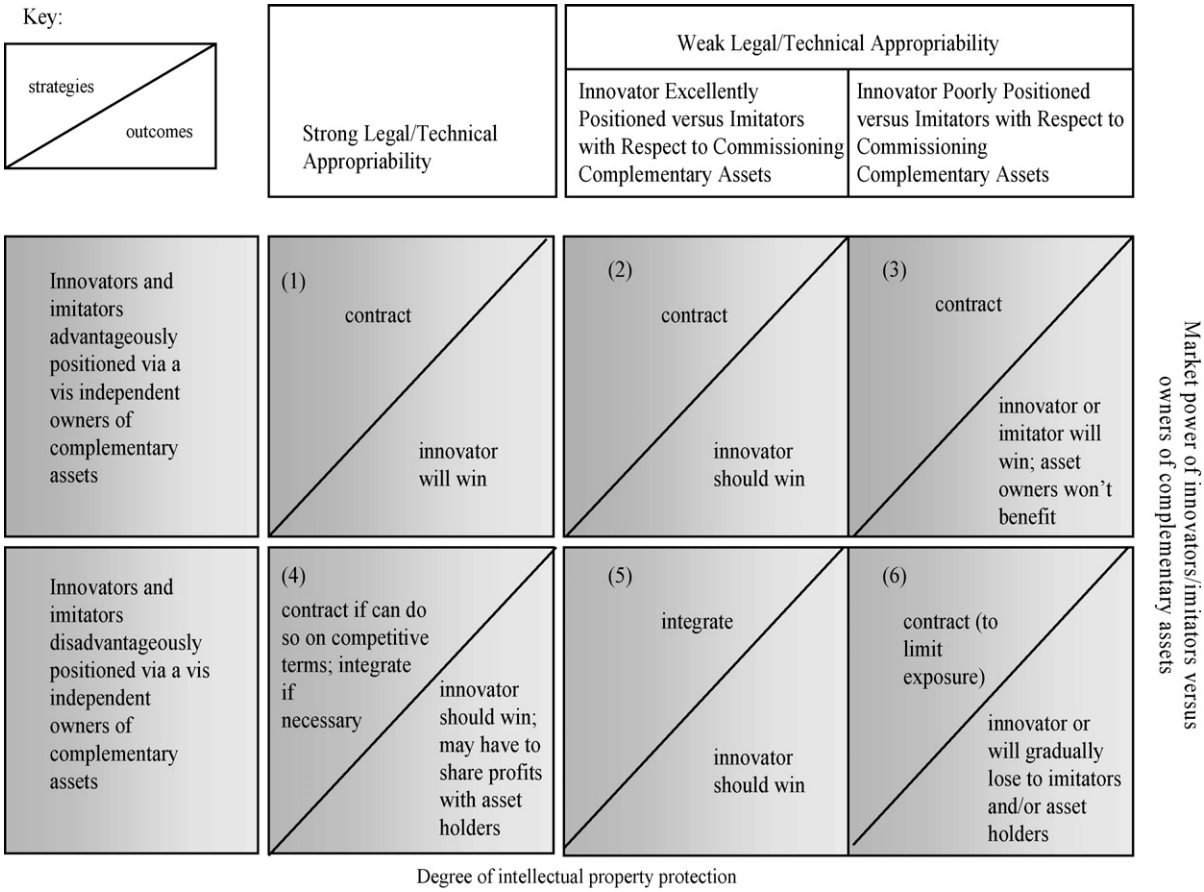

Fig. 2. Contract and integration strategies and outcomes for innovators: specialized asset case (Fig. 11 in Teece (1986)).

of cycle, with subsequent improvements often vastly more important than the initial innovation. Innovators and "imitators" often build on each other. The complexity associated with understanding innovation and the distribution of the "spillover" benefits from it is such that had the question been framed any broader, I doubt it would have been tractable.

3.2. The analytical separation between invention and commercialization

A key feature of the analytical design is that, as explained earlier, a separation between invention and commercialization was made in PFI. The separation is akin to March's (1991) distinction between exploration and exploitation; or the distinction between sensing and seizing which is embedded in Teece (2006b). As I note elsewhere (Teece, 1988, 1992a), in theory, one could imagine transactions between entities that scout out and/or develop opportunities, and those that endeavor to execute upon them. In reality, the two functions cannot be cleanly separated, and the activities must take place inside a single enterprise, where new insights about markets – particularly those that challenge the conventional wisdom – will likely encounter negative responses.

I am not entirely sure that Jim March is right in suggesting that firms cannot and should not specialize in either exploration or exploitation. The jury is still out. I note companies like Dolby and Rambus have decided to stay focused on invention, and simply license their technologies. However, the issue can be examined at multiple levels. Aside from strategic considerations, the question remains as to whether there is a useful analytical separation that can be made between invention and commercialization functions. I believe there is, and I believe the PFI framework demonstrates that utility.

3.3. A framework or a theory?

A framework, like a model, abstracts from realty. It endeavors to identify classes of variables, and their

interrelationships. A framework is less rigorous than a model as it is sometimes agnostic about the particular form of theoretical relationships which may exist. PFI is more than a framework. It is a falsifiable theory about innovation and it predicts outcomes in the marketplace (PFI, Fig. 11[12]). It not only indicates rules with respect to elements of the desired strategy; it predicts whether the innovator or the imitator will get the lion's share of the rents, depending on the appropriability regime, market timing, and the ownership of complementary assets.

Although important empirical work has been done (and was cited earlier), exploring the importance of complementary assets and capabilities, testing the PFI theory has not as yet been comprehensively accomplished. Such a test might be facilitated by data sets of the following kind: For the dependant variable: (i) a sample of inventions showing the identity of the entity that commercialized the invention; (ii) at least a rank ordering of the market share and/or profit earned in the marketplace over the life of the innovation (and possibly subsequent followons as a measure of the share of profits captured). Independent variables might include: (i) data on the positioning of innovators/imitators with respect to access to complementary assets. This would require an assessment not just of ownership, but whether the complementary asset is a "bottleneck" or a "choke point" in the value chain; (ii) assessment of the appropriability regime (weak or strong might suffice, although more granular treatments are possible); (iii) entry timing: identifying whether it is before or after the dominant design has emerged, and whether the new product is consistent with the dominant design.

3.4. PFI as a strategy paper

"Strategy is the deliberate search for a plan of action that will develop a business's competitive advantage and compound it. For any company, the search is an iterative process that begins with a recognition of where you are and what you have now—the differences between you and your competitors are the basis of your advantage" (Henderson, 1991, p. 5). Under this definition, put forward by one of the fields practicing founding fathers, PFI is unquestionably a "strategy" paper. It frames important strategic decisions and explicitly takes into account the business environment, adding new elements such as the appropriability regime, and the technology cycle. It also explicitly takes into account differential positioning, recognizing each firm's command of the technology, ownership of intellectual property rights, and its positioning in complementary assets. Indeed, the paper arguably belonged in the Strategic Management Journal, but I really did not know much about the field of strategy in those days.[13]

Perhaps another reason for the articles popularity is that it is avowedly normative and focuses on strategic decisions. A derivative version of the flow chart (Fig. 10) on PFI is reproduced here (for the case of weak appropriability) from Teece (1992b) as Fig. 3. Indeed, as Gary Pisano notes in this special issue, one of the contributions of PFI is that it brought the innovation studies literature into the field of strategy, and vice versa. In Chapter 5 of Teece (2000), the article was rewritten and put more explicitly in managerial language. It was "repurposed" as "Market Entry Strategies for Innovators".

4. Refinements to PFI

While I am pleased that PFI has had a positive reception, there are many ways in which the paper could be refined, extended and improved. I discuss some of these below:

4.1. Complementary innovations

As discussed earlier, PFI was one of the first (if not the first) strategy papers to highlight the role of complementary assets. Nevertheless, the development and analysis of complementarities was limited. As I noted, "In almost all cases, the successful commercialization of innovation requires that the know-how in question be utilized in conjunction with other capabilities or assets" (Teece, 1986, p. 288). Complementary technologies were treated as just another complementary asset.

At the time of publication, the importance that complementary technologies play in the innovation process was not recognized in the contemporary strategy literature. However, they were recognized by the business and technology historians. Historians argued that if one critical piece of technology was absent, or not sufficiently well developed, the rest of the product (or system) would fail. In short, technology can be a bottleneck asset (or as Hughes (1983) calls it, a "reverse salient"). For

[12] Reproduced here as Fig. 2.

[13] The late Keith Pavitt, coeditor of Research Policy at the time, solicited the paper after the Venice conference in March 1986. I was very pleased to have it published where it might catch the attention of those most interested in innovation.

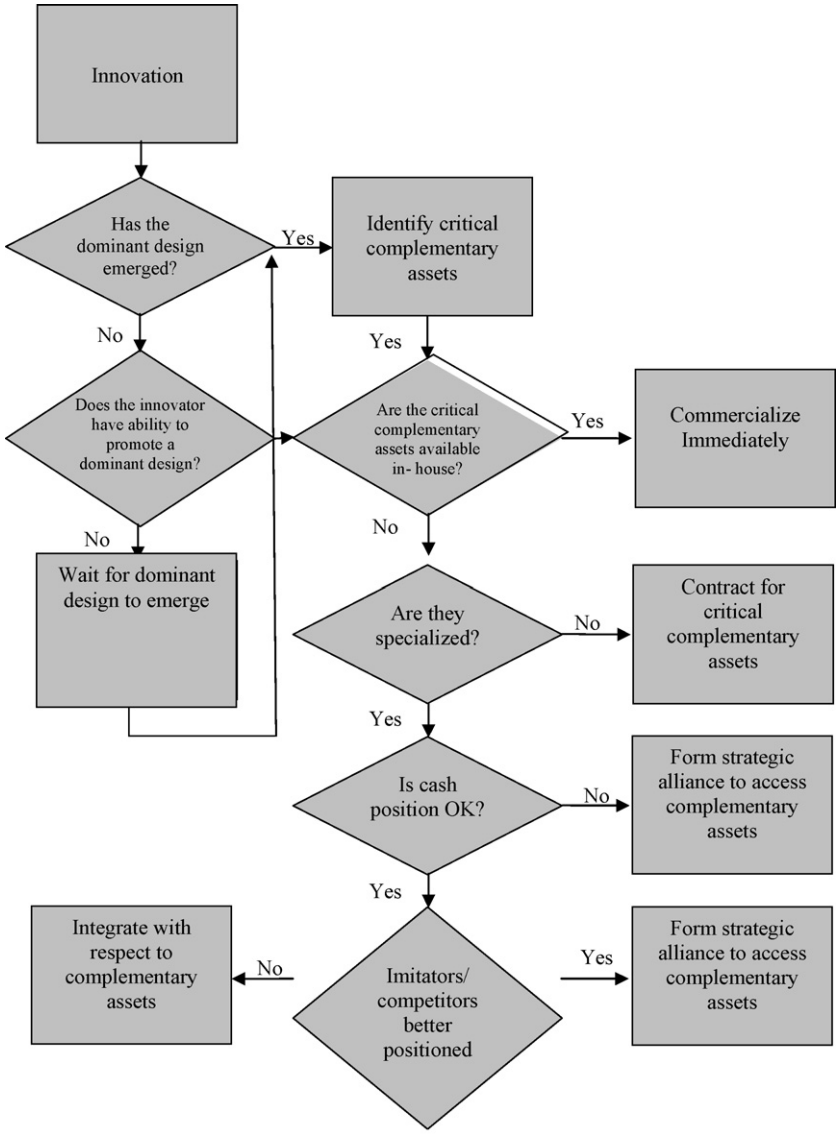

Fig. 3. Market entry strategies: case of weak appropriability regime (Fig. 7.2 in Teece (1992b)).

instance, electric cars require better batteries to compete with internal combustion engine powered automobiles. Digital photography could take off only once low cost flash memory became available, along with controller technology.

Many technologies today are systemic. Successful commercialization requires bringing together complementary technology as well as complementary patents. This is what I referred to elsewhere as the "multi-invention" context (see Somaya and Teece, 2006). Of course, many innovations require complementary infrastructure investments (for the automobile, roads and service stations; for electricity, long-life light bulbs plus generators, transmission lines, and standards). However, the focus of PFI was much more on enterprise level value chains.

4.2. Supporting infrastructure

Fig. 3 in PFI (refined and reproduced here as Fig. 1) displays core know-how at the center, and then a circle of complementary assets and technologies needed to commercialize the innovation. These complementary assets and technologies are implicitly thought of as belonging to private sector firms located somewhere in the marketplace.

An obvious extension of this framework would be to create a second concentric circle enveloping the first. The second circle would recognize supporting institutions. Social technologies often constrain physical technology, and the commercialization of innovation itself. The ecosystem that is relevant clearly includes not just owners of complementary assets but also regulators, educational institutions, standard setting bodies, and the courts.

New institutions and new laws and the provision of complementary assets may all be necessary before certain innovations can be deployed. For instance, Bell Laboratories pioneering work on cellular telephony could not go anywhere until the Federal Government allocated electromagnetic spectrum to carry wireless signals. Collective action by public authorities is frequently required to bring new technologies into existence. Neutral or competence enhancing innovations is often easier for the enterprise to embrace as they do not confront accepted ways of doing things. Veblen (1915) was one of the first to articulate that maintaining national competitiveness requires the nation state to put in place institutions that support new technologies. PFI did not pay much attention to these considerations. The role of institutions has been highlighted by writers like North (1990) and Nelson (2005).

A full discussion of supporting institutions and National Systems of Innovation could of course easily involve book length treatment. PFI deliberately avoided going down this path, because within a nation state institutions do not necessarily tip the scales in favor of one or another market participant, except inasmuch as particular firms, either through individual or collective action, can help shape institutions and standard setting decisions. In the global context, it is of course different.

4.3. Capabilities

PFI preceded the emergence in the strategy field of the "capabilities" literature. Notwithstanding that, PFI did utilize capabilities thinking, at least in a cursory way. The notion the complementary assets might represent capabilities, and that if the firm did not have them, it would need to build them, and if it did not have time to build them, it might need to buy them was central to the paper. In short, a decision tree was created in which it was implicitly recognized that capabilities were at least partially path dependent, and that at least in the very short run, the firm is stuck with what its got. Evolutionary thinking is obviously not far below the surface. These issues are explored in more detail in Section 5.

4.4. Role of finance

In terms of supporting institutions, PFI (deliberately) failed to explore this issue, except inasmuch as the decision framework recognized that the innovator's cash position should be considered in assessing whether to rent, build, or buy complementary assets. This cavalier treatment is of course very much at odds with classical treatments. There is a long tradition going back to Schumpeter and beyond which emphasizes the importance of access to risk capital, whether from internal or external sources. In PFI, the implicit assumption was made that risk capital was available from a company's own balance sheet, the venture capital community, alliance partners, or commercial banks. Indeed, the existence today of well developed venture and private equity markets, public equity markets, and debt markets is a reasonable justification for abstracting from financial issues. It is not an egregious abstraction.

4.5. Decision framework

Part of the simplicity and possibly the elegance of PFI is that it does not confront the organizational, bureaucratic, or human side of business decision-making. Its written in the rational choice mode. In this sense, the paper is not pretending to be descriptive with respect to decision-making processes in organizations. There is a large literature on over-optimism in project evaluation (Merrow et al., 1981). The PFI framework does not endeavor to prescribe rules, protocols, or procedures to neutralize such errors. For instance, imposing an "outside view" (Kahneman and Lovallo, 1993) is likely to assist in generating less biased decisions. These issues were neglected in PFI.

4.6. "Supply" chain issues

PFI had a very simple decision rule: if in doubt, outsource. Put differently, decision rules were loaded to favor outsourcing and collaboration, unless there were a compelling reasons to internalize. Such reasons could be grounded in one of two major circumstances: (a) cospecialization, which would lead to transaction costs if heavy reliance was made externally; (b) shoring up the appropriability situation by building or buying complementary assets which the innovation would likely drive up in value, or that were otherwise important to getting the job done. Here the decision rules rest on both (i) capability considerations and (ii) availability considerations, and (iii) change in asset price considerations. In essence, (iii) reflects real options type reasoning.

Hirshleifer (1971) was perhaps the first to argue that ownership of (complementing) assets – but not necessarily cospecialized assets – could enhance the innovator's returns. However, Hirshleifer had a very narrow view of the role of complements. He saw innovation as impacting asset values, and profiting from innovation PFI was about how to take long positions in assets likely to appreciate because of an innovation. Taking short positions in assets likely to decline is certainly consistent with PFI. Hirshleifer's perspective is a rather Kirznerian view of innovation, and dramatically underplays the functional role of complementarities, focusing instead merely on fluctuations in asset values.

Notwithstanding this, PFI was prescient in indicating that the supply chain and complementary assets/technologies should be thought of as choice variables in terms of enterprise level integration decisions. It also implied that those decisions should be made on transaction costs as well as capability and asset pricing criterion. Indeed, it is appropriate to characterize the PFI framework as being richer than transaction cost economics (Williamson, 1985), as it embraces asset pricing and disequilibrium notions along with contractual and transaction cost issues.

4.7. Standards, increasing returns, and network effects

In PFI, it was recognized that the emergence of a "dominant design" in an industry would lead to a "regime switch" or an "inflexion point". As designs stabilized, the terms of competition would change from features to price. The importance of investing so as to support the dominant design flowed from the need to capture customers early, and to achieve economies of scale. The first mover advantage, if there was one, would not even begin until the marketplace and/or some standard setting body anointed a particular design as a standard. Of course, not all standards "take" in the market, even if a standard setting body agrees on a standard.

A relatively new literature, nascent at the time, outlined by Brian Arthur and his colleagues, and later augmented by my colleagues Katz and Shapiro (1994) emphasized network effects and increasing returns. But this literature was generally silent on issues of learning or appropriability.

One should recognize that the emergence of a dominant design, if it occurs, is never a crisp watershed. The old and the new often coexist, and the new keeps evolving because of user experience and feedback (Rosenberg, 1982). Sometimes the replaced technology actually gets a "second wind", at least for a while, as did sailing ships during the 19th century after the emergence of steam (Giliffan, 1935). Usually the older technologies become relegated to particular niches.

Moreover, it is also important to recognize that any particular dominant design is not necessarily the "best". In the presence of network externalities, that which gets ahead, stays ahead and small "accidents" early in the choices of technology can lead to a dominant design that by some criteria is inferior. This is of course David's (1985) and Arthur's (1989) account of the path dependent evolution of technologies.

Furthermore, the presence of network effects means that early and sizable investment is necessary to try and get a standard (or dominant design) accepted in the market. Consumers do not want to be saddled with an installed base that affords limited network benefits. This does not change the story entirely in PFI, but it does suggest that the stakes are even higher than was perhaps signaled. Standard sponsoring is a risky activity, but can yield significant returns if the standard catches. Competition to "own" the standard (or the dominant design) becomes, in some ways, competition for the market.

4.8. The (multi-invention) licensing option

PFI utilizes a very simple view of technology licensing, because the analytical framework utilized assumes, for simplicity, a single innovation. The licensing story advanced in PFI is as a result a rather simple one. However, in many industries today, particularly those where systematic innovation if of importance, like microelectronics and biotechnology, multiple inventions (or items of know-how and intellectual property) are very common. The implications of this are significant in that PFI requires access to, and possibly control/ownership of complementary technologies, as discussed in PFI and as elaborated in Section 2.2.3.

Another characteristic, not mentioned in PFI, is that the dominant mode of licensing, especially amongst incumbent firms, is cross licensing, with or without balancing payments (Grindley and Teece, 1997). Another implication is that firms with valuable patent protected technology in regimes of cumulative innovation may eschew own production in order to strengthen their hand in licensing and cross licensing negotiations. For instance, Qualcomm exited the production of cellular telephone handsets embodying its Code Division Multiple Access (CDMA) to strengthen its hand at licensing, as it would no longer need to cross license if it was not engaged in production of a "system" (handsets) that would undoubtedly infringe on potential licensees'

intellectual property. Likewise, Texas Instruments decided to exit the manufacture of DRAMS in part to strengthen its leverage with potential licensees during cross license negotiations.[14] In short, the dynamics of licensing negotiations are such that there is sometimes an "inverse complementary" – or (private) diseconomies – associated with both licensing and own production. That is, mixed modes with both licensing competitors and own production are sometimes incompatible – as the Texas Instruments and Qualcomm examples illustrate.

4.9. PFI and the new emphasis on intangibles and knowledge management

Over the last two decades – and certainly since the publication of PFI – there has been a vigorous movement to stress the value and role of intangibles in business strategy and money management. Proponents of this movement, with which I am generally very sympathetic, stress that "intangible asset investing is the fundamental business trend for the 1990s" and beyond (Parr, 1991, p. vii). PFI obviously has one leg in this camp; indeed, the essence of PFI is to stress the value that can arise from innovation—particularly when that innovation is protected by strong intellectual property rights and where the innovator owns the relevant complementary assets. Indeed, the framework highlights how know-how, and difficult to replicate assets more generally, enable enterprises to generate rents. It also stresses the importance of knowledge integration and knowledge conversion, which is the subject matter of Nonaka and Toyama's important contributions.[15]

However, unlike the sometimes over enthusiastic endorsements of intangibles as a source of "hidden value", the PFI framework makes it apparent that it is by no means uncommon that intangibles create zero value for those who have invested in their creation. Indeed, absent the innovating enterprise being able to both design and execute on strategies along the lines of those outlined in PFI, there should not be any presumption that investment in intangibles will pay off. Indeed, it is suggested that PFI is a proper framework for evaluating intangibles. Absent consideration of complementary assets, it is hard to see how advice with respect to the management of intangible assets can be expertly created.

4.10. Other elements of the business model

Perhaps the biggest weakness in PFI was the narrow and somewhat mechanical manner in which "business model" issues were delineated. The product/services architecture, and the business model, defines the manner by which the enterprise delivers value to customers, entices customers to pay for value, and converts those payments to profit. It is the innovator's hypothesis about what customers want and how an enterprise can go about meeting those needs, getting paid well for doing so, and hopefully avoiding losing out to imitators. It explains: (1) which technologies and features are to be embedded in the product and service; (2) how the revenue and cost structure of a business is to be "designed" and if necessary "redesigned" to meet customer needs; (3) the way in which technologies are to be assembled; (4) the identity of market segments to be targeted; (5) the mechanisms and manner by which value is to be captured. The function of a business model is to "articulate" the value proposition, select the appropriate technologies and features, identify targeted market segments, define the structure of the value chain, and estimate the cost structure and profit potential (Chesbrough and Rosenbloom, 2002, pp. 533–534). In short, a business model is a plan for the organizational and financial "architecture" of a business, which makes valid assumptions about the behavior of revenues and costs, and likely customer and competitor behavior. It outlines the contours of the solution required to make money. Once adopted it defines the way the enterprise "goes to market". Success requires that business models be astutely crafted. Otherwise, inventions would not result in commercial success.

Generally there are a number of business models that can be employed, but some will be better than others. Selecting, adjusting and/or improving the model are likely to be critical to commercial success. It involves distilling insights to customers, suppliers, competitors, and the marketplace in general. Nevertheless, the importance of "business models" has been given short shrift in the innovation literature. Important (business model) choices involve technologies, market segments to be targeted, sales versus leasing arrangements for customer access to the product, bundled v. unbundled sales, joint ventures v. go-it-alone strategies, etc. For example, in the early days of the copier industry, Xerox focused on leasing rather than selling copiers. This stemmed from a belief that customer trial would lead to further use. Another example from the U.S. is Southwest Airlines

[14] In theory, the size of a royalty base should be an equalizing factor in the sense that if a licensor like Qualcom had relatively limited production using other companies intellectual property, this should not detract significantly from its ability to extract value from its technology. However, the ability to threaten mutual injunctions may well tend to lead to "mutually assured destruction", and removal of this symmetry can increase the bargaining power of licensor.

[15] See Nonaka and Toyama (2004).

who believe that most customers want low frills, reliability, and low cost. Southwest eschews the hub-and-spoke model, does not belong to any alliances, and does not allow interlining of passengers and baggage. Nor does it sell tickets through travel agencies—all sales are direct. All aircraft are Boeing 737s. Its business model is quite distinct from the major carriers, although many have tried (without much success) to copy elements of it.

The capacity an enterprise has to create, adjust, hone and replace business models is important to success.[16] Choices around how to capture value all help determine the architecture or design of a business. Having a differentiated (and hard to imitate) yet effective and efficient "strategic architecture" to an enterprise's business model is critical to success. Both Dell Computer and Wal-Mart have demonstrated the value associated with their business models (Webvan and many other dot com's demonstrated just the opposite). Both Dell and Wal-Mart's business models were different, superior, and hard for competitors to replicate. They have also constantly adjusted and improved their processes over time.[17]

PFI somewhat narrowly defined the business model decisions around complementary assets (make or buy) according to the appropriability regime and cospecialization and (static) capability considerations. As noted, there is much more to the choice of a business model including: (a) the choice of features for the product, including the form functions to be selected; (b) the customers to be targeted; (c) items to be bundled; (d) distribution channels to be selected and so forth. Clearly, PFI is too simplified to capture all of these elements of the business model. However, I have come to recognize that getting the business model right is important to the innovation process and to business performance more generally.

[16] Let us take a simple example. A rock star might decide to use concerts as the key revenue generator, or the concert may be used primarily to stimulate sales of recordings. The star could decide to spend less time performing at concerts, and more time in the recording studio. There is clearly a choice of various mediums to extract value: live productions, movies, sale of CDs through stores, on line sale of music through virtual stores such as the iTunes store offered by Apple Computer, etc. The emergence of the Internet, Napster, and Napster clones in turn requires artists (and recording studios) to rethink their business models. The ability to reconfigure business models for delivering and pricing music profitably is undoubtedly a dynamic capability for both the recording studios and the artists.

[17] Indeed, a critical element of Dell's success is not just the way it has organized the value chain, but also the products that it decides to sell through its distribution system. The initial products were PCs, but now include printers, digital projectors, and computer related electronics.

5. PFI and the resource based theory of the firm

The PFI framework in a cursory way outlined the importance of not just complementary assets but also "resources". Resources have been defined as stocks of available factors that are owned or controlled by the firm (Amit and Schoemaker, 1993, p. 35). My terminology around complementary assets recognized that some complementary assets are generic and some are specialized. Generic complementary assets – although not the key focus of PFI – may well be what Penrose (1959) referred to as "fungible" resources.

The resources approach recognizes how (1) difficult to imitate assets (including complementary assets) can be the basis of differentiation and hence competitive advantage and (2) enterprise assets can be classified as either fungible or generic. In Penrose's theory of the growth of the firm, certain assets are fungible and can be leveraged to support diversification. Her emphasis was on the accumulation of resources, not their strategic orchestration. PFI does, however, recognize how the competitive access to cash on the balance sheet and timing with respect to the accumulation of complementary assets can influence outcomes. In this sense, PFI can be seen as an early application of the resources based approach. Like the resources approach it is not particularly "dynamic".

The PFI framework, and its highlighting of complementary assets, goes to the very heart of the role of management in the innovation process, and in enterprise activity more generally. The framework makes clear that innovation creates new demands for certain assets. Tushman and Anderson (1986) use the language of "competency enhancing innovation" to signal the impact that innovation can have on asset values. PFI goes one step further. It differentiates between specialized assets, and generic assets available in competitive supply. Even if demand for an asset if increased, its value is unlikely to increase if it is available in competitive supply. Moreover, the Tushman and Anderson approach suggests that owners of complementary assets passively enjoy or suffer from the fallout from innovation. The PFI framework, in contrast, outlines the strategic considerations which managers must reference in order to capture value from innovation. It suggests that proactive strategies are more likely to increase the share of profits going to the innovator. The PFI framework in this regard also anticipates critical aspects of the dynamic capabilities framework—in particular, the notion that value can be created through the orchestration of cospecialized assets. Indeed, PFI was, I believe, the first piece of scholarship to advance what I now believe to be an important set of ideas in management

and the theory of the firm: the notion that economic profit, and hence enterprise value, is determined in substantial measure by the ability of management to build and/or buy and then combine cospecialized assets that yield scope economies and/or appropriability enhancement (Teece, 2006a). While PFI articulated the theory in the context of innovation, it is perhaps considerably more general and applies to any situation where value can be provided in unique ways—including modest product differentiation.

6. From PFI to dynamic capabilities

PFI isolates a set of strategic issues associated with commercializing technological innovation. It is innovation specific. It asks what set of decision rules and strategic choices (given technological trajectories and the state of play with respect to dominant design, appropriability conditions, and relative positioning with respect to complementary assets) will enhance the share of profits captured by the innovator. Of course, a completely symmetrical answer is given with respect to imitators. These are essentially static questions. The PFI framework does not seek to answer what factors are likely to lead to sustainable competitive advantage at the enterprise level.

The extended dynamic capabilities framework (2006b) has the ecosystem as the center piece of an analytical framework within which firms can assess opportunities. The language of (complementary) assets, tangible and intangible assets, and appropriability conditions all define elements of an enterprise ecosystem.

Porter's (1980) Five Forces framework by contrast invites one to consider where to position the company (taking industry structure as given) against competitive forces. The essence of the strategist's job, at least in the first instance, is to position the firm where competitive forces are weakest. Companies are also advised to take the offensive, and try to shape competition by building defenses (like brands).

Dynamic capabilities, like Five Forces, is merely a framework. Key differences are that dynamic capabilities recognizes a whole panoply of factors in the ecosystem which are absent from Porter's Five Forces. Moreover, the enterprise is specifically seen as engaging in search activities to identify and calibrate opportunities. There is of course no one right way to do this. Once sensed, opportunities must be seized.

The dynamic capabilities framework also recognizes the challenges associated with inventing business models, and the importance of making investments behind new technologies. In the dynamic capabilities framework, sustainable advantage comes from honing internal processes, structures, and procedures to generate and successfully commercialize innovations, be they technological or organizational. In Five Forces, sustained profitability comes from hiding behind entry barriers, or building them if they do not already exist. Market structure is an important factor in Five Forces. It matters little in dynamic capabilities.

In any event, PFI does not fit comfortably into Five Forces. The "positioning" that matters in PFI relate to complementary asset ownership and the appropriability regime. The strategic decisions that matter most are around the business model, and the timing of investments in relationship to the emergence of the dominant design and/or industry standards. Most of these issues cannot be comfortably embedded within the Five Forces Framework.

Yet PFI does not explain how to continuously build and maintain durable competitive advantage. It does not pretend to, except implicitly. An enterprise that can profit from innovation can of course afford to reinvest, not just in commercialization, but in further invention and discovery. The dynamic capabilities framework explores these issues at the enterprise level, not just at the level of the individual innovation as does PFI.

The dynamic capabilities framework recognizes three analytical separate functions, which must be performed at the enterprise level to sustain success: sensing, seizing, and reconfiguring. PFI is mainly about the second activity – seizing – and it provides decision rules for how entrepreneurs can act to seize the moment, so to speak. However, it is only by attending to the other elements of dynamic capabilities that management can hope to build sustainable advantage. Thus, one can think of PFI as framing strategic decisions just around commercializing innovation. PFI does not ask how firms develop new potentially marketable products and services, or how an enterprise "selects" opportunities for additional investment, or how it renews itself and both adapts to and shapes its environment so as to sustain its ability to deliver value to clients and earn its cost of capital. However, PFI does address one of the central issues in dynamic capabilities—namely, how to strategize around commercialization. It is also purports to predict outcomes.

PFI is part Penrosian, and part Schumpeterian. It is Penrosian in the sense that the distribution of profits from innovation is in part a function of the (complementary) assets/resources and the intellectual property assets (e.g. patents) that the innovating firm may possess. However, it is part Schumpeterian in that it advises management as

to which asset the firm should "nail down", or contract for access, or just build. There is an implied asset orchestration function, which is entrepreneurial in nature, whether it is performed by an entrepreneur, or by a manager of an established enterprise acting purposefully to redesign the value chain.

7. Public policy

PFI does explore certain public policy issues. In particular, it explores how international commercial policy, by closing off access to complementary assets, can limit the ability of innovators to garner profits from innovation. With respect to intellectual property, the framework highlights mechanisms by which innovators can strategize so as to reduce deficiencies in intellectual property protection.

PFI does not make a case for either stronger or weaker intellectual property protection. However, it does indicate how small firms without significant intellectual property and without complementary assets are challenged in garnering profits from innovation. Moreover, PFI is a robust framework for helping to explain why small firms and individual entrepreneurs are likely to be champions of strong intellectual property, while certain large firms may well be indifferent or possibly even opposed to intellectual property protection. This is in part because larger firms are likely to have a broader menu of alternative strategies for capturing value from their own and other's innovations.

To the extent that an efficient market for (trading) know-how is considered desirable, the PFI framework does suggest that intellectual property rights are likely to assist. However, for the system to be efficient, property right should have clear boundaries (Teece, 2000). Ambiguity only leads to disputes and high transaction costs that impede transactions in the market for know-how. In particular, efforts to reduce ambiguity and enhance clarity, particularly around patent boundaries, will likely stimulate transactions in the market for know-how and enable the viability of a richer array of organizational forms, such as fabless semiconductor technology developers.

There is also clear relevance for antitrust policy. Unfortunately, a critical cospecialized asset in PFI can be an "essential facility" in the hands of the plaintiffs (antitrust) bar—so essential that the regulator might compel public access. However, it is rarely the case that owning a cospecialized asset is likely to be synonymous with controlling a relevant antitrust market, so that mandating access is unlikely to be good public policy.

8. Conclusion

PFI remains a nascent framework for understanding outcomes from investment in innovation, and the role of strategy and organization in that process. It also offers key building blocks for a Schumpeterian theory of the firm. I do hope that in the next two decades those challenges are more fully accepted by scholars interested in the critical economic and business issues of our times.

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