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THE DYNAMICS OF GAMES OF INNOVATION

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Many executives see innovation as an unmanageable process, riddled with risks. The research we conducted with the Industrial Research Institute, interviewing over 200 vice-presidents of research and development and chief technical officers in many sectors around the world, yields a more nuanced view. Innovation becomes manageable once managers move away from normative prescriptions that view the process as uniform and recognise that different rules and practices apply to different circumstances.

Our argument is that clusters of interdependent firms contributing to the building of a set of interacting products and services tend to self-organise themselves into distinct and relatively persistent "games of innovation". Such games operate at a meso level of analysis, grouping together many complementary agents, such as competitors, suppliers, public regulators, universities, innovation-support agencies, and venture capitalists. Six games of innovation, each with a distinct set of rules for innovating, have been identified around value-creation exchanges between buyers and sellers. Three games focus on market creation: "patent-driven discovery", "systems integration" and "platform orchestration". Market maintenance games are "cost-based competition", "systems extension and engineering" and "customised mass production".

The perspective proposed in this paper recognises that heterogeneous innovation patterns and strategies can coexist within a single industrial sector and that the same game can be played in many sectors. Specific conditions call for distinct rules and practices. Customer expectations, for example, are central in some games but almost irrelevant in others. Rules for managing innovation are neither generic best practices that can be applied universally nor narrow industry recipes. They are game- and role-specific ways to create and capture market value.

Keywords: Strategy; value creation; heterogeneity; innovation; strategic logic; eco-system; dominant logic.

Many people see innovation as an unmanageable process, riddled with high uncertainty and risk. For them, innovation is like playing the tables at Las Vegas. To succeed requires making many bets, in the hope that a few winners will more than compensate for the many losers. More sophisticated and frugal approaches attempt to impose various degrees of structure and method on the screening process, as a way to avoid costly errors.

The research that we conducted as part of the Research on Research Committee of the Industrial Research Institute yields a more nuanced view. In spite of the uncertainties, innovation becomes a manageable process once managers move away from universal prescriptions and recognise that different rules and practices apply in different contexts. The "games of innovation" perspective proposed here recognises that heterogeneous innovation patterns can coexist, that specific conditions call for distinct and persistent rules of action, and that the meso level of analysis, between the macro and micro perspectives, is most appropriate for the task.

The intuitive and evocative of idea of games of innovation emerged from field research and seminars with working groups of 200 CTOs and VPs of R&D. Statistical analysis of our 600 survey responses from these executives led to the identification of six statistically different clusters. Sectors such as biotechnology, telecommunications, software, aerospace, aluminium, pulp and paper, engineering and construction, and multimedia were covered. We call the coherent patterns within each of these clusters "games of innovation". Here are some of their basic characteristics:

i. They are economic processes that take place at a *meso-economic* level, between the level of the individual firm introducing innovations and the level of the aggregated larger economy.
ii. They are *collective* constructions. Rules generally transcend the preferences and actions of any single player, no matter how prominent.
iii. They are *emergent*. They do not follow any established blueprint, nor are they determined by constraints. They are oriented by the flow of spontaneous interactions between a set of interdependent players.
iv. They provide *affordances* to, but also impose *constraints* upon, the very agents that have caused them to emerge. Paraphrasing Winston Churchill, we could say that "firms fashion their innovation games and, thereafter, are fashioned by them".
v. They are *open-ended* and path-dependent. They are indeterminate processes, though subject to increasing inertia.

vi. Despite their open-endedness, they are bound by some basic economic forces and tend to fall into a small number of "*natural trajectories*" (cf. Nelson and Winter, 1982). In this paper, we identify some of these trajectories.

This paper consists of five parts. The first part outlines the limitations of universal approaches to innovation processes. The second part proposes the "games of innovation" concept as a parsimonious taxonomic approach to the innovation processes in the observed games. In the third part, the heterogeneous dynamics of innovation in the six different archetypes is illustrated. In the fourth part, the migration of sectors, industries, and firms is sketched. Then a conclusion about the strategic choices to build innovative enterprises follows.

The Inadequacies of Present Theoretical Approaches

Present theoretical perspectives often stress universal approaches and thus fail to recognise the heterogeneity of innovation processes. By contrast, empirical studies acknowledge variety by showing forms such as outsourcing, technology partnerships, and involvement of venture capital. Emphasis on the diverse realities of innovation, however, leaves the reader with no unified view.

Views stressing universal approaches

The conventional view builds on both Schumpeter's theory about the routinization of innovation in large incumbent firms and on the experience of internalised R&D management in chemicals, pharmaceuticals, and consumer products. Incumbents, under conditions of oligopolistic rivalry, often have the resources to invest in R&D, develop innovation steering methods, and build the necessary competencies (Chandler, 1977; Schumpeter, 1947). To make rational choices, managers are further encouraged to adopt best practices and universalistic prescriptions (Abrahamson, 1991). Here are the main assumptions underpinning the conventional model of innovations:

i. Markets exist as exogenous demand spaces waiting to be filled by solutions meeting customers' needs as identified by marketing research.
ii. R&D laboratories build on evolving scientific knowledge to develop and launch products or solutions (Cooper, 2001; Urban and Hauser, 1993).
iii. Market selection takes place on the basis of relative merits and utility. Customers use clear performance attributes in their selection of winners.
iv. Innovation is basically an in-house affair: products are fully developed before they are launched. The complexity of products and production is hidden to consumers who simply use them.

v. The process of diffusion of products may be slow but eventually the estimated market space fills up. The capture of value relies on product superiority, strong patent protection, or regulatory barriers (Teece, 1998).
vi. Rent from innovation depends on temporary monopolistic positions in many markets.

Instead of being universal, practices are highly differentiated, depending on the context. Furthermore, the widespread tendency to imitate "best practices" sometimes results in entire sectors being trapped in negative-sum competition with low-innovation, low-growth, and low-profit practices.

Realities of innovation processes

Here are a few new realities about innovation processes:

i. The division of labour and the specialisation of firms into complementary capabilities lead to the disintegration of many firms' innovative activities. In many industries, symbiotic relations link small entrepreneurial and large firms. Network-oriented firms with evolving capabilities are able to face dynamic situations. Innovation thus has to be viewed in an open systems perspective (Chesbrough, 2003).
ii. The dream of rational planning under conditions of uncertainty has given way to highly sceptical attitudes. The process of innovation was found to be highly iterative, involving multiple feedback loops and many forward path-dependent constraints (Kline and Rosenberg, 1986; Pavitt and Steinmuller, 2002). High levels of cumulativeness, learning by doing, and collective sharing also characterise the process (Lazonik, 2001).
iii. Products are often systemic and bundled with services (Langlois and Robertson, 1992). Systemic products are built from modular subsystems designed separately by independent firms but integrated by core architectures in order to function as a whole (Baldwin and Clark, 2000; Schilling, 1998). The benefits of modularity are greater innovativeness in product development, multiple options for buyers, and product flexibility (Baldwin and Clark, 1997; Garud and Karnøe, 2003).
iv. Product superiority or patents do not guarantee winning. Market inertia is often strong, leading to the persistence of market positions because of switching costs, incumbents' opportunities for learning, and prior organisational investments. Buyers rely on reputation, prior choices, and producers' marketing capabilities, which result in hyper-selection (Olleros, 1995).
v. Innovation is not limited to radical changes leading to disruption. The vast majority of innovations focus on cost reduction, architectural improvements, and

incremental changes. Furthermore, leadership in innovation requires building of organisational capabilities, codification of product development processes, and structuring of strategic control and incentives (Jonash, 1999).

vi. Institutional arrangements influence the rates and directions of innovation. The competitiveness of nations depends on nations' abilities to initiate and sustain a technology race (Porter *et al.*, 2006). The effects of capital and labour are multiplied when knowledge is taken into consideration. National systems of innovation stimulate, support, and regulate the creation and diffusion of technologies (Edquist, 1998; Nelson, 1993).

Recognition of heterogeneity

Previous efforts to make sense of variety in innovation processes led to distinctions between high- and low-velocity environments (Bettis and Hitt, 1995; Einsenhardt, 1989), disruptive and sustaining innovations (Christensen, 1997), and competence-destroying and -enhancing changes (Tushman and Anderson, 1986). Turbulent periods of discontinuities and change were observed to be followed by periods of stability during which large monopolistic firms come to the fore (Abernathy and Utterback, 1978; Klepper, 1996). A number of authors dissatisfied with simple distinctions developed more elaborate taxonomies. Here are a few:

i. Keith Pavitt (1984), working from a database of 2,000 significant innovations, identified four sector-based technological trajectories: supplier dominated; scale intensive; specialised suppliers; and science based. Each trajectory appears to be associated with core sectors, distinct means of appropriation, and relative size of innovating firms.

ii. Christopher Freeman and Carlota Perez (1988) sketched a taxonomy of four trajectories: incremental innovations; radical innovations; changes of technology systems; and changes in techno-economic paradigms.

iii. Michael Best (2001), proposing that the conventional science-based model has rivals, outlined five production systems around which technology management and clusters of capabilities are organised: interchangeability; mass-production Fordism; Toyotism and flexibility; product-innovation-led competition; and systems integration of multiple technologies, teams, and open networks.

iv. Jane Pollard and Michael Storper (1996) identified worlds of innovation activities that generate growth information and management of intellectual capital; high-technology-based industries; variety-based manufacturing; and mass-production Fordism.

v. Rebecca Henderson and Kim Clark (1990) suggested that there are two stages in the evolution of complex technological systems: first, revolutionary change, in which radical and architectural shifts affect the core of the system; and second, evolutionary change, in which modular and incremental shifts affect mainly the system's periphery.

The "games of innovation" concept can help provide a synthesis.

Games of Innovation

Why propose the concept of "games of innovation" when the field is already brimming with constructs? Our first argument is that the rates and directions of innovation processes lead to distinct and highly differentiated trajectories characterised by different technological opportunities, appropriability conditions, or cumulativeness of knowledge (Malerba, 2002). Second, managers experience the dynamics of the innovation process as a function of the contexts in which they are involved, and they build configurations of strategies and capabilities to respond.

We do not use a contingency-based approach, in which the degrees of fitness of strategic choices with contextual conditions determine innovative behaviours and performance. Instead, our perspective is evolutionary: many distinct trajectories lead to high levels of differentiation in the building of economic structures (Dosi, 1984; Nelson and Winter, 1982). Innovation forces trigger variations that are subject to selection and eventually institutionalised (Metcalf, 1998; Nelson and Winter, 1982). Contextual forces orient but do not determine actions. Here are the main attributes of games of innovation as systems.

Innovation games are trajectories requiring a meso level of analysis

The focus of analysis has traditionally been on sectors, industries, strategic groups, firms, or product-development activities. By contrast, games are meso-level processes nested in between the micro level of innovative firms investing to displace incumbents, and the macro level of aggregated industry structures, sectors, and institutions.

Games refer primarily to the multiple trajectories or pathways followed by innovation processes resulting in new industries and the maintenance of existing ones (Nelson and Winter, 1982). Variety is introduced by entrepreneurial firms aiming to displace existing methods and build new production systems. Guided variation, selection, and retention lead to distinct trajectories (Metcalf, 1998). A constant restructuring and shifting of boundaries of industries takes place as innovative firms adopt new technologies and create markets.

Games at the meso level also refer to concrete systems of interacting complementary capabilities, strategically interdependent organisations and institutions in which firms are embedded. Customers often provide firms the problems to solve, as well as some of the solutions (Carlsson *et al.*, 2002). Universities, science and technology communities, and start-ups provide pertinent knowledge, while financial resources come from venture-capital and innovation-support agencies.

Games involve distinct logics of innovation

Specific market demands, technological opportunities, or accumulated knowledge about ways to build products result in distinct logics of innovation (Dosi, 1988). Innovating in aircraft design is not the same as developing info-mediation platforms to link multiple markets. Games call for specific and distinct types of assets, transactions between producers and buyers, and interactions with suppliers, investors, and innovation-support agencies (Langlois and Robertson, 1992; Williamson, 1996).

Scientific and engineering knowledge is combined in different ways with marketing to design and build distinct classes of goods and services for which buyers are ready to pay. In some games, the influence of emerging science and regulatory forces is central, while in others buyers' demands and engineering dominate. In still other games, aligning with or shaping dominant platforms with different degrees of openness is the way to create and capture value. Sometimes customers drive the innovation process while in other games they play limited roles.

Games, as coherent logics of innovation, cut across sectors and industries. Similar patterns of innovative activities can be found in sectors and industries that face comparable technical, competitive, and regulatory contexts. For instance, firms in the oil-and-gas sector exhibit patterns of innovation that are similar to those of firms in the aluminium, petrochemical, and steel sectors. On the other hand, when new knowledge continually opens up opportunities, some sectors, such as pharmaceuticals and telecommunications, involve multiple games of innovation.

Innovation games are governed by distinct systems of rules

The dynamics of each game promotes the emergence of distinct sets of rules and practices. Rules are neither generic best practices that can apply universally nor narrow industry recipes. They form cognitive frameworks that emerge as managers learn to face competitive issues and discover ways to appropriate benefits. Rules then inform decision making and foster the persistence of coherent patterns of activities.

Rules for each game allocate problem-solving activities within firms and across networks of complementary organisations. Rules outline various business models that will sustain investments in knowledge building, capabilities development, and methods of appropriation. For instance, rules about economically sustainable levels of investment in R&D and capabilities building vary by game. In stable games, investments in R&D and capabilities building in the range of 2.5% of sales are high. By contrast, in highly effervescent games, innovation expenditures are on average 44% of sales for R&D and capabilities building.

A variety of complementary roles are played within each game of innovation

Various complementary roles emerge in each innovation game (Christensen *et al.*, 2000). Shapers launch new platforms and growing ecosystems, while niche players search and fill specialised segments (Christensen and Overdorf, 2000). Some large incumbents in mature sectors prefer defensive, collaborative, and imitative moves.

Incumbents are challenged by entrepreneurial firms when business models or architectures are shifting (Cusumano and Gawer, 2002). Small technical firms may be symbiotic knowledge developers or subordinate contractors. Firms at the periphery of a platform may act as independent innovators hoping to fit with its architecture. Pure-play participants select the strategies that are best adapted to the contextual conditions of the game. By contrast, active mixed-play participants add innovative strategic moves to gradually modify the rules of the game and diversify.

Games are dynamically stable

As long as contextual forces remain basically unchanged, the specific patterns of innovation prevail. Persistence stems mostly from shared knowledge, learned practices, and continued demand for categories of products and services. Also fostering persistence are division of labour across parties; institutional structures; and specific assets to produce goods and services.

Persistence does not mean inertia. Rules are adapted to the opportunities opened up by technical progress and successful strategies. For instance, strategies used in the "battles of architectures" game, such as info mediation, are similar but improved versions of those used in the development of personal computers. Similarly, the automobile sector has been in the mass-production and customising game for 70 years or more but improvements were diffused, adopted, and learned.

However, turning points appear when exogenous or endogenous discontinuities arise. Conditions no longer fit with specific assets, levels of investments. and rules. Firms may be born into a game, but as conditions are transformed, transitions to another game take place. Firms may also diversify and thus learn to play multiple games.

Outcomes of games are indeterminate

Games are collective constructs built from multi-player interactions. As such, they can lead to healthy industry performance, just as they can fall into negative-sum competition. Such differences depend on the strategies pursued by players (Chakravorti, 2003). The collective impact of the strategic coordination between players can lead to market growth, competitiveness, or destructive competition.

Games in which new markets are created will display high levels of innovation, high growth in sales, and wide variability in economic performance. By contrast, maintenance games will display lower levels of sales growth but more consistent economic returns.

Taxonomy of Games of Innovation and their Dynamics

To match our empirical data about games to meaningful trajectories, we used two contextual dimensions with strong endogenous influences. Figure 1 presents a parsimonious taxonomy of archetypes corresponding to the clusters that we have identified. The vertical axis is divided into two evolutionary processes: first, market creation and takeoff; and second, maintenance and institutionalisation. Market takeoffs are usually preceded or accompanied by technology races conducted either

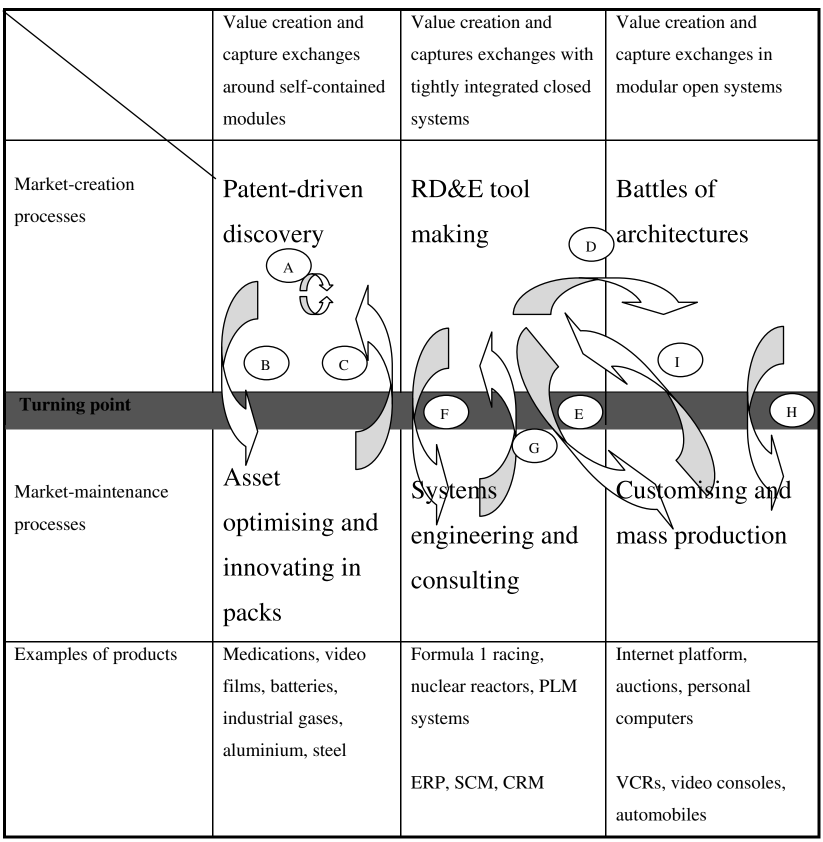

Fig. 1. Archetypes of games of innovation.

by independent entrepreneurs or by corporate ventures to identify options, arrive at proof of concepts, and build intellectual property. The horizontal axis presents three types of value creation and capture exchanges between producers and buyers around self-contained products and services, highly integrated systems and services, and modular open systems, in which innovation often results from co-evolution and learning between producers and buyers.

The games are "patent-driven discovery", "optimising and innovating in alliances", "RD&E tool-making", "systems engineering and consulting", "battles of architectures", and "customising mass production". The dynamics of each game are illustrated in Table 1, which compares dominant logics of value creation and capture, levels of investment in innovation and capabilities, and so on.

Games of innovation involving simple self-contained products

Two archetypes of games exist around self-contained products: market creation through "patent-driven discovery", and market maintenance through "optimising and innovating in alliances". Simple self-contained products are independent modules such as pharmaceutical products, medical devices, and newspapers, that require little user learning and infrastructure.

Patent-driven discovery

Patent-driven discovery games are closest to the conventional model of innovation. Sponsors or entrepreneurs in technology races realise that sets of patent-protected functional principles could eventually lead to lasting market power. Innovative products are either superior substitutes or novel solutions to meet targeted needs.

Buyers have well-known needs: they can understand the functionalities and select between alternative products according to explicit dimensions. Markets exist as exogenous demand spaces waiting to be identified by market research and filled with innovative products. The task of marketing is to specify the attributes that meet users' projected requirements and support the diffusion of products within channels (Cusumano and Gawer, 2002).

Value for buyers is in the direct use of products, and selection is meritocratic. Processes for finding and producing products may be complicated, but in the end, the complexities are encapsulated into easy-to-use modules. Buyers can try at low cost and rapidly assess performance or rely on the recommendations of professionals.

Regulatory issues often drive R&D activities and force a clear focus on both the effectiveness and the side effects of products. Due largely to concerns for public safety and security, highly structured regulatory frameworks often control launch. In the pharmaceutical sector, for example, with the increasing presence of government health services and private HMOs, pressures to reduce costs are high.

Table 1. Forces shaping games of innovation.

Name dimension	Patent-driven discovery	Process optimising	RD&E tools	System engineering and consulting	Battles of architectures	Mass production and customising
Dynamics of exchange buyers/ producers	Value is in self-contained products meeting explicit needs Buyers have clear criteria to assess: little learning or information required	Commodities and innovation services offered to rational buyers Margins disappear: high competition Substitutes are threats to existing markets	Buyers pay for performance tools Producers challenge to innovate Integrated solutions selected on merits	Value is in strategic and systems services to tailor solutions Operators ready to invest in mission critical systems Standard platform tailored and implemented through services	Buyers want plug and play to escape closed system lock-in Contentious process of competing platforms vying for dominance by interacting with buyers	Customers want differentiation at point of sale: style and price Producers interact and learn from buyers to customise within dominant designs

Table 1. (*Continued*)

Name dimension	Patent-driven discovery	Process optimising	RD&E tools	System engineering and consulting	Battles of architectures	Mass production and customising
Dominant logic of value creation	Science-driven discovery with marketing for diffusion Relentless activities in portfolio Scouting for radical novelty by small firms	Scale and scope efficiency; cost reduction Finding applications to renew markets Hunting for process efficiency with suppliers	Systems integration Architectural knowledge Partnership with lead users Complex problems, smart solutions	Large capital projects to improve coordination, productivity, and product development Hardware combined with services from consultants to build large solutions Superior project and risk management	Stabilising in one or few core dominant architectures and interfaces Opening platform to generate decentralised creativity Innovation at periphery is high	Systems integrators: front office and assembly Back office: component suppliers with scale economies Global design, engineering, and production
Innovation efforts						
• RD	16.5%	2.57%	32%	10.99%	8.76%	6.04%
• Capabilities	5.45%	1.3%	12.16%	4.04%	1.46%	1.69%

Table 1. (*Continued*)

Name dimension	Patent-driven discovery	Process optimising	RD&E tools	System engineering and consulting	Battles of architectures	Mass production and customising
Value capture	Intellectual property and product superiority Wide portfolio of patents and firms	Buyers capture value by low price Producers reduce costs and seek volume	Reputation and superior products: niche market positions sustainable After-sale services and partnerships with customers	Operators capture value by superior efficiency and effectiveness Strategy and systems consultants gain reputation and position for future projects Many competitors in niches	Few platforms are selected: Hyper-selection (all or nothing) Meritocratic selection at periphery	Strong assembler and info mediator capture value not component supplier When value is in components suppliers may capture value

Table 1. *(Continued)*

Name dimension	Patent-driven discovery	Process optimising	RD&E tools	System engineering and consulting	Battles of architectures	Mass production and customising
Performance: fraction of revenue from new products	Average	Low	Highest	Lowest	Low	Highest
Ecosystem dynamics	Large firms leadership and followership Scouting by small firms, 45% external source of ideas	Streamlined value chain Global outsourcing or offshoring	Centralised large firms with alliances with certified partners Dependence relations	Hierarchy of interdependent specialists Contractual and generative relations Outsourcing and offshoring	Value is in ecosystem to develop solutions and markets Platform leadership win by building alliances	Suppliers are part of coordinated value chain Suppliers of key components may hold power
Representative sectors	Pharmaceuticals Agribusiness	Industrial gases Metals	PLMs, SCMs, ERPs, CRMs	Management and IT consulting Large engineering projects	Telecom Info mediation	Automobile PC Watches

The dominant rules for innovation are, first, to recruit and train knowledgeable scientists and entrepreneurs; second, to build research programmes to discover superior, patentable, and approvable solutions. Continued training of research staff is a concern. The average expenditure on R&D is 16.5% of sales, with an additional 5.45% to build capabilities for strategy making, marketing, and production. Innovation is largely an in-house affair, with 60% of relevant ideas emerging within the boundaries of large firms. Yet, in the pharmaceutical sector, reliance on external sources of ideas from universities or biotech start-ups is on the rise as the blockbuster model runs into problems.

Organisational processes have been codified through systematic learning. New products usually need to be entirely functional and approved before they are launched. In the pharmaceutical sector, research projects run into the hundreds of millions of dollars and involve pre-clinical tests; proof of concept for humans; large clinical trials, lasting many years with 10,000 to 50,000 individuals in treatment; control groups; and post-marketing surveillance. The major downside risks are the inability to gain regulatory approval as adverse effects counter beneficial ones and having a portfolio of approved but non-performing products.

The pressure for innovation is relentless. Dominant positions tend to be easily contestable because of low market inertia. Superior options proposed by competitors or small firms challenge positions. Products that once were winners will lose their value as legal protection disappears. As a consequence, firms need to build diversified portfolios of research programmes. Intellectual property allows innovators to carve out a dominant market position and capture monopoly rents for a temporary period.

The ecosystem is composed of large and small firms. Sustained revenue streams provide large firms with the resources to invest in R&D, develop innovation steering methods, and build competencies. Economies of scope in research and economies of scale in marketing are present. New sectors of opportunities, especially in early phases of product development, are opened by small firms that scout new territories with support from public funding and corporate sponsorship. Complementary and symbiotic relationships with small science-based start-ups fuel the relentless process of innovation.

Venturing activities to productize promising ideas proposed by small entrepreneurial firms are gaining importance. Venture-development activities focus on gathering strategic opportunities, licensing, conducting due diligence, financial modelling, and deal-making. Sometimes, small ventures are competitors, but usually they are acquired by larger firms or they fail.

Value capture is made possible by patents, regulatory approvals, or uncontested product superiority; these create temporary conditions for rent appropriability (Davies and Hobday, 2005). Once products are launched, the innovation process ends. In the simplest of cases, once patents and regulatory approvals are secured, the game is essentially focused on diffusion and marketing efforts. Firms face transition points when patents in their portfolios come to the end of their valid life.

Optimising and innovating in alliances

This game is widespread in mature, capital-intensive sectors such as steel, industrial gases, aluminium, oil and gas, electric power, petrochemicals, and generic drugs. Products have become commodities and profits erode as competitors and imitators enter the fray. Competitors focus on efficiency, market share, and profit margins. Late entrants can gain substantially if they have the required marketing capabilities and the financial resources.

Buyers of commodities are large firms such as carmakers, semiconductor foundries, and food producers. Selection is based on merit and price. Innovation focuses on cost reduction, efficient coordination, and renewal of disappearing markets.

The dominant rules of innovation are to hunt for process efficiency by using the existing knowledge of suppliers and partners. Investments in innovation are on average 2.57% for R&D and 1.3% for capabilities building, for a total of 3.87% of sales. Innovation activities focus:

i. *Asset optimisation*. Incremental improvements, rather than new scientific or engineering knowledge, are emphasised. For example, R&D at Syncrude Canada Ltd. reduced expenditures on mining and extraction of oil from tar sands by close to 60% per ton over the past 10 years with systematic improvements in mining methods, materials handling, equipment wear, and extraction processes. R&D and operations defined problems jointly, but ideas for improvement were developed through alliances with equipment suppliers and consulting firms.
ii. *Organisational processes and IT systems.* These are developed to improve efficiency and facilitate interactions with customers. Typical processes are systems for supply chain management, customer relationship management, and enterprise resource planning. Globalisation is a major driver of business processes as firms need processes to sell in developed countries, design products in Japan or Taiwan, and coordinate mass manufacturing in China.
iii. *Finding new applications.* Without market-development efforts, substitutes reduce demand for commodities. In response, producers organise alliances with customers and equipment suppliers to develop workable solutions to customers' problems and bottlenecks. New applications for aluminium, industrial gases, and steel help to maintain growth in these industries. For example, oxygen originally used for cutting and welding metals found new applications in

steel making, petrochemicals, health systems, semiconductor foundries, and biotechnology.

The innovation ecosystem is composed primarily of large buyers that rely extensively on networks of suppliers and consultants to complement in-house innovation capabilities. The most important external stakeholders are technology partners, suppliers, and environmental regulators. Small firms tend to be specialist contractual suppliers and not independent innovators.

Value capture favours buyers that can profit from low costs and new applications. Buyers may sometimes face many competing suppliers. Producers capture value by streamlining activities, optimal scale processes, and industrial secrets.

Games of innovation involving tightly integrated products and services

Tightly integrated products and services are designed to help perform complex tasks. Components are so tightly interdependent in a closed architecture that they cannot be easily modified or replaced. Two types of games are associated with tightly integrated products. Market-creation games such as "RD&E tool-making" focus on developing systems to enable complex integration. The "systems engineering and consulting" game aims at deploying complex systems and building organisational processes to help large firms achieve operational excellence in their basic mission.

Research, development, and engineering tool-making

The game of RD&E tool-making provides buyers with systems to manage design activities, simulate interaction processes, and coordinate the work of thousands of engineers on a real-time basis. Examples of products are rational drug design software systems sold to pharmaceutical firms; design automation systems sold to semiconductor manufacturers; design engineering systems sold to airplane or car builders; and factory automation products and services sold to mass manufacturers. Tools are based on concurrent and robust design engineering principles: they are used to test design hypotheses, speed product design, and enhance quality (Blanchard, 2003).

Buyers are well aware of the high costs, functionalities, and risks of tools. Large firms also know that better results are achieved with complete and tightly integrated systems (Christensen and Raynor, 2003; Ulrich and Eppinger, 2003). Nonetheless, buyers are ready to pay considerable sums when they discover the potential value of initial prototypes. Improving functionalities and reliability becomes a top priority for tool designers as buyers raise their ceilings of expectations.

Markets for RD&E tools do not pre-exist but emerge and co-evolve as toolmakers interact with buyers. Each new and improved version builds on accumulated experience and leads to the creation of wider markets. Over the last decade, markets have grown at rates of 30% per year. The selection of winning products and firms is highly meritocratic.

The dominant logic of innovation is centred on building integrated systems that meet demands for ever-rising performance. Toolmakers create value by transforming familiarity with customers' problems and using accumulated engineering experience to build closed systems and long-term partnerships. The degree of information, expertise, and purchasing power of lead users plays a determinant role in innovation. Early buyers are highly prized: long-term collaborations to improve systems are common. Customer intimacy is necessary in order to structure, understand, and solve problems. For instance, the collaboration between Toyota Motors and Dassault Systemes has led to tools that substantially reduce design costs and time while enhancing quality: Toyota reports that with the use of PLM systems, model development costs fell by 43% and development time by 44% (Auto Channel, 2002).

Patents or copyrights provide entry tickets, but innovating is based essentially on systems integration and accumulated engineering expertise. Toolmakers invest heavily in innovation: 32% of sales go to R&D, accompanied building strategy, marketing, and production capabilities, for a total of 44.16% of sales. High levels of innovation expenditures are necessary to sustain capabilities in marketing, customer intimacy, and production and to produce new versions of tools periodically.

Toolmakers do most of their work in-house using a process of decomposition into modules followed by tight integration. For specialised applications, they contract with subordinated and certified technical firms in peripheral roles. They also enter into alliances with strategic partners to reach markets.

Alliances with buyers are prevalent: value may take years to appear and depend on the learning interactions between buyers and toolmakers. Buyers accept that overall performance is superior when they use subsystems designed to work in an integrated fashion. Some large customers, however, insist on inter-operability and demand openness. Opening up the architecture of closed systems is not always the ideal strategy for dominant firms, as they lose opportunities to add services. The architecture is opened when it is forced by competitors' advances, regulatory pressures, or irresistible technical evolutions.

Value is captured by tool developers through the building of proprietary systems and long-term relationships. Reputation of technical leadership and high-quality services are important. Many competing and non-interoperable systems can survive and share the market. Even marginal market positions are sustainable if the tools embody specialised architectural knowledge. Once committed to tightly integrated systems, buyers train engineers and staff to learn and build their knowledge around integrated systems. Switching away involves high learning and unlearning costs.

Systems engineering and consulting

This game concerns the design and implementation of mission-critical infrastructure systems. Major investments to improve efficiency are made by operators of large-scale networks for electric power, banking, retailing, financial services, manufacturing, communications, and so on. Mission-critical projects involve networks of specialised suppliers: projects often put operators at risk.

Before committing to substantial irreversible investments, operators want strategic advice to identify their main options. The building of mission-critical systems entails high risks of cost overruns, inadequate performance, and long delays. The project-management literature is replete with stories of large engineering projects gone awry (Miller and Lessard, 2001). Many critics suggest that the organisational transformations and re-engineering of processes entailed by such large projects create havoc, downsizing, and, eventually, bureaucratic formalisation of firms (Davies and Hobday, 2005).

The dominant logic of innovation is a hierarchical and shared process of collective problem solving involving specialised firms. Tools and business processes for new product development, supply chain management, or customer relationship management are tailored with consulting services: hardware, software, and work practices are combined. New ideas and solutions arise from generative debates and discussions. Typically, the process starts with interactions between the senior management of operating firms and strategy consultants to help define salient issues: analyses help identify potential technological systems and scenarios about likely futures.

Operators aim to radically transform their cost structures, improve the delivery of new products, and better interact with customers so as to understand emerging markets. As globalisation progresses, worldwide coordination of materials, activities, and information flows is desirable.

Once strategic issues have been decided upon, operators build a project team and invite systems engineers to imagine, design, and articulate novel architectures. Specifications for infrastructure investments are then outlined. Systems engineering firms are knowledge repositories and clearinghouses between buyers, vendors, and software suppliers. Contractors and suppliers called in by systems engineers may do the creative work internally or engage in further generative interactions with their own partners. Proprietary systems are assembled from closed, open, or interoperable tools; extensive outsourcing of activities is included.

Consultants must stay significantly ahead of the operators they are trying to advise. On average, 15.03% of sales is invested in R&D and capabilities by consultants and systems engineers. R&D is not a distinct department but an activity funded at the corporate level and involving consultants with networks of university professors, gurus, or vendors. To keep ahead, strategic relationships with leading operators and technology suppliers are developed. Knowledge accumulation takes place through the formalisation of strategic or engineering methodologies, the codification of past learning experience in archives, knowledge management systems, or expertise directories. To imagine future evolutions of sectors and scenarios, many strategy and systems consultants are funded by research institutes.

The ecosystem is composed of a hierarchy of specialised consulting firms. Value creation is in strategic and systems integration services. Operators choose from a limited range of strategy consultants, systems engineers, and product suppliers around the world. Reputation and experience are dominant choice criteria. As one goes down the hierarchy, competitors are more numerous and many contracts are outsourced to low-cost areas.

Operators capture value by building organisations that are efficient in performing their missions. Strategy and systems consultants gain by improving their reputation for strategic and system integration services. Systems integrators capture value by building partnerships with operators, top-level consultants, and product suppliers and involving all of them in learning about the platform evolution. Bankers or investors involved in the financing of infrastructure projects gain by being able to rely on the reputation of specialists in past projects.

Games of innovation involving modular products and services

Modular products and services appear when tightly integrated systems are broken into many technologies, components, and markets. Coordination to perform the intended functions is achieved through open architectural platforms with connectivity standards (Baldwin and Clark, 2000). Two games appear. "Battles of architectures" are focused on market creation, while "learning and customising" takes place once one or a few dominant architectures have emerged.

Battles of architectures

Battles of architectures are contentious market-creation tournaments in which platforms that integrate components, services, and markets compete for dominance. Patents at best provide entry tickets to the cross-licensing rounds that will leave several competitors in a situation of technical parity.

The telecommunications sector is currently involved in a battle of architectures. The PSTN (Public Switch Telephone Network) platform is competing with Internet service providers' platforms that coordinate multi-sided sets of customers through info-mediation business models such as auctions, VoIP, financial transactions, and entertainment. Platforms are continuously evolving and shifting; for instance, Internet mobile communications moved from business communications tools to entertainment services to young customers.

Buyers want plug-and-play products and not to be locked in to closed systems. The complexity of early platforms is baffling to buyers who are often ill informed, unable to assess performance, and lack the willingness to try and learn (Langlois and Robertson, 1992). Customers need to be convinced to try platforms that often require unavailable complementary infrastructures and entail the risk of turning out to be market orphans. To reduce risks, buyers rely on external signals such as reputation of sellers, winning choices, and low-cost trials. Selection takes place in the context of network effects, convergence toward *de facto* or *de jure* standards and the reputation of strong players.

The dominant logic of innovation is based not on scientific prowess but on the leveraging and orchestration of the inventive power of supply and demand markets to arrive at the emergence of dominant platforms. Participants in this game spend on average 10.23% of sales on R&D and capabilities building.

The logic of innovation consists in entrepreneurs proposing platforms and standards around which suppliers and customers are invited to align. The goal is to eventually stabilise around a dominant design to decentralise innovation at the periphery. To get there, a contentious process of mutual alignment of core architectures, peripheral components, and standards takes place. Initially, the goal is to attract attention and investments from potential complementors, venture capitalists, or corporate investors capable of furnishing the missing elements. In turn, components suppliers align with the architectures that show promise.

The first generations of platforms co-evolve with markets as orchestrators interact with early buyers, producers, and complementors and redesign them. The paths of evolution of platforms are varied, uncertain, and sometimes fizzle. Few of the initial platforms survive the contentious process because early successes need to be followed by large investments to attract buyers, sellers, and component makers. Eventually, the contentious process dwindles and one or a few dominant platforms emerge.

The ecosystem is central to market creation and emergence of dominant design. Promoters will develop alliances to grow technical options, market applications, and credible collaborations. The purpose is to trigger positive feedback around their platforms. For example, Sun Microsystems viewed JAVA as a platform to compete with Microsoft. The UNIX experience had taught that pushing one's architecture often leads to polarisation in which one family of products with its architecture eliminates another. To make JAVA a *de facto* standard and create markets for its workstations, Sun Microsystems engaged in coalition building with Oracle and IBM as well as 190 ecosystem firms (Miller and Floricel, 2004).

Should platform promoters favour rapid value creation and capture, they may choose closed, proprietary architectures that impose high switching costs on users. By contrast, they may choose to accommodate a variety of current and future customer needs and segments; they will launch prototypes with the hope of triggering independent innovations around them. Betting on the wrong platform for promoters or suppliers will destroy the chances for success of superior products or services.

Even governments are involved. The 839 strategy of the Ministry of Information and Communication of Korea aims at developing the telecommunication field. The goal is first to foster the development of services such as VoIP, mobile communications, digital TV, and in-vehicle mobile office. Demand for services will require the development of digital broadband infrastructures. Demand for services and infrastructures will trigger the emergence of many new businesses for Korean industry.

Customised mass production

Over the past 25 years, mass production has been transformed as a result of innovations that make flexibility and customisation possible. For example, a few optimal-size plants produce watch movements in Japan and Switzerland, but most watches are custom assembled for distinct market segments. Similarly, in the automobile sector, information and communication technologies have made individual customisation a real possibility.

Customers want low-cost but differentiated products: their criteria are style, price, reputation, brands, and so on. Assemblers cater to customers' diverse needs at affordable prices. The commoditization of products is avoided through strategies by producers to design new product features, segment markets, and brand families of products. Customised mass production often becomes a "battle of brands". By focusing on segments, not only are competitors staying away from each other but they may even be increasing the size of each others' pies.

Value is created and captured by combining design capabilities, styling and reputation with global, efficient supply and production networks. Here are the main elements of the logic:

i. Networks of very-large-scale firms supply low-cost standardised modules or components. Globalisation of production is a major strategy. Suppliers are often called the "upstream back office". Flows of information, materials, and transactions with suppliers are coordinated by assemblers with tools such as ERPs, SCMs, and inter-organisational PLMs.
ii. The assembly part, often called the "downstream front office", has extensive contacts with customers through marketing, retailing, and distribution efforts. Depending on transport costs, assembly may be located close to buyers or

suppliers. Assembly systems are designed to make mass production highly responsive to customers' pull for highly differentiated products. IT systems and business processes are used to deliver highly customised and differentiated products to a wide variety of segments.

iii. Assemblers learn about demand directly by engaging in e-commerce and info mediation. They invest heavily and directly in Internet tools and databases in order to become intermediaries interacting with communities of customers. Producers exploit their data to understand emerging product differentiation and market segments.

System integration by assemblers drives value creation: RD&E activities are conducted generally in-house. For instance, automobile assemblers perform most competitive R&D activities internally with the exception of technology development, which is partly shared with outside partners, suppliers, or contractors. However, suppliers rarely undertake independent innovations to challenge the assemblers' platforms: they coordinate actions with assemblers.

For instance, the automobile sector has been in the mass production and customising game for 70 years or more, in spite of significant changes in industry practices. Should an open platform replace the present dominant design, a radical change would take place, but this has not happened yet. Economies of scale and tight coordination with suppliers are required, thus imparting inertia, and regulations to stimulate fuel economy, safety, or pollution controls have not succeeded in triggering radical changes. Technical limitations to battery performance, absence of infrastructure, and the inertia of buyers are thwarting the development of hybrid electric cars.

Barriers to entry, accumulated design and engineering capabilities, and cost advantages impart a high degree of stability and inertia. Investment and innovation in this game total 7.73%, with 6.04% for R&D and 1.69% for capabilities building. Assemblers need, on the one hand, to come up periodically with differentiated designs and, on the other, to achieve incremental improvements in mass production to reach higher levels of productivity.

Suppliers of standardised components are part of the value chain of assemblers: coordination leads to high levels of efficiency. Economies of scale and tight coordination with suppliers impart inertia. Suppliers of critical non-standardised components (such as Intel for computer chips) can capture benefits for themselves. In the automobile industry, regulations to stimulate fuel economy, safety, and pollution controls have not succeeded in triggering new platforms that would replace the present dominant design. Technical shortcomings in battery performance, absence of infrastructure, and the inertia of buyers are thwarting the development of electric cars.

Persistence of Games and Migrations

Games are ongoing, collectively shared processes of value creation and capture. As long as contextual forces remain basically unchanged, the same patterns prevail. Games are shaped but not determined by basic underlying forces including the shared knowledge and activities necessary to meet demand and produce for goods and services; the learning movement from high uncertainty in knowledge and market creation towards maturity and inertia; and the rules of action that are learned and codified. Furthermore, the division of labour across specialised organisations, innovation support agencies, and institutions also fosters persistence. However, indeterminacy and strategic freedom by innovative players are always there to impart unpredictable direction.

Turning points

Eventually, sectors, industries, and firms reach turning points. Major turning points occur when the distance between the requirements associated with contextual conditions and the range of strategies pursued by firms grows. Sectors, industries, and firms are then ready for a game change.

Turning points may come from exogenous forces such as long-wave technical shifts. The diffusion of fibre-optics and broadband Internet has triggered a battle of architectures in the telecommunications sector in which new entrants, especially ISPs, are competing with established public switching networks. Turning points may come from endogenous changes as customers demanding better performance, new solutions, or radically different approaches.

Turning points may also be institutional. The flight-simulation sector moved to high-fidelity full-flight simulations because regulations developed jointly by public agencies and industries fostered achievable targets. However, shifts in regulations in the electric power sector did not lead to a game change. Power-generation firms remain focused on asset optimisation because of persisting economies of scale and the remaining indivisibility of many networks.

Migration paths

Games persist but sectors, industries, and firms go into cycles of birth, growth, and maturity. The process does not inevitably end in demise. Instead, renewal or evolutionary dialectics occur as radical innovations thrust established sectors back into market-creation activities. Problems, bottlenecks, and shifts in customer demands can rejuvenate mature sectors such as steel, aluminium, and paper. Presently, the shift towards digitisation is introducing discontinuities in many sectors (Malone and Laubacher, 1998; Zysman, 2003). Here are some of the migrations indicated in Fig. 1:

i. Arrow A indicates the migration from "patent-driven discovery" to "optimisation and innovations in alliances". The transition points occur when the key underlying patents in portfolios come to the end of their valid life and new conditions lead to commoditisation. Arrow B indicates that the possibility always exists that some players will make a discovery that opens up new opportunities and fields (Day *et al.*, 2000). When this happens, the game returns to a relentless search for discovery.
ii. Many innovations start as tightly integrated systems and move eventually to open systems. Arrow C indicates a transition from closed systems in "RD&E tool-making" to open platforms in "battles of architectures".
iii. The transition from "RD&E tool-making" to "systems engineering and consulting" is illustrated by Arrow D. Buyers want services to design and implement tightly integrated systems. Customers want bundles of hardware, software, and services to fit generic tools such as PLM to their specific conditions.
iv. Arrow E refers to the long migration from "RD&E tool-making" to "customised mass production". Two new conditions appear: products begin to overshoot customers' expectations, and buyers want customised products made from commoditised lower-costs and flexible components. Strong competition sets in (Chesbrough, 2003; Christensen, 1997). For example, personal computers, which started as closed systems, moved to open systems as Microsoft succeeded in orchestrating a *de facto* standard. IBM delayed actions to open the architecture of its Personal Computers.
v. Arrow F refers to the reverse and rarer migration from "systems engineering and consulting" back to "RD&E tool-making". This transition takes place when specialised firms involved in large projects develop novel applications; these tools thrust them back into market-creation games.
vi. Arrow G illustrates the migration from "battles of architectures" towards "customised mass production". As choices crystallise around one or a few dominant architectures, basic functionalities are more than adequate for most potential users. Interactions between the various elements of the system are better understood and their interfaces can be clearly specified, codified, and standardised. Improvements are done mostly at the periphery, while the core architectural elements tend to be very stable. Arrow H indicates rare movements back from "customised mass production" back to "RD&E tool-making." Major technical discontinuities arise and force competitors to reintegrate so as to develop high-performance integrated systems.

Conclusion

Our argument has been that clusters of interdependent firms contributing to building categories of products and services tend to self-organise into distinct and relatively stable "games of innovation." Such games operate at a meso level of analysis, bringing together many complementary contributors such as focal firms, suppliers, public regulators, universities, innovation support agencies, and venture capitalists.

Normative prescriptions to manage the innovation process are generally derived from theories that view innovation as a uniform process. In reality, however, the contextual conditions, the pertinent knowledge, and the specificities of products and services to build call for distinct approaches.

As managers and public policy-makers develop the concrete systems of innovation activities to fit the problems at hand, distinct sets of rules for managing innovation emerge. For instance, customer expectations are central in some games but almost irrelevant in others. Rules for managing innovation are neither generic best practices that can be applied universally nor narrow industry recipes learned over the years, but game- and role-specific ways to create and capture market value.

A majority of firms limit themselves to pure plays in one game, basically adapting their moves to the established rules. Others may borrow strategies from other games and apply them innovatively to their own. Many firms diversify and learn to play many games. As firms migrate into new games, shrewd managers spot the indeterminacy still built into the game rules and mobilise the requisite resources to shape those rules to their advantage.

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