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Benefiting from innovation: Value creation, value appropriation and the role of industry architectures

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Abstract

Extending Teece's landmark 1986 article, we consider how innovators benefit from value appropriation and creation. We elaborate on value appropriation, first by pointing out the importance of "industry architectures", i.e. sector-wide templates that circumscribe the division of labor; and second, by treating complementarity and factor mobility as distinctive components of co-specialization. This allows us to qualify Teece's prediction, by positing that firms can create an "architectural advantage" in terms of high levels of value appropriation without the need to engage in vertical integration. Such architectural advantage comes about when firms can enhance *both* complementarity *and* mobility in parts of the value chain where they are not active. We then elaborate on value creation by indicating how actors can benefit from investing in assets that appreciate because of innovation, which suggests that firms can benefit from encouraging imitation while investing in complementary assets. We also consider how investment in complementary assets changes the scope of the firm and thereby the development of capabilities that support future innovation. Finally, we provide an integrative guide that explains how firms should manage their position along the value chain to capture returns from innovation, thus extending and qualifying Teece's [Teece, D.J., 1986. Profiting from technological innovation: implications for integration, collaboration, licensing and public policy. Research Policy 15, 285–305] original predictions and prescriptions.
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1. Introduction

The last two decades have brought important changes that have made organizational boundaries more fluid and dynamic in response to the quickened pace of innovation and international competition (Chesbrough and Rosenbloom, 2002; Feenstra, 1998; Santos and Eisenhardt, 2005). These recent developments inspire a reconsideration of Teece's problem: who stands to gain from an innovation?

One of Teece's (1986) core contributions was to link the question of who can benefit from innovation to the contractual conditions surrounding the innovation (and innovator), as well as the nature of the relationships between the innovator and other, vertically related asset-holders. In this paper, we aspire to extend Teece's framework, by revisiting the unit and mode of analysis (shifting from dyadic relations to industry-wide architectures), by revisiting the construct of co-specialization, and by considering additional strategies to both create and appropriate value from innovation, e.g. through focusing on asset appreciation, and pursuing a strategy aimed at obtaining "architectural advantage". This allows us to generate a new set of predictions that might help navigate the

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increasingly complex and dynamic competitive landscape faced by firms in the age of international and global competition.

Our first contribution is to extend the Teecian purview (which focuses on the potential dyadic relationships between innovators and outside asset holders) by considering *industry architectures*, i.e. templates that emerge in a sector and circumscribe the division of labor among a set of co-specialized firms. We explain why these architectures emerge, usually early on in an industry's life, as a result of balancing advantages from division of labor with transaction costs relating to the certification of quality of the final good or service. We further explain why these architectures sometimes become stable, thus creating the contours of an industry. We then argue that firms may be able to affect the architecture of their sectors, especially when it is not sharply defined, and as such create an "architectural advantage".

To explain when and how this happens, we elaborate on Teece's original argument, which was that co-specialization (the mutual adaptation of two firms or assets) was often necessary to effectively use an innovation; but that this co-specialization could lead to problems of bargaining due to bilateral dependence. We argue that co-specialization is really the composite of two distinct components: complementarity and factor mobility. We concur with Teece that complementarity (i.e. the extent to which two mutually adapted factors can yield superior value in combination) usually leads to limited factor mobility (i.e. few alternatives to these factors, leading to bargaining problems). Yet we observe that complementarity does not *necessarily* limit mobility. This is because complementarity is defined at the level of a particular set of factors to be combined—how two or more factors along a value chain are "tailored to each other"; whereas, mobility is defined at the level of the *population* of combinations—how plentiful these (more or less complementary) factors are in each part of the value chain, and how easy it is to replace one set of complementary factors with another. So, high complementarity (at the level of any dyad or asset combination) does not necessarily entail low mobility. Disentangling the two constituent components of co-specialization gives rise to the new insight that firms which manage to obtain *both* high complementarity *and* high mobility in their vertically adjacent segments can appropriate value without owning the complementary asset, thus evading the canonical Teecian co-specialization conundrum. Examples include Fannie Mae and Freddie Mac in mortgage banking, and Microsoft and Intel in the PC sector.

In addition to qualifying and extending Teece's framework on how to best *appropriate* value from innovation, we also build on recent research that points to new ways of *creating* value. First, we point out that, other than capturing the value from innovative efforts through fending off imitators and achieving superior profitability, firms can also benefit from *investing in assets that will appreciate*. Indeed, we argue that under some conditions (which we identify), innovators may be better off if they encourage imitation in order to benefit from asset appreciation instead of beating the others to the punch in providing the good or service (Jacobides and Winter, in press). This leads to a fresh set of predictions, that provide an analytical foundation for some of the recent arguments put forth in the context of "open innovation" (Chesbrough, 2003). We also point out that changing the scope of the organization not only affects the extent to which it can capture the fruits of its innovative labor; but it also affects the extent to which it can be innovative in the future, thus updating Teece (1986) with insights drawing on Teece et al. (1997). Combining these two observations, the paper provides a new prescriptive framework that can help a firm to manage its boundaries in a way that strikes an advantageous balance between the twin concerns of creating and appropriating value.

2. By way of background: the foundations laid down by Teece

Before delving into the proposed elaborations relating to the question of profiting from innovation, a brief consideration of the intellectual history of Teece's landmark paper is called for. Much of Teece's early work can be understood as a pioneering effort aiming at developing a framework which is broad enough to accommodate both transaction cost economics and evolutionary approaches. His 1986 paper, for instance, combines incentive-based reasoning with dynamic ideas on innovation and evolution. Rather than advancing narrowly specialized theories, the interest lies in what Simon (1997) called 'empirically based' reasoning. Teece's research is inspired by a real concern for managerial practice. Thus, his early work focused on issues relating to the internal organization of business firms, the choice of boundaries and diversification, and the empirical verification of transaction cost economics (as developed by Coase and Williamson).

Teece enriched transaction cost theory with ideas from evolutionary economics, from Edith Penrose's pioneering work on resource-based theory, and from the behavioral theory of the firm. Thus, he introduced the ideas of complementary assets and appropriability regimes as pillars of a conceptual framework that could help understand how firms benefit from innovation. In

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later works, he developed the idea of dynamic capabilities in order to characterize the adaptive nature of innovation and business strategy—a concept that (as co-specialization did too) diffused widely in the management, innovation, and strategy literatures.

Teece's recent emphasis on dynamic aspects of the business enterprise has become a significant ingredient in several key contributions to strategy and other fields, and his more recent work on dynamic capabilities complements the early work inspired by transaction cost economics, a combination which is arguably needed to explain foundational issues in economic organization, such as the boundaries and structure of the firm. For example, the complementarity between transaction cost economics and dynamic capabilities has been noted by Williamson, Teece, and Winter. Williamson (1999, p. 1098) notes that transaction cost and internal firm perspectives "deal with partly overlapping phenomenon, often in complementary ways". Indeed, the first empirical study to show the predictive power of asset specificity in setting firm boundaries (Monteverde and Teece, 1982) also showed that even greater predictive power was associated with co-specialization or "systems integration". This led Teece (1990, p. 59) to the observation that: "[I]n order to fully develop its capabilities, transaction cost economics must be joined with a theory of knowledge and production" (also see Winter, 1988).

This general shift from incentives toward evolutionary and dynamic considerations is quite consistent with developments in areas such as management, innovation and strategy. Even if the idea of co-specialization was born into the pre-capabilities literature (Augier and Teece, 2006), it was broad enough to encompass recent probes into the relation between value creating strategies and the possibility of benefiting from innovation (Lippman and Rumelt, 2003b; Teece, 2005). While the concepts of co-specialization and capabilities were developed (and evolved) largely independent of each other, they are both part of the same important question relating to the ways a firm can benefit from innovation (Teece, 2005). And it is in this spirit that our own analysis aims to extend Teece's original framework, drawing on recent advances in institutional and evolutionary economics.

The remainder of the article is organized as follows. Section 3 below broadens the concept of co-specialization to encompass both industry-level and firm-level architectures of co-specialized assets to the level of industries, and network of activities. Section 4 suggests that the concept of co-specialization contains two distinctive components that must be disentangled: complementarity and mobility. Section 5 combines the arguments laid out in Section 3 (on architecture) and Section 4 (on co-specialization) in order to consider how firms can manipulate their sector's structure to achieve "architectural advantage". Section 6 moves beyond the immediate concerns of value appropriation, pointing out that innovation can generate value by asset appreciation. This insight has important implications for choosing firm boundaries, which are spelled out by identifying the conditions that allow an innovator to benefit from asset appreciation. Building on all of the constituent pieces of the puzzle, Section 7 proposes a comprehensive framework to guide the choice of firm boundaries so as to benefit from innovation, mirroring Teece's (1986, p. 296) oft-cited decision-tree. Section 8 concludes and considers implications for research.

3. From bilateral dependence to asset combinations in industry architectures

Teece uncovered some of the ways in which co-specialization can influence financial returns to innovation. In particular, he explained how co-specialization, in combination with appropriability regimes, determines who will capture the fruits of an innovative effort. His discussion of appropriability applied at the level of the potential dyad, considering how bilateral dependencies in production may influence the distribution of returns when an innovation comes to market. In this section, we observe that mutual dependencies among economic agents are not just bilateral. In consequence, the understanding of both industry dynamics and of how firms can profit from innovation, can be enhanced once the focus is shifted from the dyad to industry-wide networks of relationships.

Strangely enough, and despite the growth of interest in clusters (Krugman, 1994; Saxenian, 1994) and networks (Powell, 1990), research on innovation and surplus division has rarely focused on co-specialized relations beyond the dyad. Even though Teece (1986) indicated that co-specialization might include multiple assets, the focus of that article and much subsequent research was bilateral dependence, in dyads of innovators and among complementary asset holders. Yet most economic organizations, including firms and markets, exhibit a considerably more complex structure of co-specialized agents and assets. We shall refer to such a structure of co-specialized agents and assets as architecture, and suggest that industry architectures are the common frameworks determining the nested structures of industry organization.

An industry architecture, we argue, is a sector-wide construct that defines the terms of the division of labor. A

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casual purview of how fairly similar tasks are organized in different countries indicates that there are different ways to "chop up" the production process, and define roles and interactions. Consider, for instance, the case of construction in the European Union, where very different ways of organizing a set of co-specialized firms have emerged in countries with similar levels of development (Winch, 2000, p. 95):

> [there exists] extensive variation in the configuration of [the structure of the building sectors' value chain]. Construction business systems have evolved over very long periods, and display well-rooted rigidities, with the balance between the actors in the system hard fought and hard won ... [A careful comparative international analysis shows] the different modes and directions of evolution across Europe. It is also noticeable that, with the exception of The Netherlands, the principal forces for change are generated domestically and neither by directives from the European Commission, nor international competition in construction services.

Put in our parlance, there are a number of different potential architectures, i.e. means to organize and divide labor in the construction business; and each architecture shows remarkable stability. But, before explaining why this is the case, and why this may matter, a definition of architecture may be called for. Drawing on recent work on design, we argue that architecture is an abstract description of the economic agents within an economic system (in terms of economic behavior and the capabilities that support the feasible range of behaviors) and the relationships among those agents in terms of a minimal set of rules governing their arrangement, interconnections, and interdependence (the rules governing exchange among economic agents).[1] Architectures provide the contours and framework within which actors interact; they are usually partly designed (e.g. by regulation or de facto, by standards), and partly emergent (by the creation of socially understood templates and means to coordinate economic activities). Architectures affect industry participants in ways that may be either anticipated and designed in, or unanticipated (ESD Architecture Committee 2004, p. 26).

Having argued that architectures are important, and that they provide contours for action, the question arises: why do they emerge in the first place? And why don't players who are *not* favored by these architectures just ignore them altogether?

The first answer to this question is that architectures offer a viable mode of production and exchange for a set of economic agents, especially as industries mature and centrifugal forces begin to push towards dis-integration (Jacobides, 2005). With the birth of a new industry, a range of possible architectures may be viable. Gradually, as an industry, architecture becomes stable and a system of interfaces among economic agents emerges. We define interfaces quite broadly, as the technological, institutional, or social artifacts that allow for two or more independent entities to divide labor between them. Interfaces are both the catalysts and the evidence of co-specialization between players. They can emerge through conscious action or through happenstance; they both reflect and amplify the division of labor among industry participants. In service sectors, interfaces often consist of regulatory frameworks; and in technology sectors, of technological specifications that allow different players or constituents to connect. Technological interfaces, in particular, can be proprietary (such as the USB Flashdrive interface) or open (such as other parts of the PC architecture). Such a system of interfaces moderates a set of productive units (firms) whose functions are co-specialized so their interaction is based on a well-defined distribution of roles (division of labor).[2] To the extent that the individual players receive positive feedback, the emergent interfaces, and co-specialized players will tend to coalesce, inviting newcomers to define their business in a way that aligns with the emergent architecture.

Once a promising way of organizing transactions emerges, it is likely to be followed by a number of players to the extent that they can avoid transactional investments in making things happen. Often, as "winners" emerge in some parts of the value chain (because of their idiosyncratic, superior capabilities), potential upstream suppliers or downstream retailers come to co-specialize. Thus, an industry architecture will emerge on the basis of the interfaces defined by firms that initially happen to hold superior capabilities, in terms of technical efficiency (Jacobides and Winter, 2005). The

[1] Our definition is consistent with the definition provided by the ESD Architecture Committee (2004). Thus, our definition both comprises a physical architecture and a technical architecture, which is "an elaboration of the physical architecture that comprises a minimal set of rules governing the arrangement, interconnections, and interdependence of the elements . . ." (ESD Architecture Committee 2004, p. 5).

[2] Whether the emergence of interfaces will lead to co-specialization is an empirical question, which depends on both the level of complementarity and the level of mobility among the firms that relate through interfaces. As mobility increases and complementarity tends to zero, the degree of co-specialization among interfaces will approach zero.

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stability of such a system increases with positive feedback from current operations and negative feedback from trying to change the architecture (cf. Padgett et al., 2003). This results in one, or, at most, a small number of rival "platforms", co-specialized "business ecosystems", with their own sponsors, orchestrators, and keystone members (Gawer and Cusumano, 2002; Iansiti and Levien, 2004). Sectors thus become interdependent "systems" (Dalziel, 2006). With highly specialized members of an industry architecture connected in ways that minimize transaction costs, the negative feedback (adjustment costs) to a player that tries to change the architecture single-handedly is likely to be substantial (Scott et al., 2000).[3]

The determinants of industry architectures, though, are not purely technical, nor are they only driven by the path-dependent evolution of firm's capabilities. They are also shaped by legal and regulatory authority, and this explains why in different jurisdictions (different states or countries) we observe different ways of organizing labor.[4] Also, industry participants who stand to benefit from a given architecture usually fight the introduction of new alternatives through legislative or regulatory means (e.g. Shell, 2004). To wit, charter fights between different guilds over control of the production process constitute some of the earliest documented skirmishes in business history. And this is not only a phenomenon of a remote past: in many sectors today, including healthcare, financial services, public services and other important parts of the GDP that remain unstudied, political forces and lobbying can play a substantial role, not only in supporting any one architecture, but also by discouraging other alternatives. Firms or industry associations spend substantial effort trying to manipulate these rules, giving remarkably under-studied battles which will not only define "who does what" but also, and more importantly, "who takes what".

In addition to the legal and regulatory reasons to "stick" with a given industry architecture, another critical issue that induces stability and adherence to a sector's architecture is the challenge of verifying quality—the Akerlofian (1970) "lemons" problem. Duguid's (2003) discussion of wine trading in the 18th to 20th centuries provides good illustration of this point: he observes that different participants along the value chain, with a distinct view of how the industry architecture should be structured, fought to be the guarantors of quality. In Port wine, for instance, it was the *shippers* of wine (prosperous merchants such as Sandeman or Warre) who managed to gain the trust of the public, and as such managed the architecture of the sector around that reputation, unlike the French Claret, where, backed by the French government and hefty advertising, the producers themselves were able to establish their repute in the 19th century, relegating the importers to an actor of lesser importance, not only in the eyes of the regulator (vis-à-vis their prerogatives), but also in the eyes of the consumer (vis-à-vis their expectations of quality). Still, try as Port growers might to change the architecture, it was very difficult to displace the old architecture, *precisely* because of the inherent information problem, which was, in the eyes of the consumers, being tackled by the Shippers.[5]

These historical examples show that new ways of safeguarding against loss from transactional hazards were important in shaping and stabilizing emergent industry architectures. Similar dynamics are currently discussed in development economics and in economic sociology (Gereffi, 1994; Gereffi et al., 2005). Consider, e.g. coffee or cocoa production, where the question is whether certification of quality can happen at the stage of retail (by corporate giants such as Nestle) or at the place of origin (through the certification of either the type of coffee, or of the way it is grown)—see Gibbon and Ponte (2006). We can view the struggle between Intel and PC manufacturers in a similar light, the key question being, "who will be the guarantor of quality in the emerging PC sector structure"? In each case, different parts of the industry will try to keep this "certification" function for themselves, yet their desire to be the "guarantor" will not always be successful. So, on one hand, actors may be reluctantly forced to keep with the current architecture; and on the other hand, they may be engaged in a

[3] Industry architectures also change whenever new ways are found to "put together" the various industry participants: legal innovations that alter transaction costs (e.g. broadband auctions), new ways of safeguarding against loss from transactional hazards (e.g. electronic monitoring), and technical innovations that alter the payoff to bundling specialized production factors (e.g. assembly line) could inspire adjustment of an industry's architecture.

[4] Architectures can be mapped using a variety of techniques including design structure matrices, design hierarchy diagrams, and network graphs (Baldwin and Clark, 2000; ESD Architecture Committee, 2004). A technique pioneered by Andy Grove, "stack mapping," shows promise as a way to map industrial architectures (Grove, 1996); ditto for Fransman's (2003) recent work on "layer maps" in exploring the evolution of the telecommunications sector.

[5] These examples dispel the idea that large, vertically integrated firms invented branding to redress information asymmetries, and show how branding (and coping with information problems) both defines and results from the architecture of a sector.

battle to change it. Such a battle is not only fought vis-à-vis the regulators, but also with regard to the consumers' concern for legitimate structures of organizing production, and who can be trusted to serve as a guarantor of quality.[6]

This analysis suggests that each industry may adopt one or a number of distinct architectures, i.e. different ways in which roles are distributed among a set of interacting firms. Once an industry architecture emerges and stabilizes, it is difficult to stray from it, for reasons relating to inter-operability (who else is willing to participate in a new architecture, or is capable in so doing); regulation (which reinforces some ways of dividing labor and excludes others); and information (what the customers have learnt to expect). Thus, industry architectures provide two templates, each comprising a set of rules: (1) a template defining value creation and the division of labor, i.e. who can do what and (2) a template defining value appropriation and the division of surplus, or revenue, i.e. who gets what. These templates are related: co-specialized ways of carrying out production are related to rules of dividing surplus, i.e. the organization of payments for services and goods.

The effort to shape a field to benefit a group of industry participants can be seen in a variety of sectors—from nanotechnology (Grodal, 2006) to health care (Scott et al., 2000; Gartland and Stack, 2006) to construction (Cacciatori and Jacobides, 2005) to smart cards (M'Chirgui, 2006) to mobile telephony (Leijponen, 2006) to several network industries (Eisenmann et al., 2006). Firms, such as Fannie Mae or Freddie Mac in mortgage banking, have been able to keep a large part of the industry profits by carving out a comfortable position in their sector.

Thus, a broadening of the concept of co-specialization can help explain why lobbyists, pressure groups, industry associations, or even firms direct so much energy and resources towards attempts of changing the structure and nature of an industry's (or sector's) division of labor and the related templates for the division of economic surplus.[7] It also helps us understand the struggles between members of potentially competing, or at least partly overlapping industry architectures, which on the one hand need to secure an advantageous position within their own architecture; and on the other hand want to ensure that their architecture will emerge victorious. Indeed, the processes that lead to stable dominant architectures may help understand the dynamics relating to "dominant designs", with firms coalescing into particular, fixed roles that shape the roles also of other firms and thus industry trajectories (Utterback and Abernathy, 1975; Tushman and Anderson, 1986).

Let us now return to the issue of innovation, and how to benefit from it: why should an innovator care? And what can an innovator do? We propose that an innovator often has a substantial opportunity to *shape* the architecture of complementors around them, and think strategically about how to organize the set of other participants (their roles and the ways in which they are connected). Recent research by Santos and Eisenhardt (2006) observed that even small, budding entrepreneurial ventures can achieve a comfortable position in the industry architecture by influencing *the structure of their sector in ways that would eventually fit their own capabilities*, a finding echoed in earlier research by Morris and Ferguson (1993) on technological architectures and more recently on platforms by Gawer and Cusumano (2002). This suggests to us that managing or influencing an architecture can allow a firm to capture a disproportionate amount of the benefits created by an innovation, especially because innovations often require (or justify or legitimize) the creation of a new architecture. Opportunities for changing the architecture thus emerge in new sectors, for new technologies, or whenever a substantial technological, institutional or demand discontinuity allows for the reorganization of production.

[6] Duguid (2005) provides another fascinating example of how regulatory an information-certification issues combine. He considers how firms in the publishing and printing sector in the UK since the 16th century fought for control of quality, and how *booksellers* in the early days of the industry would provide the "stamp of approval" of the quality of the content (to be used by the public as a guide for experiential or credence goods), and how the *publishers* (originally a mere technical part of the process) gradually took over that role. The key in this fight was the ways in which each would interface both with authors, and with the government, trying to pass regulations favorable to one or the other segment.

[7] Most industries have fairly well established rules about what activities each party undertakes. In some cases, there are even specific benchmarks about the division of surplus inherent in industry architectures—such as the de facto fees of investment banks (a common 7% commission for IPO's). In addition to haggling over surplus between two parties, we should pay attention to the dynamics at the level of the industry architecture—at the attempts of redefining the rules that both regulate the distribution of activities and the division of surplus in industrial systems. The importance of these rules can be seen in nascent fields, such as nanotechnology, whereby industry participants try to draw on different *analogies*—different was of conceptualizing "what their environment should be like", or different rhetoric devices that can influence the division of labor and the division of profits (e.g. Grodal, 2006).

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The dynamics of architectural adjustment open new possibilities of reaping advantage from innovation that emphasize dynamic efficiency over control. A particularly interesting possibility is to control asset complements. Teece built on the critical assumption that problems of appropriating value from complementary assets can be remedied by buying or building them if the company's cash position (or perhaps its potential speed of implementation) allows it to do so. This implies that the costs of setting up or controlling a new operation in terms of complementary assets would be well spent. But why would the innovator entering into a new terrain avoid a loss of efficiency in comparison to experienced operators? (See Barney, 1999; Hoetker, 2005). Rather than a foregone conclusion, it seems to be an open question if the value of controlling complementary assets in a new line of business necessarily compensates for the loss of efficiency. Obviously, losing control of an asset that is part of an innovative combination can be costly. If the combination is unique (complementary assets are immobile), the holder of a complementary asset is likely to extract a high premium from the innovator.

In such cases, an innovator (say, Apple Computers) should not only consider how broad or narrow boundaries will influence current value appropriation, but also assess the loss of possible future growth opportunities, i.e. a possible loss of activities that would promote the growth of its own platform (Boudreau, 2006). That is, a dynamic consideration would include assessment of the extent to which a choice of boundaries that minimizes the current loss of value impedes the future ability of the overall platform or vertically co-specialized players (in essence, the new, vertically co-specialized eco-system) to fend off the competing set of vertically co-specialized eco-systems. Given scarce resources, does it make sense to keep the biggest part of a potentially shrinking pie, or a modest part of a growing pie? (See Gawer and Henderson, 2006 or Baldwin and Clark, 2006a, for a related analysis). Focusing excessively on value appropriation can, we would argue, impede value creation. This point and a number of further dynamic considerations relating to the trade-off between dynamic efficiency and control over asset positions are considered in Section 7, which proposes a comprehensive framework to guide the choice of firm boundaries so as to benefit from innovation.

Yet exactly how can an industry architecture be changed to benefit a particular industry participant, and especially an innovator? The next section will provide a conceptual clarification that paves the way for an answer to this question.

4. Co-specialization and the returns from innovation: complementarity versus mobility

With the first "stepping stone" in place – the contrast between dyads and architectures, which operate at the level of the industry – we can now move to a second elaboration of Teece's work, which is to identify complementarity and mobility as two distinct components of co-specialization, and to consider how firms can benefit from managing each component separately.

Our argument helps motivate some of the recent discussion of "open innovation" (or, to use our terms, "open architectures"). To do so, we draw on received wisdom in the area of dual or multiple sourcing (e.g. Anton and Yao, 1987; Farrell and Gallini, 1988), where the basic argument is that a firm benefits from competition in the market for the complementary goods. Even if the argument itself is pretty obvious and well established (Grossman and Hart, 1986; Williamson, 1979), it highlights that Teece (1986, p. 289) and subsequent literature bundles two distinct issues when defining co-specialized assets as ". . . those with bilateral dependence". The first issue is (bilateral) dependence in the sense of superior returns to a combination of two or more assets, i.e. *complementarity* in products, services, and processes. The second is (bilateral) dependence in the sense of the number of assets that can potentially enter a combination, with negligible switching costs, i.e. *mobility* in assets that are components of a combination. The notions of complementarity and mobility are best treated as independent aspects of co-specialization because they capture distinct economic effects. Complementarity influences the size of the value to be bargained over (some combinations yield higher value, others lower value, depending on their "fit").[8] In contrast, mobility influences the bargaining power of the asset holders, and thus the division of the value (some assets cannot be replaced other assets can be replaced by numerous equivalents at negligible

[8] In this paper, we adopt a simple stance vis-à-vis the role of complementarities, by using the term to describe whether the marginal impact of one component changes with the nature of another component; or whether one level of an attribute affects the marginal impact of another (see Milgrom and Roberts, 1990, for an example; Topkis, 1998, for an authoritative discussion). This is consistent with production economics, as well as organizational studies. In particular, our definition is consistent with research that draws on Kauffman's NK-landscapes (see Gavetti and Levinthal, 2004; Levinthal, 1997), modeling varying degrees of complementarity between actions or attributes, as they jointly affect some outcome. It is also consistent with qualitative and conceptual research on "fit" (see Siggelkow, 2003). However, we largely exclude strategic complementarities in games, such as described by Cooper (1999), from our approach.

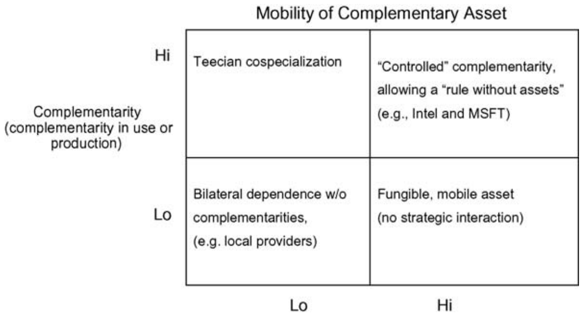

Fig. 1. Complementarity vs. mobility: dependence and complementarities.

cost). Reduced mobility may be due to a variety of factors; for instance, as Sutton (1991) noted, it could be due to the existence of Endogenous Sunk Costs (ESC), e.g. to large advertising or R&D budgets, or network externalities which make it hard for existing players to replace each other or for new players to enter (Varian and Shapiro, 1999).

Fig. 1 provides a 2×2 exposition. One axis represents the mobility of assets (and capabilities)—the key question is whether they are fungible or not. (Later on in the paper, we will consider the impact of the relative mobility, i.e. the question of whether one set of assets is more mobile than the other). The other axis represents the complementarity of these assets (or assets and a focal innovation) either in use or in production. This yields four quadrants, two of which have been examined in prior research: first, the upper left-hand side quadrant is the usual Teecian world of co-specialization, with high levels of complementarity and rather immobile assets, which yields the familiar concept of bilateral dependence as defined by Teece. Second, the lower right hand-side represents the prototypical generic or fungible assets in production—low complementarity and high mobility. Yet, in addition to these two quadrants, two unexplored possibilities exist.

The first possibility that transcends the usual analysis is the upper right-hand quadrant, which represents the combination of high complementarity *and* high mobility. Recent discussions of modular design provide good illustration of this possibility. An "open" modular system creates complementarity among modules that largely work independently (Baldwin and Clark, 2000). Even though the components of a modular system could be tied down to a particular "platform" (see Gawer and Cusumano, 2002, for an extended discussion), a modular design is usually accommodating towards functional substitutes (e.g. a new piece of code for a software module). Thus, complementarity in modular systems might be able to avoid dependencies of the sort discussed in the literature that has followed Teece (1986). PC manufacturers from Intel's perspective, or the mortgage banking sector from Fannie Mae or Freddie Mac's perspective are examples of industry actors that have created competition in the complementary good. This advantage, whether brought about by happenstance, lobbying or strategy allows them to "rule without assets" and without needing to integrate.

A second possibility that transcends the usual analysis, the lower left hand-side quadrant, represents the case of assets that, for some reason, are just "stuck" on the ground even though they are not particularly adapted to each other. One example would be a local factory (within a specific region) and unskilled local hands (stuck in the vicinity of the factory). Despite low complementarity (e.g. in terms of mutual adaptation), the parties are stuck with a problem of mutual dependence that makes the assessment of ex ante bargaining positions very hard (Brandenburger and Stuart, 1996, 2004).

This figure suggests that mobility plays an important role in determining (relative) bargaining positions of two parties, regardless of their complementarity.[9] Furthermore, it suggests that firms might want to *actively use* mobility as a tool that can help them manage the potential dynamics of the components of an interdependent design. That is, a firm might want to ensure that there is substantial mobility in the complementary assets, as this might induce *freer competition and entry in these assets*. In this sense, we argue that innovators may have a richer set of choices. First, they might pursue complementarities without fearing that limited mobility is an *inescapable* consequence. Second, rather than just accept the trade-offs as given, they may try to *actively shape the menu of choices they face*, *by re-shaping the industry architecture*.

Considering the extent to which mobility can affect the distribution of value from innovation also hints at another assumption embedded in the Teecian analysis: the view that tight intellectual protection of property rights in conjunction with co-specialized assets plays a primary role in capturing returns from innovation. Thus, Teece suggests that a weak intellectual property regime in conjunction with co-specialized assets is the least promising as regards profiting from innovation. Accordingly, he offers the prescription that loose intellectual protection of property rights should induce innovators

[9] An additional, but *distinctive* bargaining problem ensues if the number of potential assets to be combined becomes very small.

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to secure a position in co-specialized assets. Because we define complementarity and mobility as distinct components of co-specialization, our analysis differs in the way the relative mobility of the productive factors determine outcomes.

We would further qualify Teece's analysis by positing that, even if there is tight intellectual protection of property rights, it is unclear how much value that will be captured by the innovator. If, for instance, there is substantial downstream mobility, the competition in the downstream market will ensure that the upstream user captures a solid return from the innovation.[10] Conversely, if we have limited (rather than high) mobility, intellectual protection alone will *not* suffice to ensure a high payoff to the innovative effort.

As Brandenburger and Stuart (1996) and Lippman and Rumelt (2003b) have recently illustrated, bargaining over surplus in such cooperative games is a fairly complex affair, with outcomes depending on the competitive conditions (influenced by mobility and collusion) along different parts of the value chain. While imitation clearly influences the value an innovation can yield, the analysis must be qualified by considering the relative mobility of related parts of the value chain. It is the latter that drives the amount of surplus that, say, downstream users of the innovation are willing to pay; the more competitive and mobile the complementary asset, the higher the returns, for any given level of intellectual rights protection, of the innovation.[11] Thus, unbundling co-specialization and mobility not only points to the new strategies to manage scope, outlined in the next section; it also qualifies Teece's thesis that, given tight intellectual rights protection, specialization is the appropriate strategy.

5. From co-specialization to bottlenecks: creating architectural advantage

We have now elaborated Teece's analysis in two ways: first, we suggested that the level of analysis can usefully be extended from dyads to architectures that define the division of labor and the division of value in industries and firms; and second, we argued that complementarity and factor mobility are best viewed as distinctive components of co-specialization that codetermine bargaining positions and thus division of surplus among agents. With both of these stepping-stones in place, we can now move to the articulation of the first major contribution of this paper, which is to explain how firms can benefit from innovation by engaging in architectural manipulation. Essentially, we find that firms can benefit from innovation by *managing the industry*'*s architecture* carefully so they become the "bottlenecks" of their industry (Baldwin and Clark, 1997; Ferguson and Morris, 1993; Morris and Ferguson, 1993; Iansiti and Levien, 2004).[12]

To illustrate, consider the case of the personal computer (PC), also featured in Teece (1986). Whereas all IBM-compatible parts of the value chain are in effect mutually adapted (system level complementarity), the resulting dependencies are not symmetrical (Bresnahan and Greenstein, 1999). These asymmetrical dependencies are *not* caused by the technical attributes of any one of the PC components; *neither* is it a question of whether Intel chips can be deployed to any other type of PC. Rather, the dependencies arise from "bottlenecks": de facto exclusion of possible producers limits entry into particular segments of the industry architecture, whereas mobility (both in terms of switching costs and potential entry) is high in others. The issue is not so much whether the factors of production are mobile or not, i.e. whether chip manufacturers have limited alternative use for their production capacity, whereas software firms have many alternatives. The issue is rather if potential competitors can possibly serve the need of a particular segment within the system of mutually adapted components (Varian and

[10] This point differs from a Teecian argument relating to generic (rather than specialized) downstream assets. Teece (1986, p. 289) defined generic assets as those general purpose assets which do not need to be tailored to the innovation in question, specialized assets as those with unilateral dependence and complementary asset as those with bilateral dependence. What we argue here is that downstream mobility could be high even if assets are complementary and thus (highly) tailored to a joint function. In contrast, the possibility of high mobility from generic assets (suggested by Teece's analysis) by definition implies an absence of tailoring to a joint function and thus a lower level of complementarity.

[11] In addition to the question of mobility, which influences competitive dynamics along the value chain, additional considerations of the structure of competitive interaction, i.e. the nature of the strategic games played between vertically related players also becomes important; see, e.g. MacDonald and Ryall (2004).

[12] The concept of a "bottleneck" seems to be intuitive to industry executives, as they consider the attractiveness of different parts of their sector, and we have thus adopted the term ourselves. The concept of a "bottleneck" comes from linear optimization (and operations research) and denotes the part of the firms' or the industry's system that is in most scarce supply. Analyses relating to this can be found in the seminal discussion of production economics and planning (see Dorfman, 1953), which, after being influential for a while, fell into neglect for a surprisingly long time, and were used only in the context of Supply Chain Management or Operations Management. We suggest that there would be much merit in returning to some of the issues analyzed by that stream of research.

Shapiro, 1999). To appreciate this, though, we have to look beyond any pair of assets, and consider the entire system of mutually adapted assets within the industry architecture.

What are the dependencies in the entire IBM-compatible PC sector? Clearly, this is a case of almost one-sided asymmetrical dependency where Microsoft and Intel have managed to impose de facto dependency on all other actors. How could this happen? Largely because entry into these two segments is very difficult—Microsoft's position being protected by network externalities and Intel's by fixed investments and superior capabilities. An attempt to challenge Microsoft or Intel in their own segments would require huge sunk investments (cf. Sutton, 1991). In contrast, entry and active competition in the other segments is much easier. Interestingly, this was made so through bold actions by Microsoft and Intel, and through the inability of IBM to respond.[13] So peripherals, or even the design and assembly of PC's can nowadays be done by many different firms. Over and above the issue of intellectual right protection, the question is whether firms are able to enter and compete more aggressively. Indeed, most of the PC components are protected by patents, so that the appropriability regimes are not drastically different from the chip-manufacturing case.

Bottlenecks (i.e. segments where mobility is limited and competition softened), then, not only drive the direction of innovative activity (see Rosenberg, 1969, for an important discussion), but also determine how an innovative combination creates and distributes value. This highlights the role of architectures at the level of industries and technologies.[14] What Intel and Microsoft have done, through a process of tough competition (see Dixit and Nalebuff, 1991; Gawer and Cusumano, 2002) is to shape the architecture of the PC sector. Through a judicious use of standards, they *facilitate* entry and competition in the complementary assets (anything but their core activities), *without* participating actively in these parts of the value adding process. So the success of Intel and Microsoft can partly be attributed to the creation of *convenient rules of the game* that ensure they will end up with the lion's share of the benefits although their activities have been joined with many other parties. In other words, they have focused on *achieving architectural advantage* by nurturing complementarity in an emerging open eco-system. This allows for ferocious competition in the complementary assets rather than in their own segments.

Given the recent rise of opportunities to engage in creative restructuring of business models with the support of outsourced production, the question of how a firm can get architectural advantage becomes an important issue. Focusing on architectural advantage allows us to support, but also qualify recent work on open innovation (see Chesbrough, 2003). Inasmuch as a firm has an architectural advantage, it can afford not to care about protecting or investing in complementary assets. Instead it should focus on maintaining its advantage by holding on to one part of the complement while increasing mobility in the other part.

Also, shifting our focus from the dyad to the architecture helps explain a number of observations that would otherwise appear puzzling. One of the interesting dynamics in the PC sector has been Intel's ability to leverage its upstream position by carefully structuring its relationship with other industry participants, and especially Microsoft, as well as making its product more "visible" through branding. The interesting point is that Intel has accomplished this *without* downstream integration into production of personal computers. Rather, Intel used the structure of complementary assets to enhance its downstream demand.

[13] The decline of the role of PC manufacturers can be partly traced to IBM's relinquishing key parts of the system, as it tried to rush to the market early on, and as it did not fully recognize the threat from a more open architecture. Microsoft, in contrast, was strategic in changing the sector's architecture to its advantage, helping clone the IBM BIOS, creating a Graphical User Interface, and linking with Intel to create the "Wintel" standard through a complex relationship (Casadesus-Masanell and Yoffie, 2005). IBM did try to respond, but it either failed in court (e.g. losing the "cloning" case) or in its efforts to dominate the PC architecture (e.g. through not being successful with the OS/2 Operating System, or its more integrated PS/2 system (see Bresnahan and Greenstein, 1999; Cringley, 1992). So the current structure of the sector is a function of previous architectural fights.

[14] Consistent with the original definition of the term, note that "bottlenecks" can only be seen in a relative, as opposed to an absolute sense. That is, a "bottleneck" in a sector is the sector which has the least mobility; and as soon as the situation changes, whether because of an exogenous factor or endogenous change, another part of the segment will become the "bottleneck". To provide a concrete example, the "bottleneck" in the PC sector in its earliest days might be related to its design and service; but, partly driven by exogenous pressures, partly driven by the desire of firms in the sector to compete in the arena of design and PC manufacturing, mobility grew, and the bottleneck shifted from the design of the PC to the structure of its key components. However, there has been a fierce battle by the incumbents of these two segments to protect themselves and maintain the bottlenecks in their parts of the value chain. Understanding the largely endogenous processes of bottleneck formation in sectors, which means understanding how power and profits shifts along the value chain, remains an exciting research frontier; despite Rosenberg's (1969) prescient analysis of how bottlenecks explain the evolution of technology at large, little subsequent research has build on or extended that insight.

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Consequently, the main firm-level prescription turns on leveraging a position in complementary assets, not through changes in any one dyadic relationship, but through the manipulation of rules that define who can participate, and thereby structure the incentives and powers that determine appropriability (see Baldwin and Clark, 2006a, for a recent related analysis of "footprint advantage"). Our perspective, then, allows consideration of critical battles over the definition of industry architectures. This perspective can illuminate recent struggles for industry and technology standards. Standards cannot only promote greater interconnectivity, but they can also open up one part of the value chain to a population of competing entrants that align with the requirements of the "standard platform" (Varian and Shapiro, 1999). Standards shape industry architectures. They can be used to manipulate the mobility, competition, and entry into complementary assets.

To be sure, changing or setting architectures is no easy feat; and it is more likely to be effective either in the formative years of an industry, or when institutional change becomes possible. Setting an industry's architecture is very rarely a choice that any one firm faces. It often involves a great variety of players that need to converge, often through a contentious process; and may well include actors such as "systems integrators" (Prencipe et al., 2003). Only in exceptional cases do firms have the luxury that IBM had in the 1980's, to almost unilaterally shape the PC sector's structure. More often, the sector emerges through a trial-and-error process with several firms engaging in cooperation and competition at the same time. Yet while firms cannot immediately and unilaterally decide the nature of their industry's architecture, they still have the possibility of making a substantial impact. More important, it still appears that many industry participants are not fully aware of the competitive implications of changing architecture (Morris and Ferguson, 1993; Iansiti and Levien, 2004; Jacobides, 2005). Consequently, much value can be had by focusing on them.

To be more specific, a firm may want to try to change the architecture of its sector, helping shape standards to encourage competition in its complementary activities, while restricting mobility, entry and competition in their own segment. In that regard, becoming the "guarantor of quality" to the eyes of the final consumer is often a critical factor, as IBM painfully found out after Microsoft and Intel became the de facto signals of quality, and after other PC components became standardized. More broadly, a firm may want to try to change the architecture of its sector, helping shape standards to encourage competition in its complementary activities, while restricting mobility, entry and competition in their own segment. To do so, firms, small and large, established and nascent, will often engage in alliances and other collaborative efforts in order to affect the paths of industry evolution (Rosenkopf and Tushman, 1998; Leijponen, 2006; M'Chirgui, 2006).

In addition to building mobility in other vertical segments *within* their architecture, firms should consider how they might strategically re-shape the structure of the sector; and that is often a non-collaborative game. For instance, a firm may want to "envelop" its sector by connecting to a broader "bundle" of services and products that would leverage its own strengths while muting those of its competitors. The basic idea is to identify a structure of the sector where the firm has one key strength, and then use this strength as a "thin edge of the wedge" to gain architectural dominance. Thus, the firm must heed two strategic imperatives: it must both attain architectural advantage and ensure its own architecture can dominate.

Consider the digital music distribution sector where Real Networks had initially secured architectural advantage by focusing on the "bottleneck" in the value chain, which happened to be the file format. Microsoft soon "enveloped" it, by using its own installed base, by providing a bundled product (a streaming media server with all the other server components). Real Networks, however, had also used its ability into streaming, into expertise for music downloads, so it re-positioned the offering as a music subscription business. As a result, Real Networks for a brief period became the dominant player. Yet this architecture was attacked by Yahoo, which again enveloped Real Networks by addressing a different, broader set of customer needs on the basis of its proven advantage (internet subscription) which secured limited mobility. This effectively re-cast the architecture of the sector in a way that leveraged its own strengths while muting those of Real Networks. So fights on "what the industry consists of", "what are the players", and "how do we compete", and "who can envelop whom" drove the nature and structure of the industry (Eisenmann et al., 2006).

In mobile music downloads, a related, but distinctive market, architectural strategy has played a pivotal role. Apple, with 70% of the market as of mid-2006, has kept the key position in their own architecture, ensuring there will be no challenge in the key part of their value-added process; yet at the same time it has encouraged the development of an eco-system by using outsourcing partners or even other OEM's like Bose to draw the architecture around the iPod's and thus maintain architectural dominance. (Whether this will be sufficient to fend off other architectures remains to be seen.) Yet the battle for architectural dominance in this sector still looms large. Other players, like Cingular/Verizon, are trying to use access to mobile devices and their subscribers as their "thin edge of the wedge". Their effort is to either change, or create their own architecture for the musical downloads or subscription sector. And, in what may be the best illustration of our framework, Microsoft has just released Janus/PlaysForSure, a service which is likely to become the bottleneck in the industry, since it allows *any* file that licenses it to be played on *any* device. By ensuring that there is maximum mobility in its vertically related segments, by encouraging entry and competition in the sector around it, and by maintaining tight control in their segment (through IP as well as branding—becoming the new "Intel Inside" in music distribution), Microsoft is about to change the dynamics of the sector; we would predict that they will soon gain architectural advantage. And of course, legal and regulatory battles still loom, with deep consequences for the sector, as well as new collaborations, deals and technologies which may redefine who does what and who keeps what.

A deeper understanding of industry architectures, then, can be used as a basis for advising companies that would aim to maximize the control of their industry, and fight for their eco-system's growth. Our approach suggests that firms must be more strategic as they face the structure of their sector, focusing on the dynamics of their architectures. Such an approach might also serve policy makers as a rough guide to maximize innovation, and eliminate firms that hold an excessive architectural grip over any one sector. Our approach shifts attention *both* to how firms can be successful within their own architectures; and to how different architectures, or different segments, compete for the control of established and new needs. By focusing on architectures, and the roles of firms within them, we may also attain a deeper understanding of the strategic dynamics behind the emergence and change of dominant designs (Utterback and Abernathy, 1978).[15]

[15] Our approach suggests that dominant designs may be the result of particular industry architectures—the manifestation, at the level of the product, of a given division of labor. Thus, studying industry architectures can help appreciate when and why dominant designs come about, and what are their implications. Also, our analysis suggests that a sector does not come with segments which have smaller or greater "ESC" (Sutton, 1991); the extent to which one or another part of the value chain has endogenous sunk costs, whether there is, e.g. advertising intensity or network externalities, may be the result of the *battle to shape the industry architecture*.

6. From protecting the innovation to pursuits of value creating moves

While the previous sections provided a fresh take on Teece's basic problem of benefiting from innovation, and extended his analysis in a number of ways, it retained an important limitation in focus. The analysis primarily focused on value appropriation – *protecting* and leveraging an innovation – as opposed to value creation as a first imperative and value sharing as a second order qualifying condition (see Moran and Ghoshal, 1999, for an extended discussion).[16]

Letting go of this remaining limitation leads us to consider the possible gains from *value creating* moves that encourage, rather than protect, the imitation of an innovation. To illustrate, we draw on Jacobides and Winter's (in press) recent analysis of asset appreciation. Consider an innovating restaurateur, who knows "how to create value" both by inventive cooking and a talent in spotting "trendy" industrial post-modern chic properties that can be spruced up at modest costs, and then turned into a restaurant. Further assume that there is complementarity between cooking and real estate identification in the sense that our restaurateur can do either of the two in isolation, but the value of joint pursuit of the activities is superior. There is also complementarity between investment in real estate and the restaurant business; the restaurant provides value to the locale; and the locale is specialized to the particular aesthetics of the restaurant (say, of a "hip, post-modern, recently urbanized style" that transforms shabbiness into pizzazz).

Viewed from the traditional Teecian perspective, the problem is fairly straightforward. The issue is whether such innovative restaurateurs can somehow secure intellectual protection of their new concept. If so, they should use the intellectual right protection to exclude others from using the same "style". Our restaurateur would then be safe, at least according to received wisdom. She could enjoy the profits from her inventive efforts, and even license to any other party that found promise in superior cooking in combination with an "upgrade" of their real estate from sleepy industrial existence to glamorous, and richly paid post-industrial use. If imitation could not be

[16] Teece's article, written in 1986, was largely predicated by the concern, at that time, of the erosion of competitive advantage in the US, and the growth of the Tiger economies in Asia. The common vantage point was the entrepreneur's and the effort was aimed at capitalizing on profits, by excluding others from getting a share. Thus, imitation was discouraged (through tight appropriability regimes) or, in the absence of intellectual property rights, downstream complementary assets were captured in order to cement the success of the innovative effort.

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hindered, though, Teece's analysis suggests we have to consider the possibility of accessing downstream assets (e.g. real estate ownership). With easy access and plenty of cash to finance access, we would be fine inasmuch as the combined bundle (i.e. restaurant "concept" and specific real estate) would be less liable to imitation than the restaurant concept alone. A number of finer points notwithstanding, the best our entrepreneur could do per this analysis is to opt for the least imitable solution, and enjoy the fruits of superior profitability till the advantage gets emulated, and eventually erodes.

Even though this analysis has proven to be very useful, it only covers a rather narrow part of the canvas. Its focus on barriers to imitation and its conception of "strategy as attempts to fortify the fortress" distracts from considering alternative sources of value to the customer as well as identifying alternative sources of profiting from a superior idea or skill. Recall the original premise that we started from: the innovating restaurateur has a new idea, a working concept that can deliver more value to customers. We are now broadening our innovator's question: what are the possible ways in which the restaurateur can benefit? Clearly, this encompasses more than just the operating profit. A restaurateur can also make money by increasing the value of the assets in hand. If the restaurateur has identified the "new" area and helped create a "hip" restaurant that earns superior profits (the extra returns she can earn in the restaurant business due to the fact that she cannot be copied or emulated), she will also have affected the value of the underlying asset, i.e. the restaurant. Her activities might even have affected resource values more broadly, so that some resources have appreciated and others depreciated in response.

So the bottom line is that, over and above the changes due to the increased profitability related to appropriability conditions, innovations present new opportunities to benefit from appreciation of the underlying assets. Indeed, as Hirshleifer (1971) pointed out, for entrepreneurs who carve out competitive positions by securing assets that are likely to appreciate, imitation may be a good thing, rather than a bad thing! In the presence of imitation, an innovator can profit by investing in the complementary asset – such as real estate in the case of the innovation of placing a chic restaurant in ex-industrial areas – before the imitation fully diffuses. The opportunity to benefit from asset appreciation can more than outweigh any losses of operating profits.

Our analysis, then, suggests that firms should include considerations of wealth creation when aiming to maximize profits (cf. Lippman and Rumelt, 2003a; Tripsas, 1997, for an empirical illustration). And in this calculus, firms should trade-off how actions that can decrease profits (such as imitation) can increase the value of their assets. For instance, it would be wise for our entrepreneur to buy up assets that can be converted into restaurants if there were a limited supply of appropriate ex-industrial sites, and if the value of these sites would rise sufficiently after the new restaurant becomes established, and because of the excess demand due to such restaurants. Additionally, for the restaurateur to be interested in investing in these sites rather than doing the whole thing (from building to concept) herself, there also has to be some constraint (cash, capacity, or even time to convert the properties) that makes investing in the complementary assets (i.e. the property) more profitable *on the margin*, than providing the integrated offering.

The key insight is that while imitation by competitors may reduce profitability, it also increases the value of the underlying assets; and the innovator can benefit from the latter. So our restaurateur will have to trade-off just how much she will loose from *not* beating others to the punch in providing the integrated service, versus how much she can make on potentially appreciating locked-in assets that others will use. To establish that, she will have to identify the highest returns on her cash and effort (a point we will elaborate on in the next section, where we provide more concrete prescriptions). But to see the latter we have to shift away from a narrow focus on profiting from innovation (in terms of operating results), ideally by excluding others, to broader considerations of changes in relative prices induced by innovations.

Once we accept this shift, a new set of predictions and prescriptions present themselves.[17] As Hirshleifer (1971) and Jacobides and Winter (in press) suggest, this subtle shift of mindset from "profit" (and isolating mechanisms) to "wealth creation" (and the potential for asset appreciation) can yield a very different set of predictions and prescriptions (see Lippman and Rumelt, 2003a,

[17] This idea is as old as entrepreneurial activity itself. Aristotle (346BC [1957]) discusses the case of Thales of Militus, a pre-Socratic philosopher who, when challenged by his opponents as "overly hairy–fairy" decided to show he could use his superior knowledge to material gain, i.e. that he *could*, if he wanted to, act as our notional entrepreneur. On the basis of his superior knowledge, he predicted a very good year in terms of the olive production; and he worked with some financial backers (in a prototypical venture capital agreement) to rent olive groves for a year, paying the "standard" rate. So, while he could have used his knowledge to profit through a "productive" innovation, he preferred to focus on what assets would appreciate and as such benefit from these. To provide a more contemporary example, anyone having seen Roman Polanski's *Chinatown* (1974), only loosely based on the development of the city of Los Angeles, will know the importance of innovations such as irrigation channels not only in terms of their direct productive usage, but also on their ability to change the value of the related assets.

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for a related discussion). This shift in focus, from profit and appropriation towards creation and re-distribution of value, is in the spirit of Teece's original article, yet surprisingly absent from the literature. Yet, even the most casual empirics suggest that new ideas and innovations can create benefit in many very different ways—among these, asset price changes is an important one. While a systematic examination of these factors would be outside the scope of this paper, Appendix A provides the contours of a promising analytical treatment, building on general equilibrium analysis and drawing on the Stolper–Samuelson theorem.

7. Towards a comprehensive framework

This section ties the pieces of our argument together in a new prescriptive framework that can help a firm to manage its boundaries so as to benefit from innovation. The framework consists of two related components presented in Figs. 2 and 3. First, we provide an analytic summary of the innovator's relevant considerations in a decision flow chart that identifies the strategies that are available to a profit-seeking innovator. We argue that an innovator should engage in a net assessment of architectural advantage versus integration. As we explain, the relevant strategies for the innovator relate to vertical mobility, to shifting the focus of the business model and to the choice of contracting versus integrating. Second, we provide an analytic summary of the innovator's calculus with regards to the potential benefits from innovation through investment in associated complementary assets. Thus, we argue that an innovator should extend her first order considerations of architectural advantage versus integration by engaging in a second order net assessment of operating profit versus asset appreciation.

7.1. Architectural advantage versus integration: an analytic summary

Fig. 2 below provides an analytic summary of the relevant considerations in a decision flow chart that identifies the strategies that are available to a profit-seeking innovator. The range of strategies is considerably broader than the binary choice of contracting versus integrating offered in Teece's (1986) seminal article. Teece found that an innovator confronted by weak intellectual property protection and the need to access specialized complementary assets and/or capabilities would be forced to expand activities through integration, at least if it were to prevail over imitators. This conclusion was premised on a narrow focus on intellectual protection and appro-

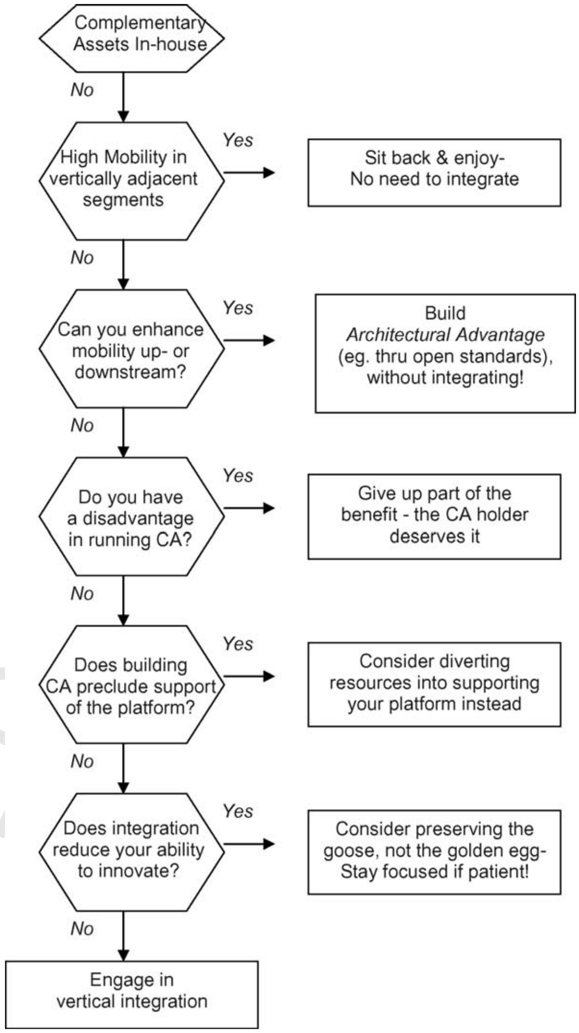

Fig. 2. Choosing scope to maximize profits: the role of architecture and capabilities.

priability. Instead, we point to a broader assessment of the possible gains from architectural manipulation net of loss from weak intellectual protection.

Fig. 2 brings the main elements of our discussion together. This figure both qualifies and extends Teece's (1986, p. 296) decision-tree, and provides a fresh set of prescriptions, guiding firms as they choose their scope. Our objective is to help guide through the decision of a firm considering its appropriate scope; so the left hand-side contains the questions to be answered, and the right hand-side contains the corresponding advice. Our "left-hand-side" questions correspond to three elaborations on Teece's (1986) analysis, with fairly important implications for business strategy (and public policy). Specifically, we consider issues relating to mobility and architectural advantage, to the focus of the business model,

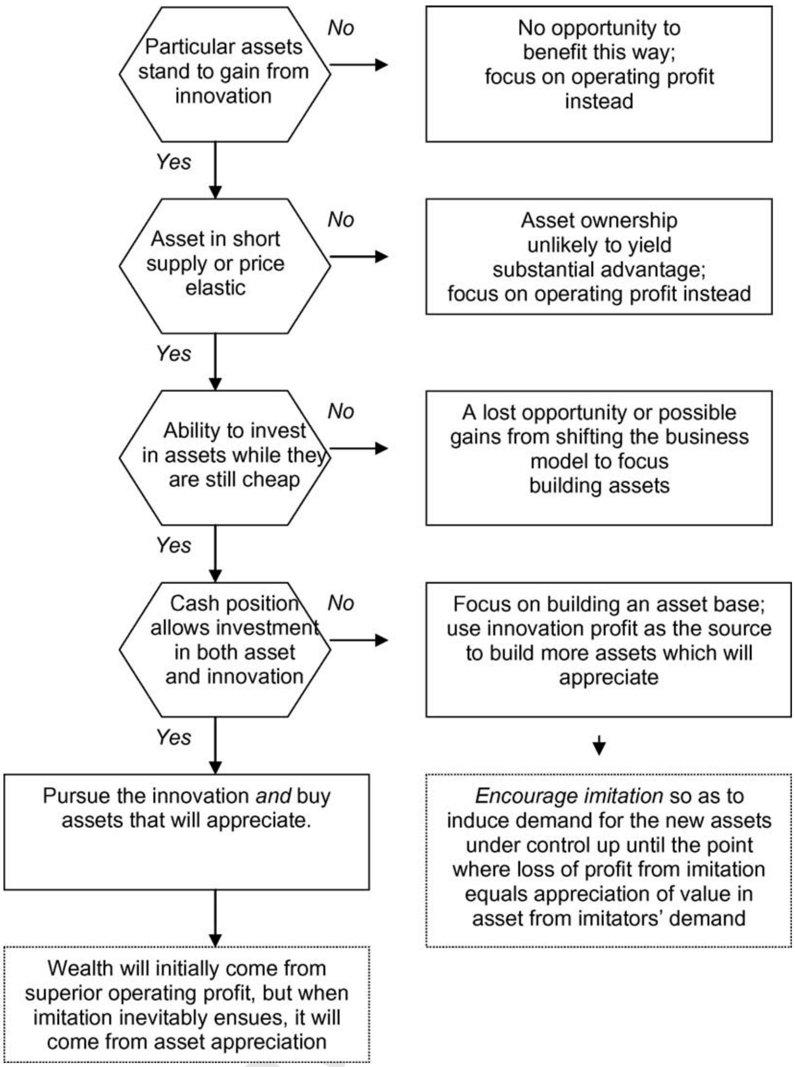

Fig. 3. Profiting from innovation: wealth creation through appreciating complementary assets.

and to the nature of capabilities that inform our choice of contracting versus integrating.

7.1.1. Issues relating to mobility

First, innovators should assess the relative mobility of the asset which is controlled and the complement which is not controlled. Relative mobility drives the division of surplus; the more competitive and mobile the complementary asset, the higher the returns, for any given level of intellectual rights protection, of the innovation. If there is sufficient competition in the complement, an innovator confronted by weak intellectual property protection would not need to access the specialized complementary assets and/or capabilities. Rather she could sit back and enjoy the fruits of her bargaining power, i.e. an advantageous share of surplus. Abstracting from intellectual rights protection, a firm can benefit inasmuch as it can enhance mobility in vertically adjacent stages, without needing to reduce the level of complementarity.

An innovator that has grasped this argument may obviously try to *achieve architectural advantage* by stimulating ferocious competition in the complementary assets rather than in their own segments. In this way, firms can gain architectural advantage, by shaping the structure of the industry around the needs of their own innovation and of their current position. Especially, for nascent sectors, an effective process of early brokering and positioning can lead to the creation of a potentially very profitable platform (Gawer and Cusumano, 2002; Iansiti and Levien, 2004; Morris and Ferguson, 1993;

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Santos and Eisenhardt, 2006). Thus, firms should aim to build architectural advantage without integrating if there is an unrealized potential for high mobility in the complementary asset (i.e. up- or downstream mobility).[18]

The flip side of our argument is that even in the presence of strong intellectual right protection, vertical specialization will not necessarily suffice. That is, intellectual property right is not a necessary (or sufficient) statistic that captures all relevant aspects of returns to innovation. A firm must therefore consider the mobility in its vertically related markets in order to asses the risk of value capture. A careful use of "mobility dynamics" can be used as a strategic weapon, and this can benefit the innovating firm *even in the presence* of strong protection.[19]

7.1.2. *Shifting the focus of the business model*

Second, innovators should consider if they would benefit from maintaining a narrow focus of their business model even in the face of loss from unprotected intellectual property or if they should rather broaden their focus and invest in supporting their platform.

Maintaining a *narrow* focus is favored when the costs of developing complementary assets are excessive, given the existing set of resources, capabilities and deftness from a focal firm's perspective favors some sharing of the fruits of innovation. In this case, "giving something away" in the negotiation process is sometimes advantageous on balance.[20] In other words, the firm should think about the strategic entry cost into the new area, *and* its ability to emulate the capabilities required for efficient operation (relative to experienced operators). The development and efficient operation of complementary assets should not be taken for granted, and we should closely examine the effectiveness with which it can be done. The latter costs were not given sufficient attention in the pre-capabilities era, the context of Teece's (1986) article, which led him to focus on the possibility of access (the firm's cash position). Indeed, when it comes to the question of increasing the relative bargaining power, or at least to increase the potential payoffs from innovation, we have to pay careful attention to the *costs needed to develop and manage complementary asset positions* (including the ability to replicate the capabilities and resource positions that characterize the asset complements). It is not quite as simple as saying that "moving into that area" (presumably, though Greenfield expansion or M&A) will resolve the problem with complementary assets. Consequently, the costs of developing complementary assets are an important determinant of the focus of the firm's business model, i.e. its boundaries.

A *broadening* of the firm's focus would be favored when the architecture within which it is located is rapidly expanding. The firm should consider whether it would be better off from getting a reasonable share of a growing pie, rather than myopically focusing on protecting a large share of a shrinking pie, a trade-off discussed by Gawer and Henderson (2006) and Iansiti and Levien (2004). Thus, a firm may be better off if diverted resources to support its platform even though such investment might also benefit its competitors. The issue here is whether the firm single-handedly, or in collaboration with others, is able to invest in sustaining its own vertical eco-system, and thus protect it against competing (and often incompatible) alternatives (see, e.g. Eisenmann and Suarez, 2006, on the case of Web Services). If the successful support of a platform requires joint investments among a set of collaborating firms, the usual free-riding problem must be solved so as not to undermine the effort.

7.1.3. *Contracting versus integrating*

Third, innovators should consider if the gains of integrating outweigh the possible loss of capabilities that drive the future innovation process. Quite apart from the cost of moving into complementary assets, a second issue is how scope shapes the capability development process; whether broader or more limited scope confers a dynamic advantage both depends on the particular context of a sector and its lifecycle (Jacobides and Winter, 2005). At a very fundamental level, the issue concerns the distribution of innovation over time. Thus, considerations of scope should encompass an assessment of the implied effect on the development of capabilities that

[18] Provided, of course, they have a strong position or innovation they can leverage. Alternatively, firms might want to consider how they can challenge the dominant architecture of their sector by *enveloping* the previous architecture—by creating a broader bundle that can encompass more, or different value-adding stages, much like Yahoo enveloped Real Networks, or how Microsoft is currently trying to envelop Apple in the digital music distribution business. Either way, the focus should be on *how a sector's architecture can be profitably managed*.

[19] Overall, the above extensions of Teece's analysis are valid when the following two conditions apply: (1) the level of analysis encompasses an industry architecture with multiple co-specialized members and (2) complementarity and factor mobility are distinctive components of co-specialization such that mobility can change without affecting the level of complementarity (and vice versa). When both of these qualifying conditions are violated, the strategies of innovation are precisely captured by Teece's (1986) core analysis to the extent that we further abstract from issues of asset appreciation (see Fig. 3 below).

[20] The conjecture that a firm would be better off leaving rents on the table has recently been convincingly demonstrated in a computational experiment (Woodard, 2006).

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support future innovation. This argument suggests that Teece's seminal 1986 article can also enrich his more recent work on dynamic capabilities (see, e.g. Teece et al., 1997): adjusting the scope of the firm both influences its current share of value and its future ability and propensity to innovate. Rather than only caring about how to protect the value of a single golden egg, we might want to think more carefully about the health of the goose that could lay numerous eggs (Winter et al., 2000). Accessing complementary assets inevitably changes the scope of a firm and thereby impacts its dynamic capabilities and propensity to innovate. In some cases, such capability adjustment may entail a costly loss of ability to come up with future innovations. Overall, the advantage of integrating should be balanced with the costs of interfering with the firm's ability to innovate in the future.

7.2. *Operating profit versus asset appreciation: an analytic summary*

Fig. 3 complements our analysis, and further extends Teece (1986) by including consideration of the fact that firms also have the choice of benefiting from innovation through the investment in associated complementary assets. Our prediction is that firms will (and should) invest in such assets when the marginal returns from asset appreciation exceed the marginal returns from supporting a firm's innovation. Fig. 3 below provides a summary of our analysis of balancing operating profits secured by control (ownership) with concerns about wealth creation through appreciating complementary assets.

Obviously, the issue of harvesting gains from asset appreciation is only relevant if an innovation will influence the value of some of its constituent assets. If so, the question arises when it pays to invest in these assets before the innovation diffuses. Overall, we should qualify the analysis of possible gains from asset appreciation (caused by innovation) by considering how the following two critical contingencies give rise to changes in asset value: (1) demand side effects and (2) factor mobility.

If factors are fixed (immobile), their value would appreciate in proportion to relative gains in productivity. Whether or not it would pay to invest in a specialized, fixed factor prior to the diffusion of innovation would in this case depend on the elasticity of demand. Only if the (absolute) elasticity of demand is sufficiently low, would it be advantageous to invest in the specialized factor (Lippman and Rumelt, 2003a,b), since this will ensure that the factor will appreciate in value as a result to increased demand, making the investment worthwhile.[21] (We abstain from an analysis of mobile factors at this point because it would involve a treatment in a general equilibrium setting that goes beyond the scope of the present work. As a useful starting point for those who wish to pursue this line of inquiry, the contours of general equilibrium treatment, based on the Stolper–Samuelson theorem, is presented in Appendix A.)

If we know the factor will appreciate in price, *once* the demand materializes (as opposed to appreciating even in the anticipation of higher demand), then we can turn to the next qualifying condition—the firm's financial resources. Only if it has sufficient capital would it be possible to invest in assets that would appreciate after the diffusion of innovation, and only to the extent that the expected returns from asset appreciation exceed the cost of capital or its alternative uses.

The firm should next consider if it has sufficient capital to invest *both* in the potentially appreciable asset and in the related innovation. If capital is scarce, so that a choice has to be made, then the advice is to *first* invest in assets that stand to appreciate and *then* encourage diffusion of the innovation (see Lippman and Rumelt, 2003a for an example). The firm should stop investing in the asset when the expected returns from asset appreciation are lower than investing in the innovation itself. Interestingly, the firm may then find it profitable to *invite imitation* in the underlying innovation, inasmuch as imitation leads to higher demand for the locked-in asset (and as such profit from asset appreciation), even though it reduces profitability.

By contrast, if the firm has sufficient capital to invest both in the asset that stands to appreciate and in the innovation, it could harvest operating profits in the early stage of the product lifecycle (when there is no imitation) and then benefit from asset appreciation in later stages of the product lifecycle (when competition reduces profits, but increases the asset value).

8. How to profit from innovation: looking ahead

This paper has taken steps towards extending the analysis and insights first presented in Teece (1986) by incorporating recent advances in fields as distinct as cooperative game theory (e.g. Brandenburger and

[21] We thank an anonymous reviewer for pointing this out in addition to providing a partial equilibrium analysis that identifies the condition under which it pays to invest in a fixed, specialized factor, namely if and only if the (absolute) elasticity of demand at marginal cost falls short of the inverse share of the specialized factor's share in marginal cost.

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Stuart, 1996, 2004), resource-based analysis (Lippman and Rumelt, 2003a; Winter, 1995), industry evolution (Langlois and Robertson, 1995; Jacobides and Winter, 2005), and theoretical economics (Deardorff and Stern, 1994). We provide the contours of an updated framework that helps integrate a number of pertinent issues in the analysis of gains from innovation. In essence, we suggest that the possibility of creating value from innovation is best viewed as a first imperative, whereas problems relating to value sharing can be seen as a second order qualifying condition.

True to the Teecian spirit, we hope to stimulate further research by reformulating some basic questions, e.g. shifting the question from "how do you protect innovation in order to reap the maximum amount of surplus" to, "how can you find a way to generate value and capture the greatest possible amount of surplus, regardless of whether others emulate the ideas or not?" We further proposed a revision of core constructs in order to facilitate a sharper analysis. Thus, we suggested that co-specialization comprises the two distinctive components of complementarity and factor mobility.

Finally, we argued that a new level of analysis (i.e. the industry architecture and the way firms can affect this) can provide new insights, and explain regularities that have evaded prior research, despite the fact that they appear to be of considerable importance in the eyes of managers or even regulators. To that aim we have provided, through Figs. 2 and 3, a specific template to help firms choose their boundaries wisely so as to benefit from innovation. We hope that this extension of Teece's research into the structural dynamics of architectural advantage might help stimulate yet a new wave of research inspired by his seminal paper.

These departures from the traditional mode of analyzing returns from innovation, complementary assets and firm boundaries are, we would argue, all the more pertinent in a time of flux in the nature and boundaries of economic organization; of increased specialization and collaboration among firms, not least due to the growth of outsourcing and offshoring arrangements; and to the dramatic challenges in fights within and between technology and industry platforms. We hope that our proposed extensions can help strategists and policy makers face such issues, as well as help steer research into promising uncharted areas.

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Appendix A. Discerning opportunities for asset appropriation

This Appendix provides the contours of a more structured analysis that can help trace the impact of an innovation on the value of assets or resources used in it. The analysis is based on a general version of the Stolper–Samuelson theorem (Jones, 1965), originally developed in the theory of international trade.[22] For a two-factor, two-good model, this general version says (Deardorff and Stern, 1994, p. 13): "an increase in the relative price of a good increases the real wage of the factor used intensively [widely] in producing that good, and lowers the real wage of the other factor".[23] To use an illustrative example, two primary factors, labor and land are used to produce two distinct commodities, manufactured goods and food.[24] Further assume that land is used widely in food production (agricultural products) and labor, by contrast, is used widely in the production of manufactured goods. The payments to the factors for the use of their services are wages to labor and rents to land. If the price of food increases relative to the price of manufactured goods, the real payments to the factor used widely in food production (land) will increase and the real payments to the factor, which is scarce (labor) will decrease.

The Stolper–Samuelson theorem is useful for a number of reasons, not the least because it highlights two critical contingencies: (1) demand side effects (increasing versus decreasing commodity prices) and (2) factor mobility. As an illustrative example, consider a product innovation that would increase the price of food relative to the price of manufactured goods. Note that land is the factor used widely in food production, whereas labor is the (relatively) scarce complementary factor. Further

[22] The Stolper–Samuelson theorem was an immense inspiration for research in international trade, and a beacon for general equilibrium theory that spawned a great number of empirical and theoretical articles. Ten of the most influential articles from the Stolper–Samuelson literature – including Bhagwati (1958), Jones (1965, 1985), and Ethier (1982) – published between 1949 and 1985, were collected in a volume celebrating the Stolper–Samuelson theorem's Golden Jubilee in 1991 (Deardorff and Stern, 1994).

[23] Deardorff and Stern (1994) refer to this general version of the Stolper–Samuelson theorem as the essential version.

[24] This is the standard example from Jones (1965).

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assume that factors are sufficiently mobile so the equilibrations assumed in a general equilibrium model are in force.

In this case, the general version of the Stolper–Samuelson theorem indicates that the (real) payments to the factor used widely in producing the good under consideration (land) will increase. That is, the more widely used resource will benefit (appreciate) from the innovation. From this follows the prescription that the innovator should invest in the widely used resource (land) before the innovation is launched. In contrast, the general advice drawn from Teece (1986) would be to contract for the specialized, and thus scarce resource (labor). Teece's advice is not unreasonable if we consider a Ricardian world with immobile resources (see elaborations in Lippman and Rumelt, 2003a,b). However, with sufficiently mobile resources, we arrive at a very different prescription. Indeed, the partial equilibrium analysis in a Ricardian world would be misleading if the production factors are actually mobile. In actual practice, the general version of the Stolper–Samuelson theorem presented here (Jones, 1965) and its extensions would be useful under three conditions: (1) if the firm would be able to influence demand by its own actions (the firm must have a significant market share), (2) if the firm could stimulate the diffusion of innovation (the firm must have good marketing capabilities), or (3) if the firm could predict swings in demand (the firm must have good market intelligence).

Our example assumed that the innovation would increase the price of food. By contrast, if food prices would decrease, the (more) scarce resource would appreciate. This again follows from the general version of the Stolper–Samuelson theorem, according to which an increase (decrease) in the relative price of a good increases (decreases) the real wage of the factor used widely in producing that good, and decreases (increases) the real wage of the relatively scarce factor. With decreasing food prices, our prescriptions align better with Teece's: the advice, in this case, would be to invest in the scarce resource or, if that were not possible, to contract for access to it as suggested by Teece (1986).

A further result follows from the Stolper–Samuelson theorem when one considers the realistic situation of a more than two goods and factors. With multiple factors, the Stolper–Samuelson model becomes much more involved and the predictions considerably weaker. According to one multi-factor version of the model, some factors will definitely gain and others lose from the innovation (Ethier, 1974; Jones and Scheinkman, 1977). According to another, complementary version, factor price changes will be positively correlated to the factor-intensity-weighted averages of the good price changes (Ethier, 1982). These results can be combined to provide the basic insight that some factors will definitely gain and others lose from the innovation, with gains and losses being related to the intensities of factors used in the production of the goods (Deardorff and Stern, 1994). A reasonable, but cautious prescription of the multi-factor version is that decision makers through experimentation must verify the identity of the factors that are destined to definitely gain and lose from the innovation. Thus, the Stolper–Samuelson theorem tells us that a fundamental indeterminacy clouds prediction of asset prices when one considers mobile factors in a realistic world with more than two goods and factors, i.e. a kind of causal ambiguity. In this case, investment in widely used assets (scarce assets) will tend to be advantageous if commodity prices increase (decrease).

The Stolper–Samuelson framework suggests that factor mobility is a critical issue in the analysis of asset appreciation and this result can be compared with the usual Ricardian analysis, according to which differences in factor payments reflect comparative advantage in productivity. The Ricardian analysis is obviously at odds with the Stolper–Samuelson theorem. The reason lies in what is assumed about factor mobility. Whereas the Stolper–Samuelson theorem is based on a general equilibrium model, assuming that all factors are mobile, the Ricardian analysis of comparative advantage is based on a partial equilibrium model assuming that factors are immobile. With high levels of immobility, the nurture of dynamic capabilities would be an important consideration. At the limit when all assets of a joint combination are completely immobile, their value would appreciate in proportion to relative gains in productivity. Whether or not it would pay to invest in a specialized, fixed factor prior to the diffusion of innovation would in this case depend on the elasticity of demand. Only if the (absolute) elasticity of demand is sufficiently low, would it be advantageous to invest in the specialized factor (Lippman and Rumelt, 2003b).

Overall, we should qualify our analysis of possible gains from asset appreciation (caused by innovation) by considering how the following two critical contingencies give rise to changes in asset value: (1) demand side effects (increasing versus decreasing commodity prices) and (2) factor mobility. The present analysis provides the contours of an analytical approach and points to the promise of opening up the "black box" of creating wealth through asset appreciation. Our treatment of this issue is obviously rather incomplete, inviting future research that can provide a comprehensive analysis.

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