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Ecosystem Advantage: How to Successfully Harness the Power of Partners

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Changes in the global environment are generating opportunities for companies to build advantage by creating loosely coupled networks or ecosystems. Ecosystems are larger, more diverse, and more fluid than a traditional set of bilateral partnerships or complementors. By leveraging ecosystems, companies can deliver complex solutions while maintaining corporate focus. This article describes six keys to unlock ecosystem advantage: pinpointing where value is created, defining an architecture of differentiated partner roles, stimulating complementary partner investments, reducing the transaction costs, facilitating joint learning across the network, and engineering effective ways to capture profit. (Keywords: Networks, Value creation, Organizational structure)

Twenty-first century customers are increasingly demanding complex, integrated solutions rather than standardized products and services delivered in homogeneous volume. Companies can no longer satisfy these demands by drawing on the knowledge and capabilities of just a few, large-scale specialist units. Instead, in more and more industries, the relevant knowledge and capabilities are abundant. However, they are also dispersed among potential players and scattered across the globe. These trends, combined with today's volatile world of uncertainty and rapid change, call for a structure of activities and interactions between businesses that can be quickly and flexibly reconfigured.

These challenges are difficult for a single, vertically integrated firm to meet. However, given the state of technology until just recently, the only really viable alternative was a market, composed of large numbers of participants, who independently and often myopically responded to price and volume signals and lacked the mechanisms for coordination and joint evolution of their specialist capabilities. When faced with products and services that depend on the exchange and sharing of complex, messy, and often un-codified knowledge, such a market often fails. It works best for the exchange of simple standardized products and certain commodities.

A potential solution to this conundrum may be found in what we term, following James Moore, a "business ecosystem"—a network of organizations and

individuals that co-evolve their capabilities and roles and align their investments so as to create additional value and/or improve efficiency.[1] Given the changing competitive context, this form of organization can be superior to both the classic integrated organization or to a streamlined supply network based on principal-agent relationships. A vibrant ecosystem can enable activities, assets, and capabilities to be flexibly and constantly reconfigured in response to the unexpected. By leveraging a network of specialized partners, it can help solve the dilemma of how to deliver more complex solutions demanded by customers while maintaining corporate focus. By enabling a diversity of tacit knowledge to be mobilized, an ecosystem can also help speed up innovation and improve customer service.

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Some ecosystems evolve through serendipity and self-organization. However, a "lead firm" can catalyze the emergence and subsequent development of an ecosystem. This lead firm is defined by *how it uses smart power*[2] *to play an active role in stimulating and shaping the business ecosystem around it, rather than because it is the largest or most resource-rich participant.*[3] By taking a strategic approach that actively promotes and guides the development of its business ecosystem, the lead firm enhances its own competitive advantage and ability to capture value. The critical question is: How a company can shape the structure and workings of its business ecosystem to simultaneously *create* and *capture* value, while minimizing the detrimental effects of surrendering hierarchy, vertical integration, and direct control?

Re-Discovering Ecosystem Advantage

The idea that a company's own success partly depends on how effectively it co-opts the complementary capabilities, resources, and knowledge of the network of firms, institutions, and individuals around it is by no means new. The management of "common land" in medieval Britain, and probably long before, was based on a network of partnerships. These preserved individual incentives and a degree of autonomy. The system maintained flexibility while enabling parties with different, but complementary, capabilities to work together for their joint benefit. Studies of the woolen textile cluster in 14th century Prato, Italy, have shown how specific companies both contributed to and leveraged upon the mutual strength of a network.[4] Leveraging a similar network many centuries later propelled clothing companies such as Benetton in Italy and Zara in Spain into the global market.

From the late 19th Century, the quest to reap economies of scale became the driving force for business. Integrated, hierarchical organizational structures followed.[5] Standardization of processes and of procurement of materials favored hierarchical firms over networks of individualistic firms, especially in an era where the primary demand was for rapidly increasing volume of standardized goods and services. The benefits of increased specialization, meanwhile, could be maximized by creating a few large, well-located units. In a world where technology for communications and knowledge exchange was primitive, corporate hierarchies offered the

most efficient way of reducing transaction costs and synchronizing supply and demand between these specialist units.

Since that time, both the demands of consumers and the technologies available to satisfy them have changed dramatically. Today's world requires the capacity to deliver complex solutions to customers, built by bringing together specialized capabilities scattered in diverse organizations around the world. At the same time, suppliers of these solutions need to maintain flexibility and a rapid pace of improvement. The imperative is to achieve not only economies of scale, but economies of scope. Fortunately, the dramatic fall in the costs of information technology and communications (ICT) allows us to co-ordinate—effectively and economically—widely dispersed capabilities and knowledge.

The potential of modern business ecosystems to enhance competitive advantage is an extension of the same benefits that are to be gained by setting up multiple, bi-lateral alliances with what have been termed "complementors"[6] (or working with outsourcing partners). A large body of excellent work has examined how to manage these types of arrangements effectively, including the need for a central strategy and processes both to maintain consistency between the partners and to manage communication and conflict between partners.[7] However, to create the kind of advantage we envisage, the ecosystem needs to be an order of magnitude more complex in size and scope. It requires the coordination of many fluid, organic, diverse, and difficult-to-manage relationships with many different types of parties. Rather than simply scaling up the established rules for managing bilateral relationships to cope with many alliances, it requires us to re-think how the lead firm might change its role to be effective as an orchestrator that shapes the ecosystem indirectly rather than through direct negotiation, command, and control.

The idea that a lead firm can succeed in promoting the alignment of a potentially large number of players, many of whom may not even be individually known to it, may seem like an impossible task. This might look even less feasible when the goal of uniting such a diverse and numerous set of protagonists is to strengthen that firm's own competitive advantage. Yet back in the 1950s, when most companies felt themselves to be largely at the mercy of market forces over which they had little control, the idea of developing a strategy to shape their future probably seemed equally radical.[8] Today, lead companies—such as ARM Holdings Plc, a major supplier of intellectual property to the semi-conductor industry; Dassault Systemes, Europe's second largest software company; SAP; Apple; and Google—have gained success by powerfully shaping (although not fully determining) the formation of business ecosystems around them that help fuel their growth and enhance their returns. (See Appendix.)

The Potential Strengths and Weaknesses of Ecosystem Strategies

Strategies that leverage an extensive and varied ecosystem can offer a number of important benefits to the lead firm. First, they allow the lead firm to meet customer demand for complex, integrated solutions by mobilizing a rich diversity of complementary capabilities while its own activities remain focused.[9] In cases where the lead

firm is able to build a platform on which the ecosystem rests, it may also be able to reap economies of scale with much lower capital investment than would be required if it tried to undertake the full panoply of activities itself.

A good example is the so-called "smart grid"—an electricity distribution grid that has been upgraded to incorporate information sensors, digital meters, and a communications network that can avoid outages, optimize energy allocation, and incorporate fluctuations in the supply from green technologies such as wind, wave, and solar power generation. IBM aspires to be one of the lead companies in this arena with its "Smarter Planet Initiative." However, to accomplish the required combination of technologies, capabilities, and infrastructure necessary to deliver the smart grid, IBM recognized that it "needed friends—lots of them" interacting intensively and in ever-changing configurations. So it kicked off the initiative with eight charter members including Johnson Controls, Honeywell Building Solutions, Cisco, and Siemens. The goal goes far beyond research collaboration. Instead, IBM seeks to launch a new business model that integrates their technologies with a complex set of products and services from the ecosystem partners dubbed "The Green Sigma Solution."[10]

Second, complementary assets can be left in the hands of ecosystem partners—provided that the lead firm acts as more than a pure orchestrator and itself contributes one or more assets that are necessary to deliver value. Many companies seek to access complementary capabilities through M&A deals. However, the benefits often fail to materialize because the capabilities, skills, and knowledge cannot be smoothly transferred and integrated into the acquirer's organisation.[11] An ecosystem strategy allows the lead firm to avoid these risks. By leaving the capabilities with the partners in the ecosystem, it can also continue to benefit from the stimulus to innovation that comes from partners' ability to go on drawing from the varied geographies and market contexts in which they operate as well as from their unique corporate cultures.[12]

One approach to gaining these advantages is to establish multiple, bi-lateral alliances with complementors. This kind of hub-and-spoke arrangement places a significant burden on the lead firm, both because of the investment required in order to set up the network and the on-going resources required to manage it. The on-going costs include the need to act as a conduit for communications, as a go-between to achieve complementarities, and as an arbiter of disputes between every partner in the web. The kinds of ecosystems we have studied are different. They require the lead company to establish an overall architecture, to structure the key interfaces and incentives, and to co-opt a small number of strategic partners, but then to rely on self-organization within the network. Once a virtuous cycle is established, partners join and depart and interact between themselves without intervention by the lead firm. In fact, in some cases, the lead firm might not even know the identity or even the existence of some of the partners who are co-evolving their capabilities and aligning their investments while also helping bolster its competitive advantage as they pursue their own self-interest.

Third, by building an ecosystem around its core activities, the lead firm can enjoy more flexibility in the configuration of its business system. It may not have to make acquisitions and disposals or renegotiate rigid contracts in order to reconfigure

the business. The ecosystem can flexibly evolve by new partners joining and others exiting the ecosystem, by partners making additional investments in capacity or reducing their commitment, or by re-focusing their own activities.

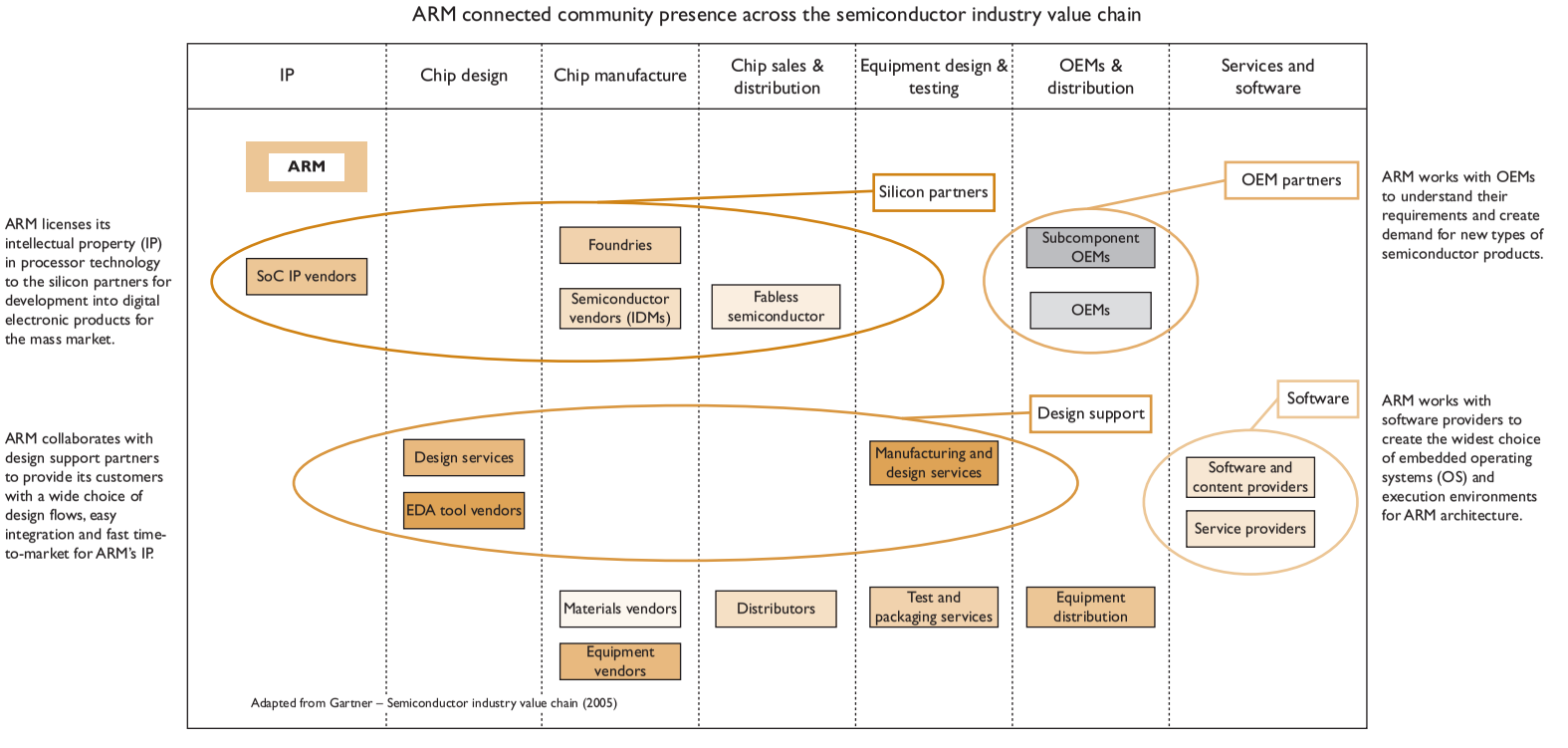
Finally, a firm that can stimulate the development of a large and diverse ecosystem will also be able to enjoy access to a greater pool of knowledge. Potentially, the ecosystem may benefit from faster learning than any single organisation.[13] Here ecosystem strategies can extend the idea of an "open innovation" R&D engine. Open innovation is the concept that: "firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as the firms look to advance their technology."[14] However, this is only one dimension of a broader ecosystem that involves re-configuring the entire activity chain to harness the knowledge and joint innovation capacity of partners in such things as production, delivery and distribution, market making, tools and training, after-sales service, and R&D and innovation. ARM, the RISC processor-design company in Cambridge, UK (and which we will use as one of our two key examples), has leveraged an ecosystem strategy to build a semiconductor business with a market capitalization of over $10 billion despite being a: "chip-less, fab-less chip company" with limited capital investment.[15] A very simplified snapshot of the ecosystem of ARM is provided in Figure 1. Shaping an ecosystem that allows knowledge to be mobilized and pooled has been a core element of ARM's success.

The potential benefits of strategies that harness the power of a business ecosystem can be high. However, we should not forget the very real benefits delivered by the traditional organizational hierarchy, i.e., a structure that internalizes the linkages between different activities and specialist competences inside the firm. Its benefits include: the advantages of lower transaction costs; the ability to maximize alignment between different specialist activities and players and optimize the interfaces; and reduced risk, uncertainty, and variability[16] through direct control.[17] The success of Intel's vertically integrated business model or the closed and tightly controlled way in which Apple designs and develops its core hardware platforms (such as the iPod, MacBook, and iPad) are important reminders that building an ecosystem is not always the optimal strategy.

Strategies based on ecosystems also expose the lead company to the risk that most of the profits will leak away to partners. They may have difficulties in appropriating the benefits created by the value offered to the final customer. Recall the early battle in personal computers between the "IBM-compatible" ecosystem of hardware, software, and services suppliers and Apple's much more independent, integrated value chain. For decades the IBM-compatible ecosystem dominated the market. However, the lead firm (in this case IBM) struggled to achieve sustainable profitability in the business. The example of Microsoft and Intel as complementors[18] provides another interesting case of how difficult it was for Intel to capture the value out of their tight relationship and how often Microsoft used its power to impose its choices on its partner. Building a thriving ecosystem around you, therefore, is far from sufficient to guarantee success.

Nonetheless, ecosystems strategies do offer interesting advantages in the right contexts. These include competitive environments where customers demand complex, integrated solutions; where knowledge is a key resource and tends to be dispersed

FIGURE 1. ARM's Connected Community



among different organizations and locations around the globe; and where the need to cope with considerable uncertainty demands flexibility in how value is created. Fundamental trends in the global market mean that companies are facing exactly these challenges in more and more industries. At the same time, new technologies are enabling the efficiency of loosely coupled networks to be improved relative to traditional hierarchies.

Contextual Drivers of the Growing Importance of Business Ecosystems

There are four reasons to believe that ecosystem strategies will become more important in determining future competitive success. First, many businesses face growing pressure to focus on fewer core activities in order to cope with rising investment demands and avoid increased costs of complexity. Focus enables them to target their capital expenditure on deploying the latest technology on their core processes and to concentrate on deepening their core competencies.[19] The adage "focus and win" has become a popular catch phrase. However, shrinking to a focused core of activities is at odds with customers who are increasingly demanding more complete solutions to their needs that bring together multiple products and services in complex, often customized, bundles. There are many examples of this trend: simple mobile phones have been replaced with smartphones that offer a myriad of services; in dense urban environments, cars have been replaced by services that offer transport by the hour; and simple loans have been replaced by complex financial products. In each of these cases, the value is created by a combination of products and services that are delivered by an extensive group of partners. The example of "cars by the hour" requires the collaboration of rental car companies with urban authorities who provide the spaces where these cars can be parked, new designs for cars (as is the case in Paris where a totally new electric car was developed), and new billing systems.

One answer to the "shrinking core, expanding periphery" problem is to outsource more to partners.[20] However, it is difficult to reliably deliver a complex solution bundle involving multiple technologies, capabilities, and services using vertical integration or the kind of subcontracting relationships familiar in traditional supply chains.[21] Rather than outsourcing a few well-defined activities, delivering complex customer solutions requires the management of complicated interactions and an exchange of knowledge between many, mutually dependent partners—a task to which ecosystem strategies are better attuned.[22]

Second, the knowledge content of many business activities is rising. The resulting increase in the number of "knowledge workers" dealing with tacit and uncodified knowledge means that simple, standardized physical interfaces no longer meet the needs for interaction and exchange required in many industries. Instead, more complex knowledge must flow between partners, grey boundaries of responsibility need to be managed, as does the claim to intellectual property generated in the course of business. Consider our second core example of the French software company Dassault Systemes (DS). They are the world's leading specialists in providing solutions for Product Life Cycle Management (PLM). Whereas the basic principles

of the modeling and design of products and processes may be common to many industries, effective software solutions need to incorporate in-depth, and very often tacit, knowledge of the industry in which they will be used. To access this knowledge, DS collaborates with hundreds of partners, including system integrators, customers, and suppliers. Many of these development partners are granted managed access to the internal DS social network. It is this ecosystem of partners that enables DS to be relevant, innovative, and successful in 11 different industries and to gradually increase its market share in PLM systems. As knowledge management becomes increasingly central to competitive advantage, the model of an extensive ecosystem will become more critical to success. This model allows knowledge and innovation to be rapidly generated through joint learning between a wide diversity of different partners stimulated by different contexts, histories, and cultures. Developing such an ecosystem with lots of partners will enhance innovation and provide more opportunities for growth. This will make ecosystem strategies with their ability to sidestep many of the issues faced when trying to move and transplant knowledge, much of it embedded in the people, systems, and cultures of external organizations.

Third, companies face increasing uncertainty. Ecosystems, where the partners can collaborate flexibly through loosely coordinated development and experimentation, can absorb this uncertainty more effectively than traditional hierarchies or subcontracting relationships, where deliverables have to be precisely specified in advance and structures are more difficult to reconfigure.[23] This advantage is being reinforced by the ability of ecosystems to enable lead firms to reap scale economies with less capital investment. This is especially important in "winner-takes-all" industries where increasing returns to scale are decisive.[24]

Fourth, advanced information and communications technology (ICT) is becoming more powerful and cost-effective. This enables business ecosystems to economically marshal diverse resources and knowledge scattered across the globe. In the past, potentially valuable networking between diverse and dispersed partners was often thwarted by the prohibitive costs of the ICT required to facilitate ongoing interaction and knowledge exchange. Remote communication will not be a complete substitute in the near future for face-to-face interaction. However, its technological advances and falling unit costs are enabling more complex and dispersed ecosystems to become economically viable. Dassault Systemes has developed software that enables engineers from the lead firm and its partners all over the world (in France, the USA, Japan, and India) to work together on a mechanical design in real time. Difficulties due to differences in language have been reduced significantly by the creation of a standard technical language for actions that designers take on the common design. The animation studio Wild Brain is another example. It uses independent writers based in Florida, London, New York, Chicago, and Los Angeles. The animation of the characters is done by specialist companies in Bangalore with edits done in San Francisco. A single film involves eight teams in Bangalore matched to eight counterpart writers working in parallel using a private network that allows every participant to share feeds of sound and images from the recording sessions, real-time script, and all the animation designs from every location simultaneously.[25] ICT is dramatically narrowing the efficiency gap between the traditional corporate hierarchy and ecosystems composed of diverse and dispersed partners.[26]

Given these fundamental trends in the business environment, harnessing the potential of your ecosystem is becoming a high-stakes imperative in more and more industries. Today's battle between the Nokia-Microsoft alliance, Apple, and Google in the market for smartphones can be described as a clash of alternative ecosystems. Nokia's attempts to build a vibrant ecosystem around its Symbian operating system decayed to become virtually Nokia-specific and its inability to leverage partnerships effectively to add user-focused services (such as e-mail, maps, and its "Comes With Music" offering) left it dangerously exposed. Apple, meanwhile, has stimulated an army of developers—from Electronic Arts (one of the world's largest producers of electronic games) to individuals working in garages—to create over 400,000 applications that run on its iPhone. Google has leveraged an ecosystem dubbed "Open Handset Alliance"—which started out with a group of 47 technology and mobile communication companies—to rapidly establish its Android platform as a major player in the market for mobile devices. Likewise, IBM, Oracle, and SAP now talk about the strength of the business ecosystems as a decisive factor in competition for tomorrow's distributed world of "cloud computing," where software will increasingly be sold as a service, rather than a product.

To be clear, we are not arguing that business ecosystems are the only way forward. However, the competitive context may well be changing in such a way that this form of organization becomes superior to the classic integrated organization or to a straightforward principal-agent relationship in a supply network. Some firms will develop hybrid forms combining the integrated organization for some of their activities with a business ecosystem for other activities. Apple, for example, has opted for an integrated system in its hardware development, whereas it has created a business ecosystem for its applications. Fundamental changes in the business environment, however, mean that ecosystem strategies can be expected to play an ever-greater role in building future competitive advantage.

Six Keys to Ecosystem Advantage

If under certain conditions a business ecosystem can deliver more benefits, it becomes important to explore how a lead firm can promote and shape the development of the ecosystem around it. Business ecosystems obviously differ markedly in their scope, structures, and the nature of the relationships and processes on which they depend. However, by examining several ecosystems in depth, we have discerned common patterns that suggest a set of rules lead companies should follow to gain ecosystem advantage.

Companies that are successful in leveraging the potential of ecosystem advantage start from a premise that contrasts with a number of traditional assumptions about the global competitive environment. They accept that knowledge is abundant and widely distributed both internally with their organization and in the external world. So the task is to harness this potential. They understand that intellectual property (IP) gains value when it is connected to the complementary IP and knowledge of many. They realize that the ultimate key performance measure (KPI) is the value you create for the customer—whether directly or jointly through others. The

ultimate KPI is not the volume of activities, the number of people you employ, or the accumulation of internal assets you control.

Once a company's senior management has adopted this perspective, the task is to turn these insights into a profitable business model. In Table 1, we present six keys to unlocking ecosystem advantage, illustrating the kinds of initiatives a lead company might take to put them into practice.

As noted earlier, the lead firm is one that uses smart power[27] to play an active role in stimulating and shaping the business ecosystem around it. This lead firm is not necessarily the largest or most resource-rich participant, as the case of ARM illustrates. The lead firm is important to the concept of an eco-system and its active role becomes clearer through the six keys of eco-system advantage.

TABLE 1. Keys of Ecosystem Advantage

Key to Advantage	Criticality	Implementation
Pinpointing the Added Value	Pre-requisite to cover inevitably higher costs than vertically integrated structures	By identifying the primary sources of value added, firms such as ARM, Google or Dassault were able to target the required complementarities and hence the right partners to attract.
Structuring Differentiated Partner Roles	Essential to achieving the benefits of specialization and focus for individual partners and promoting cooperation over competition	By differentiating partner roles, the lead firm can keep the burden of partner interaction to manageable levels. Of its more than 400 network partners, ARM for example, 20 are identified as key, bellwether partners where the relationship is managed by an ARM director.
Stimulating Complementary Partner Investments	Enables the lead firm to amplify the impact of its investment and create potential for increasing returns to scale	An analogy is that of "striking a match and positioning it to get a fire going." In its iTunes ecosystem, for example, Apple has encouraged hundreds of thousands of developers to make complementary investments in developing "apps."
Reducing Transaction Costs	Key to minimizing an important cost disadvantage relative to vertically integrated structures	Dassault Systemes, for example, facilitates co-development with hundreds of partners by granting managed access to its design tools and internal knowledge network.
Enabling Flexibility and Co-Learning	Flexibility and accelerated co-learning are important potential advantages relative to vertically integrated structures	ARM's ecosystem, for example, is structured through a mix of formal contracts and informal sharing based on continuous interaction so as to flexibly promote knowledge creation, not only for ARM itself, but also for its partners—including new entrants to the network.
Engineering Value Capture Mechanisms	Ecosystems have a risk of "free-rider" problems where the network architecture established by the lead firm creates value for participants but fails to capture value for itself	Successful ecosystem strategies by companies like ARM and Apple have deployed a combination of three value capture mechanisms: rents on underlying proprietary technology on which the whole system depends, reaping economies of scale for their own operations, and by positioning themselves to uniquely access some of the accelerated learning generated within the ecosystem.

Pinpointing the Added Value

Much of the discussion around business ecosystems focuses on how value is shared between the various parties involved. Certainly it is an important principle that participation has to be attractive to those involved to sustain a thriving ecosystem. However, it is equally critical to remember that all the costs and profits within the ecosystem have to be covered by the ultimate customers for the network's products and services. Customers' willingness to pay depends on the recognition of incremental value from the ecosystem over and above that offered by an alternative, vertically integrated supplier. A large and diverse ecosystem can create additional value for the customer by improving functionality, promoting faster innovation, or enabling higher levels of customization.

This potential for creating value is well illustrated by ARM. Despite being a tiny part of the total value chain in the mobile phone industry (Figure 1), ARM has fostered the development of an ecosystem around its designs for Reduced Instruction Set Computing (RISC) chips, and this has created significant value. In 2010, its designs powered 98% of the world's mobile telephone handsets. ARM has attracted handset makers such as Nokia and Samsung to its ecosystem because they can share the costs of developing a flexible platform on which to build their devices across virtually the entire industry. This enables them to concentrate their resources on developing their own proprietary technologies on top of ARM's base to make their products more attractive to their customers. Being part of the ecosystem for RISC chips also allows handset makers to choose from a wide range of semiconductor manufacturers who use the same standard designs, rather than being locked into proprietary technology. It improves their chances of finding supplies when an upswing in the semiconductor cycle leads to a shortage. As a result, end customers benefit from improved reliability, lower costs, and faster access to technological advances. ARM summarizes its strategy as follows: "create a partnership with our customers and broader community of third parties to enable the creation of end products more efficiently through ARM than from any other source."

Another example is Google's Open Handset Alliance. By 2011, it brought together 84 technology and mobile telephony companies working with the "Android" operating system to "offer consumers a richer, less expensive, and better mobile experience by accelerating innovation."[28] By sharing a common platform, partners in the Android ecosystem can launch a wider variety of new applications (such as games and mobile services) more quickly and cheaply.

A third example is Dassault Systemes. Their core product is a suite of computer-aided platforms for product and process design, testing, and simulation bundled in Product Lifecycle Management (PLM) systems. The core software platforms for computer-aided design, computer-aided manufacturing, simulation, and document management can perhaps be considered to be a standard product. However, the application of these products in a particular industry requires a lot of customization. The fashion industry requires a very different approach from that of the automotive industry or the food industry. Key to its strategy is its "PLM Ecosystem, a broad and tightly knit network of partners, all contributing to the enhancement of the product offering, facilitating the deployment and optimizing the use."[29] That, in turn, allows

their ecosystem to deliver a wider product offering and more customization to the needs of these users in particular industries.

These three examples show how value can be created for the customer: improved functionality, faster innovation, or higher levels of customization. The first step toward nurturing a successful business ecosystem is to pinpoint exactly why it will create extra value for the end customer. This analysis, in turn, enables the lead company to target the right complementarities and opportunities for co-learning and hence the right kind of partners to attract to its ecosystem.

Structuring Differentiated Partner Roles

In order to deliver customer value cost efficiently in an ecosystem, the activities of partners with complementary capabilities need to be aligned. This requires the lead firm to create a structure and incentives for attracting partners and to manage the overlaps and possible conflicts between them. Any partner can play one or more roles. These include providing components of a solution (as in a traditional supply chain), operational capacity, sales channels, or complementary products and services. Partners in an ecosystem can also act as an important source of technology and competence or of market and customer knowledge. Whenever ARM grants a license to use its technology, for example, it develops a reciprocal relationship with the licensee. The aim of this relationship is to gain insights into the licensee's process technology roadmaps and access to emerging applications, becoming a two-way partnership. Under this arrangement, ARM's partners not only boost ARM's sales, but also provide market knowledge and insights that help ARM to design chips better suited to future market and application needs and to developments in chip fabrication and design technologies.

Partners can also act as "market makers" for the ecosystem. Their operations or reputations may help gain acceptance of a product or technology in the market and thus stimulate additional demand. In pursuing sales of their own products and services they may "pull through" demand for the complementary offerings of the ecosystem. Likewise, partners may generate "spill-over" demand because, by training users of their own products, they create the potential to leverage this investment in new skills by using them for other activities and products that use the ecosystem's common protocol.

Ideally, the lead firm should aim to promote an ecosystem that combines a set of specialist niches, each of which makes a different contribution to customer value and that create a positive spiral by generating new knowledge or additional demand as they interact. One or more partners may profitably inhabit each niche—which itself may be large in terms of volume and revenues. In the case of ARM's ecosystem, for example, wafer fabrication forms such a specialist activity, as does the creation of electronic design automation tools. Both niches count tens of partners. Competition within each niche may generate benefits for the ecosystem by encouraging rivals to improve efficiency or drive innovation in that activity.

Overlaps between the ways in which each niche contributes to the overall value that the ecosystem delivers to the end customer, by contrast, are likely to be detrimental to the ecosystem's performance. This is because if the niches, and hence the tasks, overlap, the interfaces between the elements will become blurred.

Duplication, uncertainty, and confusion will result. The lead firm's aim, therefore, is to assist the emergence of a structure where each bundle of value-creating activities is clearly delineated from the next so as to form a neat jigsaw of niches. Each of these niches would be "plug-compatible" with the others so that customers could choose to reconfigure the particular set of delivery partners in accordance with their specific needs without disrupting the ability of the ecosystem to seamlessly deliver its end product.

Lead firms also need to be able to manage the process of joint learning in ways that maintain the delineation and compatibility between the different niches as the ecosystem evolves. However, unlike the "complementors" model based on multiple alliances, the lead firm does not need to invest in a process to actively manage the day-to-day interaction between the partners.

If the ecosystem partners are to continue to invest and innovate, however, the lead company will also need to credibly signal that it will not enter a partner's niche. Intel, for example, has taken different approaches to the issue of declining to enter some complementary markets, while entering others it felt were core to its value proposition, even in the face of damage to its relationship with partners.[30] This has arguably limited Intel's ability to expand and leverage its ecosystem. ARM, by contrast, has carefully avoided investment in any activities that threaten to squeeze the market potential for partners in its ecosystem.

The set of niches composing the ecosystem also needs to be complete; all of the necessary tasks that are required to deliver value to the end customer need to be covered. This may seem obvious, but important gaps can sometimes be overlooked. In businesses characterized by "network effects"—where the user benefits only when a critical mass of others adopt the same technology, for example—market making will be an essential ingredient for value creation even though it is not technically required to deliver the product or service. To ensure both that these gaps are filled at the outset and that the contribution of different niches is maintained, the lead firm needs to find ways to stimulate the partners to make complementary investments to the ecosystem. By stimulating partners to co-invest, a lead firm can also create a multiplier effect, thereby enabling exponential growth in the ecosystem for each incremental investment of its own resources.

Structuring the ecosystem and partner roles in this way may seem like an ambitious task, but a company like DS has been successful in designing a clear architecture that attracts the right partners.[31] As a result, DS has built up an extensive network of technology partners such as Barco or AMD (dedicated to hardware and peripheral technology developers); independent software partners such as LMS Systems or Metrologic (who use DS's platform to create and sell applications); services partners (e.g., leading IT systems integrators); solutions partners (who use the DS framework to support the growth of their business with DS software solutions); and education partnerships.

Stimulating Complementary Partner Investments

Partners will only co-invest, of course, if they see the prospect of building a profitable business. The lead firm therefore needs to consider how it can create value propositions for potential partners as well as end customers.[32] Google Maps is a good

example of this. Their proposition to partners is that: "Google Maps and associated infrastructure acts as an innovation hub where potential partners can create new applications that incorporate elements of Google functionality. Partners can easily test and launch applications and have them hosted in Google World that has 150 million customers globally."[33]

If the partner value proposition is weak, or the niches created turn out to be chronically unprofitable, the ecosystem will be unable to solicit the necessary partner investment to underpin stable growth. Likewise, if the lead firm routinely encroaches on profitable partner niches by seeking to bring them in-house, partners' willingness to invest will be undermined. In some cases, the evolution of technology may demand that the lead firm incorporates a niche into its in-house activities so as to improve the value delivered to end-users. Such was the case, for example, when Intel incorporated wireless capabilities that were formerly provided by partner firms that supplied the PCIMA cards into its Centrino chip to improve the performance and convenience of wireless applications.[34] In a healthy ecosystem, however, this should be a rare event. Even then, it is preferable if the lead firm is able to open up new niches that existing partners might migrate into in order to maintain the willingness of current and future potential partners to invest in the ecosystem.

High levels of uncertainty from any source, of course, will dissuade partners from investing. Coping with uncertainty in an eco-system is made more difficult by the diversity in the partners' objectives and cultures. This diversity increases the risk that individual partner investment decisions follow divergent, or even conflicting, paths. It also means it is difficult for individual partners to understand the causality of what is happening in the eco-system. This increases the risk of a breakdown of "sense-making," so that even well-intentioned investments in the ecosystem may prove useless, or even destructive. Providing a clear roadmap for the future evolution of the ecosystem is one of the most effective things lead firms did in the successful cases we observed. This enabled them to reduce the uncertainty for potential partners around future technology platforms on which the ecosystem was built. This is particularly important in fast-moving industries with rapidly changing technologies.

To be effective in reducing uncertainty, the lead firm must find ways of communicating the roadmap transparently to current and potential future partners, some of whom it may not even know. Such a roadmap also has an important role in helping partners converge on a coherent set of product and service offerings. Without it, activities and investments across the ecosystem risk becoming divergent. This would undermine the ability and willingness of participants to make the long-term investments necessary for the future prosperity of the ecosystem. At the same time, the roadmap's prescriptions need to be sufficiently broad to allow for the ecosystem to adapt to changing circumstances.

A shared roadmap for innovation, even if it is not very detailed, will enable the partners in the network to make sense out of unforeseen events and enable them to keep on making investments that strengthen the ecosystem. The multitude of partnerships in the DS ecosystem, for example, is kept coordinated with a very clear and well-shared technological roadmap of how such things as their software platforms for computer-aided design, virtual production and testing, and social collaboration will evolve in the coming years. This roadmap contains

information about which new industries DS wants to find new applications for, how the company wants to address specific industry needs, what the role of 3D will be as a medium, and what the timeline will be for development of enhanced platforms. For example, for software developers DS provides technical support and training to share the evolution of the roadmap, as well as an internally developed social community for the software developers that provides access to information and service links and intense online discussion of the roadmap. These roadmaps are also shared and discussed at major conferences such as the DS Customer Conference or the European Customer Forum, technical road shows, and symposia.

In other cases, the roadmap communicated by the lead firm may be very specific. In May 2008, for example, enterprise application software provider SAP unveiled a roadmap for enabling its customer relationship management (CRM) software to interface with mobile devices and so-called "Web 2.0" applications. This roadmap was targeted at ecosystem partners such as Research In Motion (RIM), the Canadian wireless communications provider behind the development of BlackBerry mobile devices, and smaller software companies developing software to work with Apple's iPhone. It provided both the information protocols and the certainty they needed to make investments in providing mobile services to sales people whose companies use SAP's CRM software as part of their core IT infrastructure.

Similar to DS, ARM also hosts an annual ARM Partner Meeting. Although the criteria for inviting partners have varied over the years, invitees include the original equipment manufacturers (OEMs), such as Samsung and Nokia, and providers of complementary products and software as well as ARM's direct customers. At this event, ARM's current roadmap was presented and discussed with a wide range of partners.

Intel followed a similar approach in entering markets for complements to its core products (e.g., chipsets, motherboards, videoconferencing, and network connectivity). In order to reassure its partners that they would not squeeze them out of these markets, it communicated clearly its strategy and platform, and it enabled partners to align themselves with Intel's strategy.[35]

Once the lead firm has established appropriate conditions to stimulate investments by ecosystem partners, it must also concern itself with enabling the interactions between partners to operate as efficiently as possible. This means finding ways to reduce on-going transaction costs.

Reducing Transaction Costs

One of the inherent disadvantages faced by an ecosystem relative to a single, vertically integrated organization is the high transaction costs that result from having a multitude of relationships, some of them loose and incompletely defined and regulated. If these are not controlled, they can rapidly come to outweigh the extra customer value generated by the ecosystem.

A lead firm within the ecosystem can, however, act to reduce these transactions costs by developing and sharing a set of tools, protocols, processes, and contracts that systematize and codify interaction between participants within the ecosystem.

The appropriate mechanisms for reducing the transaction costs in any particular instance will depend importantly on the nature of the interdependence between the parties in the relationship and the risks to which each is exposed.[36] Designing the right kinds of interfaces between partners in the ecosystem enables an understanding of the amount and nature of knowledge that must be exchanged and how this process of knowledge exchange can be made more efficient. Some interactions within the ecosystem will be asymmetric—such that one party depends on the performance of their partner, but that partner's success does not depend on interaction with the recipient. In this case, contracts with performance measures and incentives are likely to provide the most efficient way of organizing the interaction, provided the partner's responsibilities can be precisely defined and its performance is observable. However, in an eco-system it is only rarely possible to detail all the necessary tasks and responsibilities. Worse still, the performance of a partner is often difficult to observe and measure directly. Take the case of "market making" where success or failure may reflect the inherent attractiveness of the offering rather than the quality of the market making efforts of the partner. In this case, the respective reputations of the partners will be important in fostering the trust required to reduce transaction costs and make the relationship productive and sustainable. This kind of interaction will, therefore, need to be designed so that both parties put their reputations on the line (for example, by lending their brands to the joint initiative) rather than by trying to devise a performance contract.

In other cases dependence in the relationship is symmetric. In this case, success for both parties depends on the quality of interaction as well as the input by each. An effective working relationship can only be developed by experimentation (or "learning by doing") through working together. The interaction between the partners, therefore, needs to be designed so as to give adequate opportunities to learn from each other and experiment with joint activities before launching high-risk initiatives in the open market.

Given the dynamic nature of the eco-system, many of the agreements governing partner interaction will need to be flexible to avoid imposing a straightjacket of excessive detail. The lead firm can also play a role in developing standardized interfaces to govern the interaction between different partners. For example, DS has internally developed a portal as a gateway for all of its partners to access roadmaps and current campaigns. They also invested in a custom designed social network where partners can freely exchange complex, three-dimensional designs easily and flexibly. Just as in standardized commodity or financial markets, these standard interfaces and protocols reduce the transaction costs, eliminate uncertainty, and increase flexibility. They achieve this by avoiding the need for developing complex new agreements each time the ecosystem is reconfigured or specific partners alter their activities or roles. Where non-standard agreements are required to handle the complexity of a particular situation, they should focus on collaborative activities and be designed to encourage shared problem solving.

Implementing these flexible agreements—which focus more on the process of collaboration than on trying to specify precise tasks or outputs[37]—requires that a balance between the investments, risks, and rewards accruing to each partner be maintained. In an eco-system partners will almost certainly have to swallow undesirable

changes or have to perform unwanted extra activities for the benefit of the ecosystem as a whole, and for their own overall prosperity in the longer term.

In order to gain from the ecosystem long term, partners will often need to make irreversible investments or other kinds of commitments based on the expectation that they will reap benefits in the future. The participants in an ecosystem therefore face "moral hazard"—such as the risk that some of their partners will try to free ride on others or try to renegotiate the relationship after their partners have already committed capital, effort, or technology to the ecosystem.[38] The lead firm must control the risks of moral hazard by promoting transparency in interactions and by imposing sanctions or even exclusion for those who refuse to "play fair." One of the companies we worked with, for example, had to exclude a significant development partner after they found out that the partner had been consciously embedding software code from one of the other partners in the ecosystem, without having the permission to do so.

The risks involved in committing to an ecosystem will only be acceptable to partners when they don't suspect that there are hidden agendas. This means the ecosystem's decision making must involve real listening to each others' objections and opinions so that the outcomes are transparent and clearly explained. This fair process must be embedded in an environment that promotes on-going relationship building. This includes mutual adjustment—the willingness to go the extra mile and to change one's own way of operating in order to facilitate cooperation with the partners—and mechanisms to promote a common interpretation of events as they unfold. These behaviors enhance trust in the eco-system and can create a self-reinforcing cycle that helps partners through the inevitable crises and hiccups that the network will experience.[39]

Flexible Structures That Can Evolve Through Joint Learning

Few ecosystems can expect to be static in terms of their structure, partner roles, or relationships. Indeed, as we have already noted, one of the attractions of an ecosystem compared to a vertical integrated organization is its potential for dynamic re-configuration—sometimes even on the basis of "self-organization"—and for accelerated learning by bringing together a diversity of partners with different capabilities and experiences.[40] It is important, therefore, for the lead firm to encourage the realization of this potential rather to thwart it by imposing an inflexible structure.

For example, compare this objective with the intent and operation of a traditional joint venture. Joint ventures are usually optimal when a potential relationship faces so many contingencies that writing detailed performance contracts or service agreements between the parties would be too complex to be practical. A joint venture structure sidesteps this problem by binding the parties into a tight, long-term relationship in exchange for a share of unknown future profits. However, the relationship is mostly non-specific as to the precise contributions and performance requirements on each party. In other words, at its core, a joint venture agreement might be characterized by saying that: "the various parties share a common goal, will make best endeavors to contribute to the achievement of that goal, and will share the resulting (uncertain) profits." The only way that the risk of free riding and moral hazard can be controlled is to force all parties to make a substantial investment in the

joint venture and to be jointly responsible for its liabilities. The avoidance of complex contracts that try to specify each party's contribution, performance, and rewards, therefore, comes at the cost of a highly inflexible structure. As a result, joint ventures usually have only limited capacity to evolve beyond their original mandate.

In a business ecosystem, the trade-offs about where to place the constraints and responsibilities on the various parties are very different. The objective is to create a structure that can be constantly re-configured—possibly even without direct intervention by the lead firm—in response to developments in its market and technological environment. Ecosystems need to be designed to create a momentum for joint learning. As a result, successful lead firms accept the need to specify the required performance of different groups of partners in exchange for leaving the structure flexible—the opposite of a joint venture.

Take the example of the Boeing 787 that required partners to cope with the high levels of uncertainty associated with a radically new aircraft design, and to experiment and learn jointly. In order to meet this challenge, Boeing created an unconventional supply chain with approximately 50 tier-1 strategic "integrators." These firms assemble different subsystems and parts produced by tier-2 and tier-3 suppliers. It is well known that the program ran into trouble for a variety of reasons, from technological problems to a combination of supply, process, management, labor, and demand issues. While the structure somewhat resembled the business ecosystems that we describe, it was still run by a mix of hierarchy and traditional, market-based subcontracting—which proved inadequate to the task. This could have been avoided to some extent by catalyzing the development of a more sophisticated business ecosystem such as those we have described. This would have included the use of IT to ensure transparency of the entire supply network, a better vetting of the strategic capabilities of all strategic partners, more flexibility in the design of the network, and a better risk-sharing and incentive structure that would have promoted more learning by the partners and by the network as a whole.[41]

The optimum ecosystem is generally a highly malleable structure combined with somewhat tighter specifications on contribution and performance (including sanctions for failure). Thus a company wishing to nurture a successful ecosystem around its business will impose minimal specification of how the ecosystem is structured, apart from, perhaps, differentiated niche roles between players backed by a degree of boundary protection.

Ecosystems should be dynamic in their composition and renew themselves constantly. The lead firm should actively manage requirements for key partners to join the ecosystem by means, for example, of certification in exchange for minimum investments of cash, technology, or in training of staff. The "club" is probably an appropriate analogy—with its requirements to gain membership, the need to contribute an "annual fee" to maintain membership, peer pressure, and the sanction of expulsion for inappropriate or poor quality behavior.

Within a club, of course, there can be differentiated levels of membership and roles with some members accepting more responsibilities and making larger investments in exchange for certain privileges, with other "associate" members meanwhile having a much more limited relationship.

An interesting example of such a quasi-club is the informal organization of the entrepreneurial cluster in Cambridge, UK.[42] A detailed analysis of the high-tech

start-ups in Cambridge indicates that they are rarely the initiative of individual and independent entrepreneurs. On the contrary they are often started and led by small teams of entrepreneurs. These teams are a constant reconfiguration and recombination of the 40 to 50 serial entrepreneurs that were at the origin of the cluster. Many of these entrepreneurs meet each other regularly in formal organizations, e.g., the Cambridge Network or a group of Cambridge Angel investors, but also in many informal encounters created by the entrepreneurial community or the University of Cambridge. In these networks, they are the key players. Scientists, MBA graduates, outside venture capitalists, and managers float in and out. The constant formal and informal interactions between these individuals allow for a continual reconfiguration of small teams that are prepared to develop business plans around new technologies and share the risks of the new ventures.

Similarly, ARM's ecosystem involves different "levels" of membership, what is today analogous to a club of over 400 regular members and thousands of loose affiliates. ARM identified a small set of "strategic partners"—judged to have the ability to influence the technological direction of the industry, either because of their market power or technological prowess. The top twenty strategic partners were assigned to one of ARM's directors (the CEO and his direct reports) to manage the overall relationship.

The second level is managed by ARM's "segment marketing" organization and was created for each end-use applications area: wireless, storage, imaging, automotive, consumer entertainment, networking, security, and industrial. Each segment marketing team identifies their own "top twenty" partners who were key influencers in the likely future evolution of the technologies and products in their applications segment. In the case of Samsung, for example, the segment marketing person is responsible for building relationships with the wide variety of individuals in different parts of Samsung to develop a picture of their evolving needs for (say) future mobile phones.

Partnerships with early stage and start-up companies, meanwhile, are handled through a "light touch" relationship focused on providing them with the tools and the other support necessary to integrate ARM technology into their products. It also offers a flexible licensing model based on providing per-use licenses, in recognition of the fact that building a product prototype is the primary focus of such partners. This reduces the hurdle to using ARM technology, while allowing fledgling companies to focus resources and improve their credibility by using proven technologies, supporting design tools, and software from ARM. Encouraging start-ups to attach themselves to the ARM ecosystem in this way has the potential to pay handsome dividends if and when these fledgling companies succeed.

Finally, ARM's ecosystem also involves a broader community numbering tens of thousands of developers and other participants. These partnerships are facilitated by the online "ARM Connected Community" website. Managed by a dedicated ARM executive, this on-line community provides free access to extensive resources for developers, a forum for developers and engineers to exchange ideas and support from within the ARM ecosystem, and company and product listings classified by product category, market application, and ARM technology—all linked to partner sites.

The key aspect of this kind of structure is its ability to facilitate joint learning as the partners interact. Again, the lead firm usually needs to play an important role in

promoting learning within the ecosystem. It is clear that most of the relationships in ARM's ecosystem are designed with an eye toward facilitating knowledge creation, not only for ARM itself, but also for its partners—including new entrants to the ecosystem. Once key decision makers for product and technology roadmaps are identified, detailed discussions are initiated with them on how ARM aligns their development efforts. The partner-management team also tries to identify if they work with any other ARM ecosystem partners. If any such relationship exists, further work is coordinated with semiconductor vendors and other influential players within the ecosystem, as well as other teams within ARM, so as to maximize co-learning system-wide. New knowledge is, of course, also created during these partners' interactions, the ownership of which has to be agreed upon and monitored, not least because ownership of IP is critical to who is able to extract value from an ecosystem.

Engineering Effective Value Capture Mechanisms

Amid the hype around "open source" and the exponential growth of web-based communities, one might be forgiven for the impression that being at the center of a vibrant ecosystem must be inherently good for a company's performance. Of course that it not necessarily the case. Witness the experience of Sun Microsystems, acquired by Oracle in January 2010. Sun played an instrumental role in spawning and then developing a hugely successful ecosystem around its Java language. However, it had continually struggled to parlay that successful ecosystem into higher profits for its own shareholders. It is clear from Sun's experience (and also that of IBM in PCs) that controlling the overall "architecture" of the ecosystem is insufficient to guarantee that significant value will be captured in the form of profits for the lead firm. In order to reliably capture value, the lead firm needs to contribute a component or activity on which the overall value of the ecosystem to the customer depends and which is difficult to replace with a substitute offering. This component or activity should not be available on the open market, and it should be difficult and costly to imitate. The lead firm also needs to engineer a mechanism to monetize that unique contribution, such as license fees, royalties, expanded margins, or profits on higher sales volumes. The level of value captured (and profitability) will be enhanced if this contribution also enjoys increasing returns.

ARM's chip IP is a good example. As noted, it is an important contributor to the value provided to the end customer. Switching to an alternative would involve high fixed costs of reinvestment in training and related tools and processes by participants in the ecosystem, rendering substitution an expensive proposition. ARM's chip design is proprietary and to imitate it would require not only access to a large stock of accumulated knowledge, but also access to complex knowledge about the technological roadmaps of handset makers and semiconductor manufacturers that is only available on the basis of close and trusting relationships that are slow and costly to build. Moreover, the more users of its IP that ARM accumulates, the lower its unit costs and the higher the value to users through network effects—both of which generate increasing returns for ARM. These contributions by ARM are monetized through one-off license fees paid by ecosystem participants, as well as customers, for the right to utilize the firm's proprietary IP. In addition, ARM also profits from overall growth of the ecosystem's output by charging a royalty on every unit of product that embodies its IP.

Total transparency is obviously not always optimal for a company that wishes to maximize the competitive leverage it gains from its business ecosystem. Asymmetric information can be an important source of power and competitive advantage and possibly the key to capture value, particularly in knowledge-intensive businesses. At the same time, failure to share information necessary for and ecosystem to create value or reduce its transaction costs will clearly impair the overall profit pool. In achieving the right balance between these forces, a useful principle is to "share information on the interfaces, but to keep the inner workings of your contribution to the ecosystem proprietary and non-transparent."

Conclusion: Gaining Ecosystem Advantage

In the global competitive environment of the 21st Century, the capability to catalyze the emergence and guide the development of a vibrant ecosystem offers increasing potential as a powerful source of competitive advantage. This potential has already been proven in high-technology industries. In the future, more and more industries will be subject to the forces that favor ecosystem strategies over those that either concentrate activities into vertically integrated organizations or rely on traditional outsourcing. Increased uncertainty is demanding that many businesses be able to flexibly reconfigure their activities, assets, and capabilities in response to the unexpected. The dilemma of how to deliver the more complex solutions demanded by customers is becoming more acute as companies seek to create additional value while limiting capital expenditures and containing costs. The ability to mobilize tacit knowledge to speed up innovation and improve customer services is emerging as a critical competence, not only in high-technology businesses, but also in industries facing the march of commoditization—where profitability rests with identifying pockets of proprietary knowledge that can be used to re-build differentiation. Meanwhile, advances in ICT are enabling ecosystems composed of diverse and dispersed partners to closely match the level of coordination in traditional corporate hierarchies at similar cost. Each of these trends favors the adoption of ecosystem strategies.

Building an ecosystem to thrive in this environment is often more than a willingness to embrace open innovation or building a "hub and spoke" structure of multiple alliances with a limited number of complementors. Instead, it requires a lead firm. This is the firm that acts as architect, catalyst, and guide in order to promote the development of an ecosystem where partners benefit from joint learning and align their investments out of self-interest. It requires this lead firm: to pinpoint the potential for value creation for the end customer and create incentives to attract partners that can deliver this value; to structure an architecture that accommodates differentiated partner roles; to find ways to stimulate complementary partner investments by reducing uncertainty and credibly signaling that it will not encroach on partners' territories; to act to reduce transaction costs through mechanisms to create trust and smooth knowledge sharing; and to establish flexible structures that can promote and respond to co-learning, while engineering and protecting its own value capture mechanisms. It is the sum of all these actions that defines what the lead firm in a successful ecosystem is all about.

APPENDIX
About This Research

Our observations are anchored in both authors' extensive and detailed study of ARM and Dassault Systemes, which involved discussions and interviews with key players. All of the examples used are in the public domain, but the deep contextual knowledge of the authors about these cases has helped to enhance the interpretation of this information. Hypotheses derived from these insights and discussions were extended and improved though extensive exposure to companies such as SAP and IBM. We also benefited from the experience of many entrepreneurial companies in the Cambridge network. This is a network of close to 250 small to medium-sized innovative firms, co-existing with the University of Cambridge (UK) and many of them working together in a network for a variety of business purposes, thus forming a very special business ecosystem.[43] We carried out many interviews, worked with the firms in this cluster, and had access to extensive desk research about them.[44]

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