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Coevolution of Technology, Organisations and Institutions: A Literature Review Toward an Integrative Perspective on Innovation and Industrial Competitiveness[1]

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ABSTRACT

Despite a growing literature focusing on technological development as a key driving force behind the economic performance of a firm or a nation's industy, we still fall short of a comprehensive understanding of how each of the elements required of technological developent and innovation fits togther and leads to economic progress and industry change. This paper seeks to fill this gap by bringing together some of key insights from the theory and research on the coevolutionary process of technology, organizations, and industry, and on the role of institutions in this process. By combining a diverse array of research streams, we provide a broad suvey of foundational work on the following two questions: (1) how the creation and diffusion of innovation occurs and gives rise to structural reconfigurations of the industry, (2) how organisations and technology coevolve, and (3) what is the role of institutions in this coevolutionary process? Based on this literature survey, we also offer a synthesis that can serve as a ground that allows a more nuanced understanding of the sources, dynamics and impacts of technological development and innovation, and interrelationships among technology, organizations and industry change.

Keywords: Theories on technological development and innovation, industry dyamics and technological development, the role of institutions in innovations, the coevlution of technology, organizations and industry

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1. Introduction

Technological development is at the core of industry and economic progress. Scholars from divergent fields have long considered technological advancement as a key to competitive advanatage of a firm, industry and nation(e.g., Cantwell 1992; Coriat and Dosi 1998; Dosi and Coriat 1998; Dosi et al. 1999; Dosi and Winter 2000; Langlois and Robertson 1995; Malerba and Orsenigo 1997; Malerba et al. 1999; Michie and Prendergast 1997). Over the past decades, we have seen the increasing volume of empirical studies that focus on technological development and innovation as a siginificant factor shaping economic performance of the entity of interest. While this rapidly growing body of research has helped enhance our knowledge about the content and process of technological development and its effects on competitive advantage of a firm, industry, and nation, much of this work seems to lose sight of a big picture, neglecting to clarify how each of the elements required of technological developent and innovation fits togther and yields economic progress and industry change.

In this paper, we seek to fill this gap by bringing together some of the key insights from the long-standing literature on the coevolutionary process of technology, organizations, and industry, and the role of institutions in this process. We also attempt to enrich this endeavor by instilling and combining a diverse array of research streams that tend to be overlooked in much of the recent studies on technological development. Our observation is that much of extant technology and innovation studies do not appear to fully leverage on this accumulated theoretical insights. Appreciation of core ideas and concepts from neighboring fields can also help researchers to capture the aspects that otherwise could have readily escaped their attention.

As an initial step toward this goal, we begin by providing a broad suvey of foundational scholarship addressing the following three questions: (1) how the creation and diffusion of innovation occurs and gives rise to structural reconfigurations of the industry; (2) how organisations and technology coevolve; and (3) what is the role of institutions in this coevolutionary process? Realizing we lack an overarching, integrative perspective through which to view technological development and innovation process that pays due attention to the role of individual actors, structure and context, and the interplay among them, next, we offer, based on the preceding literature survey, a synthesis that can serve as a ground that enables us to reach a more nuanced understanding of the sources, dynamics and and impacts of technological development and innovation, and interrelationships among technology, organizations, institutions and industry change.

This paper will be structured as follows. In the first part of the paper, we provide a brief overview of the main arguments elaborated by preponderant theoretical approaches to the sources and dynamics of sustainable competitive advantage. In the second part, we revisit some of the crucial ideas and concepts that serve as the basis for

much of the scholarly work on the development of technological paradigms and the process of innovation generation and dissemination. Next, we outline key lines of thoughts underlying some of the most influential work on the relationship between technological development, organisational responses and consequent industrial change. Throughout the discussion, we highlight prime theoretical constructs in various approaches to technological development and innovation.

2. Literature Review

Where does competitive advantage come from? How is technological advancement and innovation linked to industry and economic progress? In a very broad manner, this part of the paper provides an overview of the assumptions, logics, and pitfalls of dominant theories related to the issues of the sources and dynamics of competitive advantage and varying perspectives on the relationships between technological advancement and industy and economic change.

The theoretical core of some of the dominant theories that concern these subject matters has widely affected the fields of strategic management and innovation studies. The analytical and methodological tools that have been utilised to address these questions take diverse forms and shapes ranging from hypothesis testing with statistical analysis, in-depth single- or multi- case study, and comparative historical analysis. On the origins of sustainable competitive advantage of a firm, the structure-conduct-performance theory and the resource-based view are featured prominently. At the level of nation-wide economy, endogenous growth theory, evolutionary theory of economic change, national systems of innovation as well as the comparative capitalism perspective are presented.

Not surprisingly, each of the theoretical or analytical perspectives on those issues maintains their own distinctive explanations of sources of competitive advantage and the linkages between technological development and industy and economic progress. To compare and contrast across those divergent lines of theories and research, the discussion of those perspective is organised along the lines that would feature their similarities and differences.

2.1 On the Sources and Dynamics of Competitive Advantage of Firms and Nations

The questions of the sources, dynamics and consequences of innovation and economic progress have long preoccupied researchers from various fields. One key question is where the competitive advantage of a firm or a nation' s specific industry comes from(e.g., Barney 1991; Nelson 1993; Nelson and Rosenberg 1994; Porter 1980, 1990; Rumelt 1991; Wenerfelt 1984). Another closely related question is why firms or nations at an aggregate level show variations in sustainable competitive advantage and long-term economic performance(e.g., Barney 1991; Porter 1980, 1990).

Foundational work on the sources of competitive advantage of firms and nations

Theories of heterogeneity in the degree of sustainable competitive advantage, and hence long-term economic performance among firms have been at the core of the strategic management research, dominated in large part by industrial economics since its inception(e.g., Hensen and Wernerfelt 1989; Jacobson 1990; Mauri and Michaels 1998; McWilliamson and Smart 1993). It is Porter(1980) who shifted the focus of strategy research outward, towards the analysis of the firm's microeconomic environment. His five forces analysis is essentially a structural mapping of the underlying economics of an industry: the degree to which competitors, entrants, substitutes, and vertical bargaining power exert pressure on the margin of a firm in a particular industry. This proves to be a powerful tool for understanding why a particular strategic action may be associated with supranormal returns, but says nearly nothing about the role of general manager or the process of strategic choice in determining profitability(Corkburn et al. 2000, p.1126). And empirical examinations to date, yet, reveal rather mixed and inconclusive results though some researchers have found evidence consistent with the so-called structure-conduct-performance paradigm(McGahan and Porter 1998; Rumelt 1991), with the industry to which a firm belongs as its main explanatory variable.

On the other hand, others have viewed sustainable competitive advantage of a firm ultimately as a return to unique assets owned and controlled by the firm(e.g., Barney 1991; Makides and Williamson 1996; Peteraf 1993; Rumelt 1991; Wenerfelt 1984). This so-called resource-based view(a.k.a, RBV) suggests that firm heterogeneity in acquiring and deploying resources and capabilities accounts for much of superior returns generated over a long period of time, and thus a sustainable competitive advantage. To some extent, the resource-based view is clearly at odds with the hitherto outward-looking perspective, which analytically depicts why a differentiated position within an industry, coupled with high entry barriers, can lead to profitability. Inspired by the work of Penrose(1956), the resource-based view redirects attention back to the underlying organisational heterogeneity that enables such a position sustainable. This is based on the intuition that an industry's structural features are partly the result of the constituent firms' organizational capabilities(Corkburn et al. 2000, p.1127).

Varying perspectives on innovation, industrial competitiveness and economic progress

While the field of strategic management has been grappling with the question of the relative impact of industry vs. firm-specific effects on firm performance, the recent decades have seen variations in overall economic performance or competitiveness among nations being increasingly examined from the perspectives that look beyond the firm as the locus of innovation[1](e.g., Archibugi and Michie 1995; Archibugi et al 1999;

[1] For example, national innovation systems, regional innovation systems, techno-global networks (De Prato, and Nepelski 2014) etc.

Batholomew 1997; Edquist 1992; Freeman 1994, 1995; Lundvall 1988, 1992, 1998; McKelvey 1999; Yoon and Hyun 2009).

In particular, some scholars from the field of sociology and political economcy have developed comparative models of contemporary capitalism on a more systemic scale. This so-called varieties of capitalism persepective has sought to appreciate the empirical reality of divergent economic development paths taken by different countries, and their influence on economic outcomes[2](e.g., Boyer and Hollingsworth 1997; Soskice 1999; Whitley 1994). Despite apparent differences in their level of analysis and mode of explanation, the latter two perspectives - innovation systems and the varieties of capitalism - share a common intuition and understanding that economic change is a profoundly path-dependent, institutionally embedded process.

Understanding critical factors that shape the economic performance of firms and nations is of obvious importance to many researchers and, in particular, numerous attempts have been made to assess the influence of different factors on industrial growth. Mainstream economic theory has tended to focus on factor accumulation as the driving force behind growth, with technological progress merely as an exogenous process in its analysis of industrial growth. As the importance of technological development gains a critical momentum, the new theory of economic growth(a. k.a., endogenous theory of growth), started to acknowledge that technological innovation has become a more important contributor to economic growth(Romer 1990; Singh and Evenson 1997). At a high level of abstraction, endogenous growth theory highlights two important determinants of the production of ideas in an economy: the stock of knowledge at the aggregate level and the size of the R&D labour pool. In particular, it shows that the cumulative R&D experience contributes to the stock of knowledge, which enhances the productivity capacity of an economy and adds to the domain of social knowledge. Thus, endogenous growth theory suggests that the cumulative stock of knowledge not only stimulates economic growth of an economy but also generates spillovers which can act as an external effect in enhancing productive capacity of all other economies(Evenson and Singh 1997).

Technological progress and its effects on industrial dynamics, in general, and on economic institutions, in particular, have become a burgeoning area of academic inquiry in various research programs, ranging from evolutionary economics(Nelson and Winter 1982) and innovation systems approaches(Edquist 1992; Freeman 1994, 1995; Lundvall 1988, 1992, 1998) to strategic management(Teece and Chesbrough 1997) and organizational economics informed by economic history(Chandler 1990; Piore and Sabel 1984; Williamson 1975, 1985). Implicit in all these strands of research programmes is the assumption that economic activity is embedded in wider

[2] For example, German, Japanese style of capitalism vs. Anglo-American style of capitalism.

institutional structures, though they differ in the degree of institutional flavour.

The scholarly work inspired by evolutionary thinking is typically premised on the idea that a population of heterogeneous firms search for more efficient techniques of production and better products in the competitive markets and performance differences and thus their ability to grow are, to a large extent, shaped by differential success in the search process manifested in their concomitant behaviour and strategies(Nelson and Winter 1982; Nelson 1995). According to evolutionary thinking, the nature and direction of market selection is determined largely by the accessibility of technological opportunities and the level of technology diffusion. The ability of a firm to absorb and enlarge its knowledge is formed by carrying out organizational routines. Evolutionary economists, on an aggregate level, have also viewed a nation's level of technological prowess as the key factor fostering its productivity level. They thus see technological advance as the driving engine behind economic growth(Cantwell 1992; Coriat and Dosi 1998; Dosi and Coriat 1998; Dosi et al. 1999; Dosi and Winter 2000; Langlois and Robertson 1995; Malerba and Orsenigo 1997; Malerba et al. 1999; Michie and Prendergast 1997). Although they do not hesitate to admit that economic institutions play a key role; for instance, intellectual property system, public organizations, antitrust and regulatory system, universities and government research centers, etc., a notable shortcoming in the evolutionary perspective is that institutions have not yet been sufficiently incorporated in their analysis that heavily relies on simulation modelling(Dosi and Coriat 1998; Nelson and Sampat 2001).

Evolutionary economics scholarship has been more or less coevolving with the comparative historical approach that also explores the process by which technical development and innovation is created and diffused within an economy. Notably, the past three decades have witnessed one of its major sub-field, the national innovation systems(a. k.a., NISs) approach, evolving into something of a distinct, independent research programme in its own right. In an effort to move beyond the limits of the neo-classical economic paradigm, which, in general, tends to downplay the importance of innovation in its account of economic growth, as noted earlier, the national innovation systems scholars have sought to study divergent ways in which innovations are created and diffused in a given nation's or sector's economy(Archibugi and Michie 1995; Archibugi et al. 1999; Batholomew 1997; Edquist 1992; Freeman 1994, 1995; Lundvall 1988, 1992, 1998; McKelvey 1999; Saxenien 1995; Yoon and Hyun 2009).

On the methodological front, researchers employing the perspective of the national innovation systems often start by providing a detailed depiction of the organization and patterns of activity that contribute to innovative behaviour in a given country or sector. The goal is to identify those institutions and actors who play a decisive role in the generation and spread of innovation, emphasizing national idiosyncrasies in innovation trajectory(Dosi 1988; Edquist 1997; Nelson 1993). In

particular, they tend to underscore the active role played by government policy and specific public institutions and authorities. As Lundvall(1988, 1992) notes, geographic boundaries matter because constant, durable interactive learning, a critical force behind the creation of innovation, is most likely to arise within a spacial setting in which few socio-cultural constraints for the transfer of tacit knowledge are present and trust relationships are easy to form. <Table 1> and <Table 2> provide a summary of key theoretical interests and anayltical strategy of each of the aforementioned perspectives on sources of competitive advanatege of firms and nations as well as the linkage between innovation and economic and industry change that have been discussed so far.

<Table 1> Dominant approaches to the sources of competitive advantage of firms and nations

	SCP (Structure-Conduct-Performance)	RBV (Resource-based View)	NIS (National Innovation systems)	Comparative Capitalism
Unit of analysis	Firm	Firm	Nation	Nation
Theoretical inspirations	IO (Industrial Organisations – a branch of neo classical economics	Penrosian theory	Evolutionary economics Institutional theory Technology management, Economic history	Sociology Political economy Economic history Institutional theory
Theoretical off-springs	Porter's competitive forces	Knowledge-based view Dynamic capability theory	Regional innovation systems	National production systems National business systems
Major Scholars	Porter(1980, 1990)	Barney(1991), Peteraf(1993), Reed & DeFillippi(1990)	Lundvall(1988, 1992,1998), Edquist(1997)	Archibugi & Michie(1995), Batholomew(1997)

<Table 2> Various perspectives on the relation between innovation, industry and economic progress

	Endogenous Growth Theory	Evolutionary Economics	National Systems of Innovation	Organizational Economics/ Economic History	Strategic Management
Unit of analysis	Macro-economy	Firm population	National economy (or industrial sector)	Firm/ Business organization	Firm

Main theoretical interests	International specialisation & economic growth	Organisational routines, capabilities & learning	Technological trajectory, knowledge creation & diffusion	Governance mode/ Organizational innovations	Sources of competitive advantage
Main issues related to innovation	Innovation as an endogenous growth factor	Innovation as growth behind economic change (Schumpeterian theory)	Innovation process determined by varying national institutions	Organizational form most amenable to innovation	Firm-level strategy to win the market in dynamic environments
Main methods	Mathematical modeling	Simulation modelling	Comparative-historical analysis	Deductive reasoning/ Comparative-historical analysis	Hypothesis testing & case studies
Major Scholars	Romer(1990)	Nelson & Winter(1982)	Lundvall(1998), Edquist(1997)	Williamson(1975,1985)	Barney(1991)

2.2 Characteristics of technological paradigms

Before we delve into various ideas and concepts of the influential scholarly work on how technological development leads to organisational responses and consequent industrial change and vice versa, it will be useful to clarify, first, some of the crucial features - including but not limited to incremental vs. radical nature of technological change, modular vs. architectural innovation, punctuated equilibrium, the S-shaped diffusion - that are manifested in each technological paradigm. This exercise will help us better understand the basis of the process of innovation generation.

An enormous literature has shown how much industries differ in their basic technologies and how these technologies affect the nature, boundaries and configurations of industries(e.g., Rosenberg 1982). It has been firmly established that specificities of a technological paradigm and the underlying knowledge base provide a powerful constraint on the patterns of innovative and production activities in each industry. Dosi(1988) defines a technological paradigm as "a pattern of solution of selected technological problems based on selected principled derived from natural sciences and on selected material technologies" (p.152). According to Dosi(1988), new paradigms represent discontinuities in trajectories of progress and how technologies are selected and retained is closely related to the question of why firms succeed or fail.

However, discussions of the characteristics

of technological change to date have offered sharply contrasting perspectives on its pace and mechanisms. Some have emphasized the gradual and incremental nature of technological change(Dosi 1988; Rosenbloom and Cusumano 1987; Rosenbloom and Burgelman 1995), while others have viewed technological change as characterized by rapid and discontinuous process (Tushman and Anderson 1986). From a slightly different angle, Henderson and Clark(1990) suggested that the use of a set of core technologies in a given apparatus constitutes a technological paradigm for the class of products that evolve along a certain trajectory of improvement building off frorm prior innovation. They proposed that once a new technological paradigm based on a set of core technologies has become established, an organization's attention tends to shift to the incremental and modular innovations, which in turn drive further performance and cost improvement within that paradigm. And they argue that the organizational structure correspondingly evolves in the manner that facilitates further improvements of particular components (we will discuss this point in more detail later). This observation is based on the analytical distinction between modular innovation – that refers to the introduction of new component technology inserted in the existing product architecture, and architectural innovation – that refers to the transformation of the ways that the whole set of components work together. At another dimension, radical innovation leads to path-breaking changes in both components and architecture - i.e., a new core technology using optical fiber, instead of metal for communications cables.

In this context, the theory of punctuated equilibrium(e.g., Gould 1992) is worthy of some mention. Developed in the field of evolutionary biology, the theory provides a useful point to reconcile seemingly conflicting ideas of incremental change in underlying science and apparent discontinuities in the commercial application of technologies. The theory of punctuated equilibrium notes the defining influence of speciation events, namely, the separation of one evolving population from its antecedents, and sheds light on how they are followed by other evoluationary events that allow populations to follow different evolutionary paths(Romanelli 1991). This framework thus can inform us of much about the origins and evolution of a given technological development path at the population level.

What forms and shapes a trajectory of the process of technological evolution and change take? It has been found that diffusion patterns of innovation tend to follow S-shaped curves(Afuah 1998; Vernon 1966). The S-curve represents the pattern of cumulative adoption of innovative technologies within an industrial context. It suggests that, when an innovation first appears, only a few pioneers or early adopters will adopt it, until its effects are better understood. Later, the innovation disseminates within a larger number imitators or early followers. Finally, the number of adopters begins to decline until the

next innovation emerges. Thus, under the S-curve hypothesis, technology evolultion and change follows a life cycle that passes though different stages of radical and incremental development.

Relatedly, it has been well established that industries and firms in developed countries evolved along a technological trajectory made up of three-stages: fluid stage when radical product innovations are explored, transition stage when dominant product designs and mass-production methods emerge, and specific stage when incremental process innovations dominate(Utterback and Abernathy 1975; Utterback 1994). To put differently, technological life cycles are initiated with a revolutionary transformation, ensued by incremental improvements and standardization, that is embodied in dominant design, until further efforts yield diminishing returns, propelling a new cycle of transformation.

3. Coevolution of Technology, Organizations and Institution towards an Integrative Perspective

As stated in the Introduction, the goal of this paper is to serve as an intial step toward building an integrative framework that allows a more well-rounded, nuanced understanding of the dynamic interactions between technology, organizations, and institutions that underly innovation. Toward this end, in what follows we revisit previous scholarship dealing with the question of how the creation and diffusion of innovation of varied properties gives rise to structural reconfigurations in the industry through the evolutionary process of organisational adaptations and technological change, which in turn provides further opportunity for continuing innovation. This theoretical appraisal of accumulated prior research is organised in the way to help us to build a conceptual understanding, which will guide future empirical investigation. Each subsection ends with a proposition deriving from the earlier discussion.

3.1 Innovation diffusion, organisational adaptations and industrial change

Then, how these characteristics of technological paradigams and trajectories bring about industry-level change? The theory of industry life cycle indicates that over a long period of time industrial reconfigurations in market structure are in essence driven by shifts in technological paradigm. That is, in the nascent stage of the life cycle of an industry in which knowledge tends to change rapidly and uncertainty is very high and barriers to entry low, new entrants are likely to be the major innovators, playing a key role in generating industrial dynamics. When the industry develops and moves into the mature stage and technological change follows a well-defined trajectory, complementary factors such as scale economies in manufacturing and marketing, learning curves, mobility barriers, and the availability of other complementary resources become critical in the competitive process. Thus, large incumbent firms, that are positioned more advantageously along these dimensions vis a vis their counterpart, often

come back to the forefront of the innovation process(Klepper 1996; Utterback 1994).

Yet, knowledge base and demand conditions also matter. That is to say, the characteristics of knowledge base and demand conditions constitute major constraints on the range of diversity in the behaviour and organization of firms active in a sectoral system. For example, empirical analysis of the evolution of the computer industry shows complex relationships between demand, knowledge base of key technologies, and the boundaries of firms(Malerba et al. 1999). Computer hardware, once dominated by a few pioneers, are now supplied by hundreds of new firms as the capacity of performance increases exponentially and price decreases accordingly, coupled with continuous improvements in complementary technologies and learning-by-using on the part of end-customers. Subsequently, the challenge to IBM's market leadership during the 1970s and 1980s in the computer industry mounted as a result of convergence between mainframes and networks of smaller computers.

Inside the firm, the decision to adopt an innovation may be motivated by three different mechanisms: rationalism, bandwagon pressure, and forced choice(Abrahamson and Rosenkopf 1993). Rationalism assumes that firms are relatively free to choose whether to adopt new technology and which technology to select. For many firms, adoption decision is shaped by how embracing new technology help them to close competitive gaps and rise to market leadership(Zahra and Covin 1993).

Bandwagon pressure occurs when firms adopt an innovation, not as a result of rational decision-making, but they do so in ways that imitate direct competitors or companies from other strategic groups (Abrahamson and Rosenkopf 1993). Hence, there is a potential pitfall for firms following this logic of adoption. Firms adopting wrong kinds of fads and fashions can be exposed to the risk that they become victimized by those adoptions: in the worst case, this may directly lead to performance problems in the marketplace.

Finally, the choice and kind of adoption may also be imposed by the demand from relational partners such as customers and vendors(Abrahamson and Rosenkopf 1993). Though to a lesser extent, this forced choice can still cause competitive weaknesses for the adopting party if risks and costs involved in the adoption outweigh the benefits that follow. Overall, it is noteworthy that the above all three mechanisms underlying innovation adoption and diffusion across the industry can be observed simultaneously in the pattern of firms' innovation adoptions (e.g., Capaldo, Lavie and Petruzzelli 2017).

The dramatic breakthrough that sets the technology on a new course is often as much discoveries of new domains of application as advances in the underlying technology. In other words, the adoption and diffusion of innovation is also a function of the finding of new domains of application. For instance, wireless communications technology that has undergone extraordinary change in the hundred years since Hertz's

experiments is a case in point. Clearly, broadcast radio and wireless telephony, two of the core technologies underlying wireless communications, would not have been possible in the absence of continual improvements of wave transmitters. But the major impetus to develop that technology and the resources to do so stem in large part from the wills and efforts at enhancing the distance and clarity of wireless telegraphy and the incentive and interest of AT&T's in coming up with an effective repeater for long-distance wired telelphone services.

Tushman and Anderson(1986) explored the dynamics of environmental change surrounding a population of firms, focusing on technology as a main determinant in shaping the environmental conditions. Working in the tradition of population ecology, they view technology progress as an evolutionary process, where periods of incremental improvements of existing technologies are occasionally interrupted by revolutionary breakthroughs. They futher posited that these technological shifts can be either competence-destroying or competence-enhancing[3], depending on the degree to which the new technology reinforces or diminishes the prior expertise of incumbents in a given industry. Competence-destroying technological changes are typically triggered by nascent firms, while competence-enhancing changes are often generated by existing firms. The majority of cotton spinners, for instance, lacked organizational competence required to compete in synthetic fibers at the time when radically different technology was introduced into the apparel industry by Dupont. Tushman and Anderson(1986) labeled such innovations as competence-destroying because they greatly undermine the value of the competence of an established organization.

The most common explanations of why attackers may hold the upper hand at points of paradigmatic technological shift have something to do with the nature of a new technology. Chandler(1970) showed that in a varying range of industries established firms have tended to prosper for extended periods because those firms are capable of exploiting a series of incremental technological innovations built upon their solid organizational and technical capabilities. When challenged by radical technological change, however, dominant incumbents are likely to lag behind aggressive entrants, sometimes with fatal consequences to their established businesses. In the similar vein, Tushman and Anderson(1996) suggested that the sheer magnitude of the emerging technology is likely to render it impossible for incumbents to cope with the challenge and succeed. In other words, there is an element of uncertainty that the structure and internal dynamics of an organization facilitates or impedes its efforts at overcoming the obstacles raised by new technologies.

Given this, the attributes and magnitude of the

[3] The idea of competence-destroying and competence-enhancing can be traced back to the work of Abernathy and Clark (1985) on the organization-environment relations.

technological change, relative to the capabilities of incumbent and entrant firms, and the managerial processes and organizational dynamics through which entrant and incumbent firms respond to such changes have been studied extensively across industries, sheddng further light on the interrelationships between technological change, organizations and industry change. For example, Christensen and Rosenbloom(1995) investigated the array of technological innovations that have underpinned frequent and substantial changes in the market position of leading incumbernts throughout the history of the disk drive sector. Their study reveals that just as organizational structure and dynamics can affect an organization's capacity to develop the requisite technological capabilities, its position in the marketplace can also affect its organizational dynamics, which in turn affects the types of technologies a firm can develop. For example, their research indicates that an incumbent organization's engagements in creating informational asymmetries in the market may influence its willingness to make strategic commitments to the development of a new technology.

Finally, it is important to note the idea that the coevolutionary development of technology, organisations and industry is an intrinsically path-dependent process. For example, David(1985) showed that, regardless of performance level of alternative technologies, local learning and interactions among organizations in themselves may be suffiicient to generate increasing returns and irreversibilities. And this can somthimes lock a given sectoral system into inferior technologies.

So far, this section has sketched key ideas and concepts in the past work on the coevolving process of technological progress and industrial structure. To sum up, the salient characteristics of a given technological environment, coupled with demand conditions, have considerably influence on the nature of the problems firms have to solve in their innovative and production activities, and on the strength of incentives and constraints those organizations face[4]. As such, technological change affects the degree of uncertainty in an industry environment, thereby shaping the industry structure by increasing(or decreasing) the entry/exit rate and the degree of concentration. From this discussion, we can advance the following general proposition:

Proposition 1:

The charateristics of the technological paradigm under which a firm operates at a point in time constrain or elevate the economic incentives and technological competence of a firm in generating innovation over time. The success of the firm in taking advantage of these conditions and thereby generating innovation, in turn, transforms the competitive environments facing other firms

[4] In multimedia, for instance, the convergence of different types of demand and technologies has originated a new sector with continuously expanding boundaries in which main actors come from various industries, creating the new multimedia sector.

in the industry. Challenged by this, other firms may seek to adapt to the status quo or innovate by themselves, therefore, instilling dynamism into the industrial structure.

3.2 Organizational forms and industry change

In the previous section, we have presented a conceptual account of the multi-dimensional relationship between technological development and industrial change, based on a typology of innovation. However, in order to gain a better understanding how the process of organisational adaptations and industrial change is prompted by shifts in technological paradigm, in this section, we review major strands of organisational theory. In particular, we focus on population ecology and institutional theory, in tandem with the resource-based view and evolutionary theory of economic change, with the purpose of illuminating the factors causing heterogeneity and homogeneity in organisational form across an industry.

Following the prior discussion on the linkages between technological change and dynamics of industrial structure, this section first looks inside the firm in search of elements that facilitate organisational adaptations to environmental changes, and then considers conditions that yield diversity in organisational forms, with special focus on such analytical concepts as selection and institutional environments and founding conditions. There is a disparate group of theories all seeking to explicate the nature of contexts and processes that may contribute to generating new organizational forms, each of which is motivated by their own theoretical interests. For example, strategic management scholars have been interested in how imperfect markets for unique resources yields diversity in organizational strategy, sructures and design and hence heterogeneity in firms' competitive advantage(e.g., Barney 1991). Evolutionary theory and organizational ecology asks how population-level events and dynamics lead to change in competitive intensity that, in turn, affects the competence level and survival rates of constituent organizations (e.g., Hannan and Freeman 1984; Nelson and Winter 1982). Institutional theory asks how isomorphic pressures emanating from external environments affect social and economic fitness of organizations (e.g., DiMaggio and Powell 1991).

Given complex interrelationships among technological charateristics, industry dynamics, and institutional environmemt, and their combined impact on the success or failure of organizations, how do firms adapt in such circumstances? Organizational economists and economic historians have paid attention to the patterns and design of organizations that are most conducive to innovative activity and adaptation to industrial change. For example, Piore and Sabel(1984) showed that small firms (i.e., in the Third Italy or industrial clusters based on flexible specialisations) tend to be more flexible and thus are better able to adapt to changing environments, engendering innovations. On the othed hand, Chandler(1970) and Williamsons(1985) held that

large vertically integrated organisations are in the better position to adapt and hence spawn innovations due to their ability to exploit massive economies of scale and scope, which would help reduce large portions of transaction costs.

In the resource-based view, within the constraints of limited information, decisions about selecting and accumulating resources that help managers of organizations to better prepare for and adapt to changing external environment are typically characterized as economically rational. This perspective posits that it is the rational identification and use of valuable, rare, inimitable and nonsubstitutable resources, which will leads to enduring supranormal profits(Barney 1991). Accordingly, as barriers to resource mobility arise, an unequal distribution of resource across competing firms and diversity in organisational form and economic performance. However, it is important to note that many kinds of cognitive biases and causal ambiguity can impose further limits on the managers' ability to perceive the link between their organization's resource bundle and firm-level performance(Amit and Schoemaker 1993; Peteraf 1993; Reed and DeFillippi 1990).

As noted in the previous section, the impact of technological change of dissimilar nature and degree on established firms vs. entering firms, and the consequent industrial structure are important topics for many researchers working closely in the field of strategic management. In particular, scholars in this camp examined how different forms of innovation affect the structure and strategy of organizations based on varying typologies of technology(Christensen and Rosenbloom 1995; Henderson and Clark 1990; Teece and Chesbrough 1997; Tushman and Anderson 1986;). For example, Henderson and Clark(1990) probed into large-scale events that disrupted photolithography, xerography, personal tape-machine, and jet-engine industries as well as hard-disk drive industries of the US and Japan. Some of these industries show how incumbents have been displaced by new entrants after a significant technological change. On the other hand, Chesbrough(1999) stressed more on the underlying institutional and market factors – i.e., the labour market for technical workers, the venture capital industry, and the structure of manufacturer-supplier relationships - that promote or impede the birth of new forms of organization that in turn can alter the configuration of a given industry. Despite some differences in theoretical emphasis, scholars working under the rubric of the resource-based view tend to hold that a specific technological paradigm, which determines the nature of the problems, also affects how organisations tackle the challenge of their innovative activities, thus shaping the structure of incentives and constraints for further innovative activities and the type of technological learning within the organisations.

Partly inspired by the genetics analogy that emphasizes micro-level processes producing specific variations, evolutionary theory also posits that a technological paradigm moulds the basic processes of variety generation (through variation, selection and retention) and hence

the dynamics of organisational evolution and industry transformation(Nelson and Winter 1982). More specifically, evolutionary theory explain that three evolutionary processes drive these changes: processes of variety creation, processes of replication that generate inertia and continuity in the system, and processes of selection that constrains variety in the system(Nelson and Winter 1982). Of particular importance for our purpose is the concept of routines, the organizational equivalent of biological genes, that refer to formal and as well as tacitly understood rules of behaviour and regular and predictable patterns of behaviour. According to Nelson and Winter(1982), routines are reflective of historically given decisions and behaviours that have come to govern the action of an organization. Thus routines express the characteristics of organizational form that are selected in or out by environmental conditions. Thus, the question of how a new dominant model, based on a set of organizational routines, establishes in a given industry environment takes a central place in the studies adopting evolutionary approach. In summary, evolutionalry theory sheds much light on the conditions for the emergence of organisational patterns and the process of selection and diffusion of specific patterns that may lead to new or established forms of organization.

It is important to note here the concept of environmental imprinting introduced by Stinchcombe (1965). Environmental imprinting can be defined as a process by which new organizational forms come to reflect environmental conditions during the early period of its life. Stinchcombe(1965) hence showed that the founding conditions of organizations have significant impact on their performance. In the similar spirit, Eisenhardt and Schoonhoven(1990) examined the extent to which the initial situation(i. e., top-management team, strategy, environment) in which an organization is founded has a direct effect on its future growth. And they found that once the firm has settled on a certain model, that is typically the combined product of initial environmental factors, it is difficult for it to change that model. Yet it is also noted that individual and organizational learning and capabilities that are entailed in the adoption of a new technology do occur, but along distinct trajectories. And this depends not only on the initial conditions of the organization but also on the degree of managerial autonomy and choice. Indeed, many studies confirm that a certain level of individual or group discretion matters even in given institutional constraints(Romanelli 1991).

Based on preceding discussion of key ideas of organizational economics, the resource-based view, evolutionary theory, and the theory of environmental imprinting, it can be summarised that heterogeneity or diversity in organisational form and the resulting dynamics of competitive advantage across firms is primarily driven by the exploitation of particularly favourable combinations of organizational design, practices and routines by firms, whose initial conditions, to a large extent, match their operational environment(Corkburn et al. 2000).

But erosions of those rents and advantages appear to occur as competitors catch up by imitating the successful strategies of market leaders. And there also appears to be other sources of pressures for similarity among firms operating in similar environments. This is the issue to which we now turn.

Given that the creation and diffusion of innovation across industries is the most important determinant of industrial competitiveness, it is useful to note that the effort towards innovation at the organizational level also largely depends on institutional elements - such as availability of skilled force, access to financial resources geared to high-risk projects, implementation of adequate regulatory regime among others. This view brings back the point that firms do not innovate in isolation, which means that innovation has to be understood as a collective process by a variety of agents. This is the point we will continue to raise in this section on institutional coordination. And it is the institutional perspective that makes it possible to develop a more nuanced, contextula perspective on the sources and dynamics of industrial competitiveness. Before turning to the examination of institutional mechanisms for innovative activity, we present a brief summary of the status of past and current efforts at institutional theorising.

New institutionalism in organizational theory(DiMaggio and Powell 1991) is interested in the role of external influence and pressures for social conformity in shaping organizational forms. The core premise of institutional theory is that institutional factors surrounding resource decision of a firm affect the potential for the firm to succeed or at least survive. In her analysis of strategic and institutional sources of competitive advantage, Oliver(1991) demonstrated that in addition to ecnomic barriers, there are political and cultural barriers to resource acquisition. She argued that the ability to mobilize the necessary political and cultural support within the firm is equally important for the use of value generating resources. This is to say that barriers to resource mobility are both economic and social and thus firms using equally valuable resources may earn different returns as a function of the degree of support generated within the firm for use.

In particular, the concept of isomorphism helps explain why organizations become structurally similar. Isomorphism refers to a constraining process that forces one unit in a population to resemble the others that face the same set of environmental conditions. According to DiMaggio and Powell(1991), coercive isomorphism stems from political influence and the problem of legitimacy. Mimetic isomorphism results from standard responses to uncertainty. And normative isomorphism is associated with professionalisation of which two sources are formal education and legitimisation of cognitive base and growth of professional networks and associations. DiMaggio and Powell(1991) illustrated that bureaucratisation and institutionalisation driven by the state and the professions are the major factor for widespread structural conformity across organizations that offer similar products. Following the logic

of institutional isomorphism, organizational field - defined as those organizations that, in the aggregate, constitute a recognized area of institutional life including key suppliers, resource and product consumers, regulatory agencies, and other organizations that produce similar services or products - institutionalizes and legitimates a range of normal strategies through an iterative isomorphic process. As a consequence, dissimilar firms face legitimacy challenges that hinder resource acquisition and hence harm organizational performance. Particularly noteworthy is institutional argument that organizational change can occur as a result of processes that make organizations more similar without necessarily making them more efficient.

It is important to note that each of the perspectives on organizational form introduced in this section are premised on essentially different theoretical assumptions about the nature of firm behaviour. For example, institutional perspective assumes that individuals are motivated to comply with external social pressures whereas the resourced-based view posits that individuals are motivated to optimise available economic choice. To put differently, institutional theory is based on the basic premise that firms make normatively rational choice that are shaped by the social context. In sharp contrast, economically-oriented analysis suggests that firms make economically rational choices that are shaped by the economic context of the firm[5]. Having noted the underlying rationales for both of the theoretical schools and taking a somewhat eclectic stance, we believe that there is a need for further study on the interaction between competitive and institutional forces(e.g., Baum and Oliver 1991) at the firm and industry levels and resultant economic outcome. Based on the above discussion, the second proposition can be articulated as follows:

Proposition 2:

The technological and institutional environments under which a firm operates at a point in time exert both homogenising and isomorphic pressures on the firm to differentiate or conform in order to gain efficiency and legitimacy as a means to obtain a sustainable competitive advantage. Therefore, in the process of competition and institutionalisation there exists a degree of tension between homogeneity and heterogeneity in manifestion of organizational forms at the industry level.

3.3 Institutional Mechanisms for Innovative Activity

In the previous discussion, we have hinted that while strategy-oriented research gives pre-eminence to firms' own organizational choices

[5]The fundamentally different positions of several dominant perspectives on the behavioural motivation of economic action is well discussed in the literature of economic sociology, institutional theory, old institutional economics, etc. See for example, Granovetta (1990), Hodgson (1991).

in their operations, the institutional perspective tends to adopt a more relational view of the firm. In other words, an institutional view of the firm assumes that private firms engage with a variety of external actors operating in multiple spheres of the political economy (e.g, Vasudeva et al., 2013).

Malerba et al.(1999) looked into this issue at a deeper level and suggested that opportunity structure that affects its availability, appropriability regimes, and the level of cumulativeness of technological knowledge, in addition to characteristics of the relevant knowledge base, play important parts in forming a technological regime. For example, technological regimes with high levels of opportunities are expected to display patterns of innovation characterized by great amount of turbulence in terms of entry and exit. High instability in the hierarchies of firms will ensue as abundunt technological opportunities allow for the continuous entry of new innovators. However, if successful, established firms can also gain a substantial leap in their relative competitiveness, thus, leading to the elimination from the market of the smaller, newer, less successful innovators. Conversely, low opportunity conditions restrict innovative entry as well as hamper the innovative growth of established organizations(Malerba et al. 1999). High degrees of appropriability, by imposing limit on the extent of knowledge spillovers and by enabling successful innovators to benefit from their innovative advantages, are expected to lead to a higher level of industrial concentration and a lower number of innovators. Conversely, by discouraging investments in innovative endeavors and by affecting spread of the relevant knowledge across firms, low appropriability conditions are more likely to result in a sectoral structure characterized by the presence of a large population of innovators. Finally, high levels of cumulativeness of technological competence at the individual firm level tend to be related to persistence in innovative activities and imply an implicit mechanism leading to high appropriability of innovations resulting in high concentration. On the contrary, at the sectoral level, high cumulativeness within a specific location is more likely to be associated with low appropriability conditions and spatially localized knowledge spillovers(Malerba et al. 1999).

In this line, the national innovation systems approach, the most influential variant of contemporary institutional research strand, provides continuous empirical support to the existence of different trajectories of the creation and diffusion of innovation rooted in each national institutional context. Accordingly, the key to the generation of innovation and sustainable competitiveness at the industry level is to find and implement the most efficient and adequate forms of coordination in the arena of innovative and production activity depending on the intrinsic nature of the industry concerned. However, the characteristics of national institutions favour certain sectors that fit better with their specificities. There is an element of chance and sectoral contingency that is an inevitable part of most great industrial success story(Malerba et al. 1999). Although an increasing body of empirical

studies exists on the issue of sectoral contingency and institutional fit, no systematic account has yet emerged in this area.

Then the question is raised pertaining to the relative importance of organizational autonomy vs. institutional determinism: for example, can the competitive advantage that a firm is likely to obtain by making relevant organizational choices compensate for the institutional comparative disadvantages resulting from weak national innovation system it belongs to(Coriat and Weinstein 2002)? Several important attempts have been made to grasp institutional transformations and organizational/institutional co-evolution processes. For example, with the vision inherited from traditional institutional approaches and the field of political economy, studies on comparative industrial organizations(e.g., Boyer and Hollingsworth 1997) show how interactions between state and private firms in various economies have brought about unique cultures of production(i.e., social systems of production).

The varieties of capitalism approach(Soskice 1999), on the other hand, draws a broad distinction between two modes of coordination: liberal economies in which firms are coordinated with other actors primarily through competitive markets characterized by arms-length relations and formal contracting, and coordinated economies characterized by intimate interactions and network relationships between various market and non-market institutions. The observation that national variations in the institutions of the political economy lead to different economic performance has been central to comparative political economic perspectives. In essence, they contend that industrial countries are not converging toward a single form, instead a plurality of social relations are clearly observable that structure markets within and across societies. At the same time, it is important to note that an imagery of the firm in this type of institutional approach is also being criticized that too often the firm remains a given by the macro-social determinants in which it is inserted(Coriat and Weinstein 2002). From a slightly different research direction, Roe(1991)' s seminal work on the political roots of American corporate finance provides lucid support to the claim that economic rationale focusing on efficiency considerations on its own is not enough to explain the development path of the American style corporate governance characterised by strong managerial control and widely dispersed share ownership. Roe presents a historical analysis on the origins of the US corporate governance system that grew out of American populism and distrust of private accumulation of power.

According to Lazonick(2000), over time financial, employment and regulatory practices and corresponding non-business organizations that play critical roles in these functions become institutionalised in a society. He posits that the historical emergence of certain institutions related to finance, employment and regulation reflect the changing requirements of business organisations for the development and utilization of productive resources and matching innovative activity. Institutional support available for the

formation of credible commitments for innovative and production activity includes mechanisms for effective information sharing, contract monitoring and sanctioning (Lazonick 2000). The incentive structure, and the modes of appropriation and distribution of surplus that are materialised through the property rights system and the modalities of capital/labour sharing are of apparent importance in institutional analysis.

The pivotal question for the purposes of this discussion is how organizational patterns of learning and the process of dynamic capability building in terms of technological competence coevolve with these institutional conditions that promotes or deter innovative activity of private organisations. In simple terms, financial conditions determine the ways in which financial resources are allocated and financial returns distributed(Lazonick 2000). Institutional analysis of financial conditions of innovative activity contains the patterns of corporate financing for innovative activity (i.e., stock market vs. bank loans, etc.), the development of adequate support institutions for dominant mode of funding (i.e., the availability of venture capital, corporate disclosure requirements, etc.) and so forth. Employment conditions determine how the capabilities of the labour forces are developed and how they are recruited by firms(Lazonick 2000). This aspect requires an understanding of higher education system, job market mobility, and remuneration system, particularly in association with high-tech areas. Regulatory conditions determine how rights and responsibilities to different groups of people over the management of society's productive resources are assigned and what type of sanction mechanisms are imposed in the case of defect(Lazonick 2000). Issues bearing on regulatory conditions are quite broad but most relevant may be the characteristics and direction of regulatory policy and the features of intellectual property regime.

Here, it is helpful to highlight the notion of institutional complementarity that has been advanced by the scholars of the varieties of capitalism perspective(Hall and Soskice 2001; Boyer and Hollingsworth 1997; Whitley 1994). This concept suggests that institutions supporting effective strategic or market coordination in one sphere of the political economy will usually be complementary to institutions supporting analogous coordination in other spheres. For example, Japanese practice of life employment would not have developed in the US institutional setting where investment capital is much less patient than that of its Japanese counterparts. In particular, the concept of institutional complementary helps us to discern the linkages existing between seemingly disparate institutions that facilitate or impede the overall workings of innovative and production activity. Our final proposition that has been derived from this discussion is:

Proposition 3:

The institutional (financial, employment and regulatory) conditions under which a firm operates at a point in time may constrain

or elevate the economic incentives and technological competence of a firm in generating innovation over time. Therefore, industrial competitiveness is a function of the degree of fitness between the technological and organisational specifics of a particular sector and institutional configurations that govern and coordinate the relationships on innovative and production activity of the sector.

4. Conclusion

In this paper, we have provided a broad suvey of foundational scholarship focusing on the following three questions: (1) how the creation and diffusion of innovation occurs and gives rise to structural reconfigurations of the industry?, (2) how organisations and technology coevolve? and (3) what is the role of institutions in this coevolutionary process? At the end of each discussion, we have developed a set of propositions synthesizing the theoretical research undertaken across disciplinary domains as there is a broad consistency or complementarity of concerns and concepts. They can be summarized as below.

The technological paradigms under which a firm operates at a point in time constrain or elevate the economic incentives and technological competence of a firm in generating innovation over time. The success of the firm in taking advantage of these conditions and thereby generating innovation in turn transforms the competitive environments facing other firms in the industry. Challenged by this, other firms may seek to adapt to the status quo or innovate by themselves, therefore, instilling dynamism into the industrial structure.

The market and institutional environments under which a firm operates at a point in time exert both homogenising and isomorphic pressures on the firm to differentiate or conform in order to gain efficiency and legitimacy, and thus a sustainable competitive advantage. Therefore, there exists a degree of tension between homogeneity and heterogeneity in organizational forms in the process of competition and institutionalisation.

The institutional(financial, employment and regulatory) conditions under which a firm operates at a point in time may constrain or elevate the economic incentives and technological competence of a firm in generating innovation over time. Therefore, industrial competitiveness is a function of the degree of fitness between the technological and organisational specifics of a particular sector and institutional configurations that govern and coordinate the relationships on innovative and production activity of the sector.

These three propositions are general in that each of these needs to be fine-tuned upon more specific variables. The conceptual constructs introduced and elaborated, including technological paradigm, the dominant organisational form, institutional complementarity can be invoked and operationalised throughout the case study in order to unveil specific variables that may lead us to more plausible explanation. Moreover,

we need to take into consideration some other contingent factors that may prove to be crucial in account for the question(i.e., timing and patterns of industrialisation, the role of the state).

In this paper, we have sought to demonstrate that overly deterministic explanations put forward by any single perspective are likely to unduly undermine the active role initiated by private firms, and the nature of technological progress that has defining effects on the development path of an industry. Toward this end, we propose a theoretical integration of technological, organisational and institutional perspectives that is to serve as a rudimentary framework through which to identify and evaluate the sources and dynamics of industrial competitiveness of a nation' s specific industry.

Our reading of the broad array of literature has revealed that there exists much scope for theoretical integration among different perspectives on sources of competitiveness. Of course, not a single perspetive has anwswers to all of the above questions. And different approaches bring different elements to the understanding of the sources, dynamics and consequences of technolocal development and innovation. Yet by invoking further questions that are otherwise locked up in the limits of their specific concepts and frames, those aspects that have been insufficiently covered or neglected in each perspective will eventually be brought to the fore. Accordingly, though some profound differences in assumptions and logics, the perspectives dealing with the aforementioned issues are far from opposing each other but instead are potentially complementary. As indicated throughout the previous discussions, many of the perspectives and theoretical constructs we have considered are far from opposing each other but instead are potentially complementary. This calls for an occasion for theoretical synthesis, which will offer a fruitful ground for future research.

However, an important caveat is to acknowledge potential theoretical problems with this kind of exercise: mixing and combining distinct theories with divergent and sometimes incompatible sets of assumption for the purposes of empirical analysis. Our justification in response to the danger of this sort is to claim that what we are trying to do in this work is not to create a new theory by borrowing the best from each approach without adequate consideration of inevitable contradictions that might arise, but to fill in the theoretical gap that has remained in each perspective by encouraging constructive interdisciplinary dialogues that might help enlighten each other. Although forcing the complexities of the real world arbitrarily into the restricted categories and definitions may pose difficulties for precise understanding of empirical phenomena, yet, by necessity, this paper limits itself to manageable portion. This is for the benefit of analytical parsimony and conceptual clarity, but may inadvertently leaves out some other aspects that might have deserved equal amount of attention.

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