A Design-Information-Flow View of Industries, Firms, and Sites

Takahiro Fujimoto

Abstract This introductory chapter discusses the research scope, framework, and key concepts of this book. Regarding the scope of our empirical research, we focus on two main industrial phenomena occurring in the period between the 1990s and the 2010s, i.e., global competition and digitization, and apply certain evolutionary frameworks and concepts to explain them.

As for the research framework to analyze the evolution of manufacturing industries and firms, we propose a capability-architecture-performance framework, which is derived from our broad concept of manufacturing as managing flows of value-carrying design information to customers, as well as that of manufacturing site (*genba*, in Japanese) as the place where such flows exist. We adopt a genba-based view of the economy, in which the most basic units of industrial-economic analysis on the supply side are the manufacturing sites, where value flows exist, rather than the firm, which is composed of the former.

In this context, manufacturing capability is a system of organizational routines that governs and improves the flows of value-carrying design information to customers. Product architecture, on the other hand, refers to the correspondence between a product's functional and structural design elements.

The concept of design-based comparative advantage derives from this framework, which predicts that certain dynamic fits between a manufacturing site's capability and a product's architecture result in higher productive performances and lower unit design costs. For example, a country whose manufacturing sites have higher coordination capabilities tends to have a design-based comparative advantage in products with coordination-intensive design, i.e., those with relatively integral architecture.

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1 Introduction

1.1 Purpose and Scope of This Book

This book is about the evolution of firms, industries, industrial sites, and products. These are the foundations of national or global economies on their supply side. They are all artifacts (designed things) which evolve overtime.

In this introductory chapter, we will discuss the purpose and scope of this book, as well as a basic framework for concepts such as economy, industry, firm, product, and site. Then, we will present a design-based view of manufacturing and industrial competitiveness, whose main components include organizational capability and product/process architecture. We will also provide a historical description of firms, industries, and sites in postwar Japan, the main research field of the present book. In the appendix, we will explore the possibility of adopting a dynamic and design-based version of the Ricardian (i.e., classical economic) model of international trade as its twenty-first-century reinterpretation.

As for the scope of this book, we will pay special attention to the period between the 1990s and the 2010s, characterized by unusually rapid evolutionary changes in industries, firms, sites, and products, when two major transformations of the world economy, namely, *globalization* and *digitization*, occurred almost at the same time.

By globalization we mean post-Cold War integration of the Western and Eastern bloc economies, which led to intense international cost competition between lower-wage emerging countries (e.g., China, India) and higher-wage advanced countries (e.g., USA, EU, Japan). By digitization we mean major industrial changes driven by innovations in digital information and computer technologies, including the Internet, mutually networked digital devices (e.g., personal computers and smartphones), and software assets that are often complementary to one another.

This historical coincidence resulted in major shifts of digital products toward open-modular architectures, massive location shifts of industrial sites toward low-wage countries, uneven growth of national economies and industries, emergence of large platform-leading firms, and increasing income inequalities. We will focus on changes in the patterns of international industrial competition during this period.

Geographically, we will look at an advanced country and its industries that were significantly affected by the abovementioned globalization and digitization, i.e., Japan and its industries, firms, and sites. As we will discuss in this book, after the end of the Cold War and China's entrance into the global market, export industries and their manufacturing sites in Japan—a neighboring country whose average wages for factory workers were over 20 times those of China in the 1990s—faced difficult-to-survive cost competition with the huge international wage handicap.

Japan is also endowed with coordination-rich manufacturing sites that tend to have competitive advantages in coordination-intensive products, including fuel-efficient automobiles, analog TV sets, and functional materials (Fujimoto 2007, 2014; Appendix). Thus, when digital technological innovations triggered a rapid growth in products and platforms with coordination-saving open-modular architectures and open interfaces, many leading Japanese firms in the electronics industry found it difficult to formulate appropriate strategies vis-à-vis the American platform-leading firms (e.g., Intel, Microsoft, Apple, Google, Amazon). Besides, their coordination-rich industrial sites lost much of their design-based competitive advantage in unit costs in various digital products with coordination-saving open architectures vis-à-vis rival factories in low-wage emerging countries, such as China.

Thus, Japan's economy, industries, firms, and manufacturing sites were significantly and negatively affected by post-Cold War global cost competition and industrial digitalization. As a result, the national economy suffered from extremely low growth rates between the 1990s and the 2010s due partly to the aforementioned globalization and digitization, as well as to the post-bubble financial crisis, chronic deflation, and population aging. Japan's industrial and trade structure also shifted toward a higher share of fuel-efficient automobiles, high-performance industrial machineries, functional chemicals, and other integral products, whereas digital electronics products experienced a decline. Also, average profitability across the country's firms decreased during the same period.

In this situation, Japan's domestic manufacturing sites struggled to survive both global competition and digital transformation. Many of them disappeared, particularly in the consumer appliances and digital devices/equipment industries, but many survived in industries with relatively integral and complex products. As of the mid-2010s, Japan's manufacturing industries still accounted for roughly 20% of its gross domestic products (GDP), a relatively high share for a larger advanced nation.[1] Moreover, physical productivity increased significantly in many of the surviving sites manufacturing tradable goods.

Based on the above observations, this book will focus mainly on the evolution of firms, industries, and industrial sites in Japan during the post-Cold War period between the 1990s and the 2010s. It will propose some theoretical frameworks that may be appropriate for analyzing such evolutionary industrial phenomena.

1.2 Some Basic Ideas on the Evolution of Firms and Industries

1.2.1 Product, Site, Industry, and Firm

Let us start by presenting some basic concepts to investigate the phenomena mentioned above. First, as an analytical framework for dealing with the research theme of the present book, we adopt a multilayer evolutionary framework encompassing economies, industries, firms, sites, and products (Fig. 1).

[1]According to the IBRD and other statistics, the share of the manufacturing sector in 2012 was about 18% in Japan, 22% in Germany, 13% in the USA, and 10% in the UK and France.

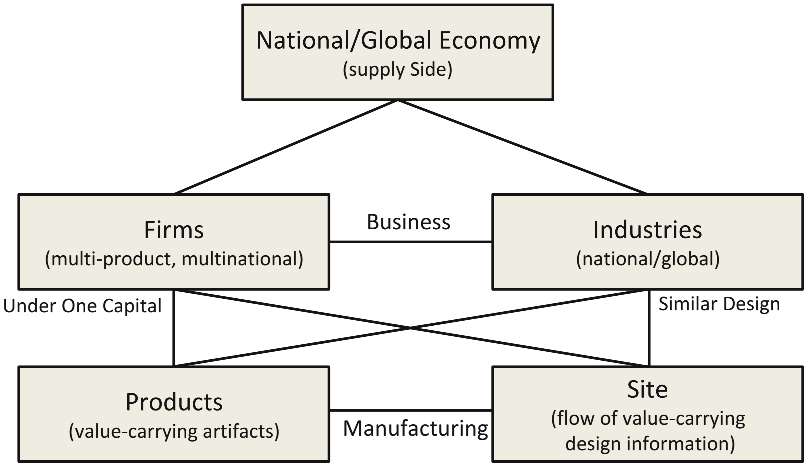

Fig. 1 Products, sites, industries, and firms

In this framework, a *product* is a value-carrying artifact that can be exchanged. More specifically, we assume that a product's value added dwells in its design information, i.e., information on its functions, structures, and their relations.

A *site* (i.e., industrial/manufacturing site; *genba* in Japanese) is the place where the value-carrying design information of certain products flows toward their markets, and it includes the people who collectively govern such flows. We regard an industrial site, or genba, as the most basic component of a firm, an industry, as well as a national economy. As such, a manufacturing site is the common element of both a firm and an industry.

An *industry* is a collection of sites that develop and produce functionally similar products and their components—this being the conventional definition of an industry. Besides, we also adopt a newer concept called *platform*, which is a collection or network of products that are functionally/structurally complementary to each other. Thus, we use a newer and broader definition of an industry as a collection of functionally similar products, platforms, and their components. Competition, collaboration, and transactions routinely occur among such sites, products, components, and platforms within an industry.

A *firm* can be seen as a collection of industrial sites that are under the control of a single capital, but they may produce very different products and be located in different countries. In other words, based on today's stylized facts, we assume that modern firms are mostly multiproduct and/or multinational firms. Thus, we distinguish between firms and industries, as well as firms and sites, based on our observations of actual economic activities today.

In any case, the fundamental value-adding units of the economy are industrial sites. Based on this multilayer framework, we analyze the evolution of the products, manufacturing sites, industries, and firms of a national/global economy. In other words, we argue that all four components evolve over time with dynamic and emergent interactions among them.

1.2.2 Manufacturing as Flows of Design Information

This book also adopts a broad and *design-based view of manufacturing* to analyze the evolution of firm, industries, and sites. That is, we argue that the value added of a product resides in its *design* or information/knowledge about the artifact's functions, structures, and their relations (Simon 1969; Suh 1990; Ulrich 1995).

Therefore, we use another basic framework to investigate industries, firms, and sites, i.e., a design-based view of manufacturing (Fujimoto 2007, 2012b). That is, we define *manufacturing*—or *monozukuri* in Japanese—broadly as all the activities of firms, industries, and sites that control and improve flows of value-carrying design information to the customers. As such, our design-based concept of manufacturing covers not only manufacturing industries but also services and other non-manufacturing sectors, as long as they involve flows of value-carrying design information to the customers.

Design here refers to knowledge or information about an artifact's functions, structures, and their relations (Suh 1990) that is created prior to its production (i.e., design realization).[2] As pointed out earlier, we argue that the source of a product's value added for customers lies in its design information, which is able to attract and satisfy them.

To the extent that the concept of manufacturing is defined broadly in this way, *manufacturing sites* (genba) are also defined broadly, including not only production factories but also product development projects, resale/wholesale stores, service facilities, farming fields, and so on, as long as value-carrying design information flows to the customers there.

In this context, an *industry* is conceived as a collection of manufacturing sites (e.g., factories, product development centers, service facilities), in which design information of a similar kind, combined with its media (i.e., materials and energies), flows to the customers in the market. This implies that an industry can be seen as a set of flows of functionally similar design information, or as a collection of mutually competing/cooperating/transacting sites that govern such value-carrying design flows.

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[2]Design here means not only industrial design but also all kinds of engineering design, including both hardware and software as well as service design, work design, organizational design, system design, and so on, as long as it represents an artifact's functions and structures and their relations. A product is an exchangeable or tradable artifact with value added (i.e., the difference between its price and material cost). Thus, a product, like any other artifact, can be seen as a combination of design information and its medium, in the form of direct materials and energy—a modern interpretation of Aristotle's being as a combination of form and matter.

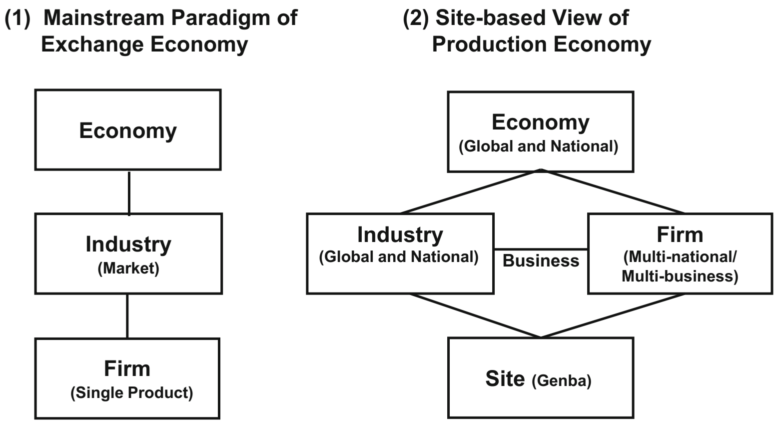

Fig. 2 Supply side of the economy

1.2.3 Manufacturing Site as Economic Agency

Next, let us discuss the nature of a manufacturing site (genba) as a semi-independent economic entity that evolves over time. In other words, we regard an industrial site as a multifaceted socioeconomic entity, since it belongs to a firm, an industry, and a community at the same time. When a firm is not simply profit-oriented but also site-oriented, and if a site (genba) is community-conscious and the community is employment-conscious, we may conjecture that a *site-oriented firm* behaves differently from a conventional profit-maximizing firm, in that the former pursues both profits (e.g., target markup ratios) and stable employment (e.g., a fixed number of regular employees) at the same time. We will discuss the nature of such site-oriented or genba-oriented firms later in this book (Chapter "Evolution of Business Ecosystems").

In a sense, recognizing a manufacturing site as a semi-independent socioeconomic agency means deviating from the standard economic model of a profit-maximizing firm. In the standard neoclassical microeconomic model (e.g., partial equilibrium analysis), the assumption is that a firm produces only one kind of product with identical design, so the distinction between firms and sites is not essential. Besides, an industry's market supply curve is regarded as a simple sum of the individual supply curves of the firms in this industry. Thus, in the prevalent neoclassical microeconomic model, the supply side of a national economy simply consists of three layers, i.e., firms, industries, and national economies (see Fig. 2, discussed later). No detailed analyses of industrial sites and products as artifacts are included in this standard model because a site is regarded merely as a dependent part of a profit-maximizing firm and a product as a non-differentiated commodity.

In this book, by contrast, we treat both firms and sites as mutually interdependent economic agencies, each of which has its own objectives, such as survival, growth, profit, and employment. Nowadays, a multiproduct and multinational firm selects its products, sites, and their locations, whereas an industrial site, which is a part of the firm and the community at the same time, tries to survive with stable employment as a semi-independent socioeconomic entity in itself.

As suggested above, when international industrial competition is intense, the simultaneous pursuit of (i) productivity improvements through the sites' capability-building and (ii) effective demand creation by means of product variety and design improvements is critical for a site-oriented firm that aims to achieve minimum profit for survival and stable employment. Thus, the present book analyzes dynamic interactions among firms and sites regarding profit, growth, survival, and employment in the current age of intense global competition.

1.2.4 Competition and Competitiveness as Driving Forces

We have so far argued that a firm and an industry can be regarded as a set of certain manufacturing sites or products and that the sites and products themselves evolve over time, which is the basic logic of the evolution of firms and industries. Then, our next question is: what is the major driving force behind such evolution? Our tentative answer is as follows: one of the main driving forces behind the evolution of firms and industries is *industrial competition*, or the competition between functionally similar products, components and platforms, as well as their manufacturing sites.

Generally speaking, we define *competition* as a socioeconomic entity's efforts to be selected by some other entities (i.e., the selectors) under the conditions of fairness and free choice by the latter and *competitiveness* (or competitive performance) as the selectee's ability to be selected by the selectors.

For example, in standard economic textbooks, it is assumed that products of a given quality compete on price in order to be selected by customers in the product market—this is *price competition*, which happens at the surface level of the economic system. Likewise, modern firms compete on profitability in order to be selected by investors and bankers in the capital market.

In the present book, on the other hand, we pay special attention to another type of competition among manufacturing sites at a more basic level of the economic system—*capability-building competition*—in which manufacturing sites compete to be selected by the firms to which they belong by improving their productive performance, such as production lead times, physical productivity, and manufacturing quality (Womack et al. 1990; Clark and Fujimoto 1991; Fujimoto 1999).

Facing today's intense global competition, many of the sites mentioned above as community-employment-conscious may collectively try to survive by improving their capability and productive performance, achieving minimum acceptable profits for the firms to which they belong, and thereby managing to be selected by said firms' top managers as the ones that can continue operations.

Hence, competitions and competitiveness are multilayered phenomena, since factories (or genba), products (or their business units), and firms all compete to be selected and to ultimately survive. In addition, because an industry, as illustrated earlier, consists of certain products of similar design as well as the manufacturing sites that produce them, we can regard price competition among the products and capability-building competition among the sites as *industrial competitions* at the surface and deeper level, respectively.[3]

We also predict that the competitiveness of products and sites in the same industry and in the same country or region (e.g., German automobile industry) will tend to converge, since said products and sites face similar competitive environments and are therefore forced to build similar capabilities over time. In these cases, it is meaningful to compare the average competitiveness performance (e.g., unit cost, productivity, quality, lead times, etc.) of an industry's products and sites among counties or regions (Womack et al. 1990; Clark and Fujimoto 1991). The comparison of physical productivity and unit production costs (proxy variables of prices) among countries and industries first originated with David Ricardo's trade theory of *comparative advantages* or *comparative costs* (Ricardo 1817), which we will discuss later in this book (Chapter "The Nature of International Competition Among Firms").

1.2.5 Evolution of Capabilities and Architectures

We have so far argued that the main driving forces behind the evolution of firms and industries are industrial competitions occurring among manufacturing sites, products, platforms, and the like. We may then ask: which characteristics of sites and products evolve over time? A brief answer may be as follows: *organizational capability* evolves on the side of the manufacturing sites, whereas *architecture* (in addition to technology) evolves on the side of the products.

First, we define a manufacturing site's *organizational capability* (i.e., manufacturing capability) as a set of organizational routines that control and improve the flows of design information in that manufacturing site (Fujimoto 1999). For example, the so-called Toyota production system (TPS) may be regarded as a manufacturing capability or a system of interconnected organizational routines (e.g., *kanban*, small-lot delivery, *jidoka*, multi-skilling, building-in quality, levelization, continuous improvements, etc.), each of which was generated through a combination of deliberate choices and emergent processes (Fujimoto 1999; Chapter "Evolution of Organizational Capabilities in Manufacturing: The Case of the Toyota Motor Corporation"). In other words, both organizational capabilities and routines may evolve over time as a result of capability-building capabilities, competition, and environments related to the manufacturing sites in question.

Second, we explore the nature of the *architectures* of products, components, platforms, processes, and other economic artifacts. Generally speaking, a product's design information has two aspects: technology and architecture. A product's

[3]Note here that competitions among firms regarding their profitability on the capital market are not the same as industrial competition to the extent that modern large firms tend to be engaged in multiple industries or businesses.

specific *technology* refers to concrete causal relations among its functions and structures, whereas its *architecture* describes the abstract graphical correspondence among them. To the extent that architecture is an abstract mathematical concept, product architectures may be compared across different industries, whereas many product technologies are industry-specific. Thus, in the present book, we explore how changes in a product's technologies and market requirements affect the evolution of product architectures.

Having sketched out some basic concepts to analyze the evolution of firms and industries—including a site-based framework for firms and industries, the notion of design information as a source of value added, a design flow-based view of manufacturing, the site (genba) seen as a socioeconomic entity, the idea of industrial competition as an evolutionary driving force, as well as the evolution of a site's capabilities and a product's architectures—we will try to construct a systematic framework to explore industrial competitiveness and evolution next.

2 A Framework for Analyzing Industrial Competitiveness

2.1 Industrial Competitive Analysis: A Missing Link in Modern Economics

Let us now look at the theoretical background of the evolutionary framework adopted in this book. The worldwide industry in the early part of the twenty-first century may be described by emphasizing various aspects—intensifying post-Cold War global competition involving both advanced and emerging nations, trends toward freer trade through various bilateral and multilateral agreements among nations, explosive growth of goods and services that use digital networking technologies, stricter constraints regarding environmental protection and energy conservation, increased complexity of artifacts that deal with such constraints, coexistence of fiercer price competition in commodity-type goods and product differentiation in brand-conscious goods, greater technology and market uncertainties faced by firms, and growing instability and influence of global financial networks on industries.

One of the propositions derived from the above description is that international *industrial performance* (*competitiveness*)—based on the concept of comparative advantage, devised in the nineteenth century by David Ricardo and other classical economists (Ricardo 1817)—still matters in this century. It is also important to note that improvements in physical labor productivity (i.e., labor input coefficients), the ultimate generator of industrial comparative advantage and national standards of living (Smith 1776), occur at industrial sites, or genba in Japanese, including factories, development centers, retailers, service facilities, and farming fields. An industry is nothing but a collection of industrial sites (genba) of a similar kind.

In the eighteenth and nineteenth century, major works by classical economists, including Adam Smith and David Ricardo, used to provide rich accounts of "industries" based on field observation (e.g., Smith's famous analysis of pin making). In the past one hundred years, however, after Alfred Marshall's *Industry and Trade* in particular (Marshall 1919), mainstream economics (i.e., the neoclassical school) tended to deemphasize the concepts of "industry" and "sites" while pursuing mathematical-theoretical sophistications such as the general equilibrium theory, which assumes profit maximization at the firm level. This meant that mainstream economics mostly neglected the field-based concept of *industrial performance*, even though it continued to be an empirically important notion for understanding the nature of today's world economy (Womack et al. 1990; Clark and Fujimoto 1991).

Indeed, the concept of comparative advantage of industries, both Ricardian and neoclassical, continued to be key to understanding the freer trade systems of the twenty-first century. Newer approaches—like the product life cycle (flying geese) theory, the new trade theory, and the new-new trade theory—certainly provided additional explanatory power to better understand today's trade phenomena involving emerging nations, foreign direct investment, product differentiation, and economies of scale (Akamatsu 1962; Vernon 1966; Helpman and Krugman 1985; Melitz 2003). Without introducing the concept of *design* of traded goods and services, however, we may not be able to capture the essential characteristics of today's international trade—*intra-industrial trade at minute levels*, such as sheet steel for inner automobile panels exported from Korea to Japan and that for outer panels exported in the opposite direction.

Besides, some 20 years after the end of the Cold War and the abrupt entrance of gigantic low-wage countries like China into the global market, the average wage in such emerging countries has finally started to soar, as the period of "unlimited supply of labor" (Lewis 1954) has come to an end. This may be a good time to introduce a somehow dynamic and field-based version of the Ricardian-Sraffian trade theory to examine how international differences in productivity and wage increases between advanced and emerging countries affect changes in global trade structures (Ricardo 1817; Sraffa 1960; Shiozawa 2007; Fujimoto and Shiozawa 2011–2012).

Against the above background, this section sketches out an evolutionary framework for the analysis of industrial performance by introducing such concepts as *manufacturing (monozukuri)* such as *design information flow*, *genba as value-flowing site*, *evolution of organizational capabilities*, *evolution of product-process architectures*, *dynamic fit between capabilities and architectures*, and *multilayer concepts of industrial performance* (see Fujimoto 2007, 2012b for details).

2.2 Economy, Industry, Firm, and Site Revisited

Here we revisit the multilayer framework concerning industries described earlier in this chapter. In order for us to conduct empirical research on industrial performance, we must modify our analytical framework for industrial analysis from the interpretation adopted by today's mainstream economics, or the "firm → industry → economy" paradigm of the "exchange economy" or catallactics as defined by Sir John

Hicks (Hicks 1976; Fig. 2 (1)), to a seemingly more realistic one, or the "site→firm/industry→economy framework of the "production economy" or plutology (Hicks 1976; Fig. 2 (2)).

Since the main goal of the present book is to empirically explore dynamic changes, or evolutions, on the production and development side of the economy, it would be natural for us to adopt a *site-based view of the production economy*, which is illustrated in Fig. 2 (2).

To sum up, the most basic value-adding units of the economy are the industrial sites or genba. In addition, economies, industries, firms, and sites all evolve over time (Nelson and Winter 1982; Fujimoto 1999, 2007, 2012a, b). Hence, many of the empirical studies presented in this book will start from field observation and perform an evolutionary analysis of firms and industries by focusing on their common components, i.e., industrial sites (genba), including factories, and development projects.

2.3 *The Capability-Architecture-Performance Framework of Industrial Evolution*

The field-based framework for the analysis of industrial performance and trade structures proposed in this chapter relies on the evolutionary framework of *design-based (architecture-based) comparative advantage*, as explained earlier, which predicts that certain dynamic fits between manufacturing capabilities and product-process architecture will result in an industry's international competitive advantage (Fig. 3).

This framework includes the following elements:

1. The design-based concept of *manufacturing* in a broad sense (monozukuri, in Japanese), which reinterprets development-production-sales activities as creation and transfer of value-carrying design information flowing from firms/sites to customers
2. The generic logic of *comparative advantage*, which assumes that a fit between a country's characteristics and a product's attributes results in the competitive advantage of a given product in a given country (Ricardo 1817; Fujimoto and Shiozawa 2011–2012)
3. The *evolutionary theory of organizational capabilities*, which explains ex post rational objects without fully depending upon ex ante rational reasoning (Fujimoto 1999; Chapter "Evolution of Organizational Capabilities in Manufacturing: The Case of the Toyota Motor Corporation)
4. The concept of *product-process architecture*, originating from the theory of axiomatic design in engineering (Suh 1990; Ulrich 1995)

Both the organizational capabilities of the manufacturing sites (genba) and the architecture of the artifacts (products and processes) collectively and dynamically

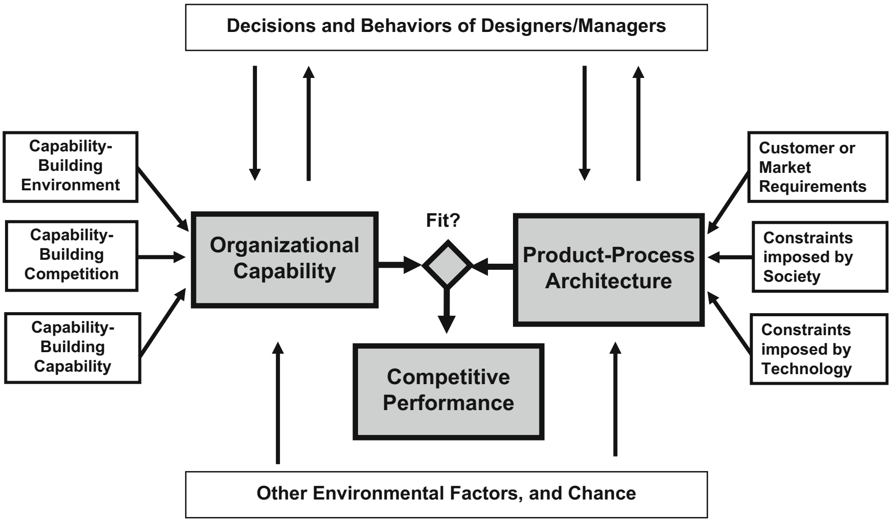

Fig. 3 Field-based view of industrial performance—design-based comparative advantage

influence the performance (competitiveness) of the industry in question, as illustrated by the shaded boxes in Fig. 2.

Moreover, both capabilities and architectures are treated here as endogenous rather than exogenous factors. This implies that they can change as their interactions with environmental and other factors change. There is no such thing as Japan-specific capability or automobile-specific architecture in a static sense, since capabilities and architectures are a result of the path-dependent historical evolution of the entire industrial system.

Having described the overall evolutionary framework of capability-architecture-performance, let us now look at its components in more detail. The following sections will briefly illustrate the design information view of manufacturing (monozukuri), industrial performance, organizational capability, product-process architecture, and design-based comparative advantage, in this order.

2.3.1 Manufacturing as Design Information Flows Among Productive Resources

Starting from the abovementioned framework to analyze industrial performance, our next question is: what are the key concepts that all industrial sites (genba) have in common? Here we adopt a broad and design-based concept of manufacturing (Fujimoto 1999, 2007) or monozukuri. According to this view, a genba is a place where *flows* of value added to the market exist and the value added in question ultimately resides in *design information*. A productive resource (Penrose 1959) or an

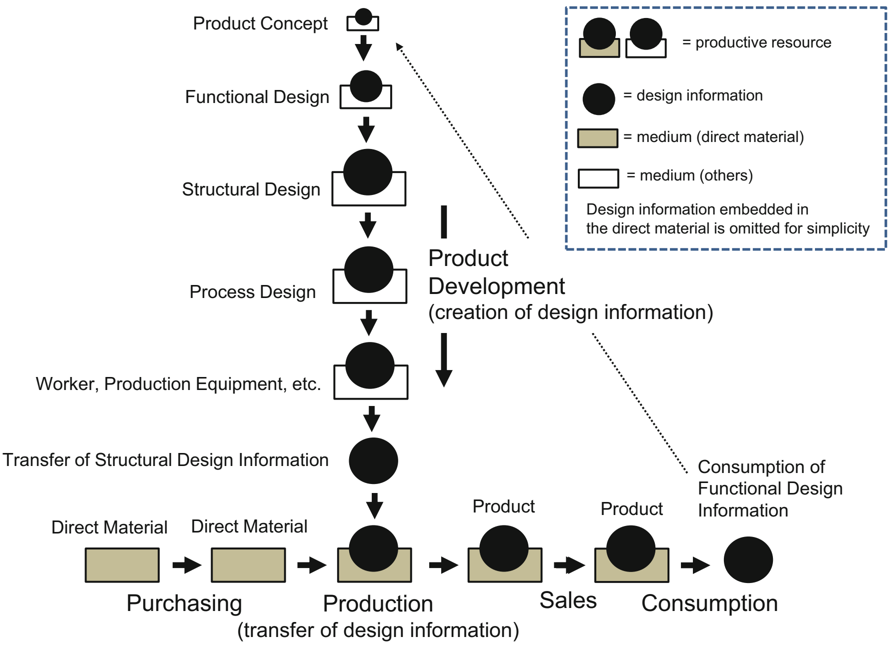

Fig. 4 Manufacturing as flows of design information

artifact (Simon 1969) existing inside the manufacturing site in question is nothing but a combination of value-carrying design information and its medium (Fig. 4).[4]

Thus, the common factors that can be observed in all industrial sites are (i) flows of design information to customers; (ii) artifacts (productive resources), each of which is a combination of design information and its medium; and (iii) the site's performance, measured as effectiveness of flows.

In this context, as mentioned earlier, *design* means information or coordination that interconnects an artifact's functional and structural elements (Suh 1990). A product (a good or service) is a tradable artifact consisting of design information and its medium, following Aristotle's logic of form and matter. Production is nothing but the transmission of a product's design information to its medium. Thus, design precedes production for a given product. In the context of trade theories, this implies that international selection of design locations tends to precede that of production

[4]A *productive resource* (Penrose 1968)—such as workers, equipment, dies, tools, standard operating procedures, digitized design files, raw materials, work in process, prototypes, or engineering drawings—is also an artifact, or a combination of partial design information and medium. In the production process, a part of the structural design information of a firm's products is embodied in workers, machine hardware, software, or other media. Raw materials and work in process are also productive resources that embody partial design information. In this sense, the design-information view regards a firm as a set of productive resources, which is nothing but design information assets deployed and stored in labor or capital stocks as their media.

locations—the notion of *design-based comparative advantage*, which is discussed below.

If the medium of the product in question is tangible, we are dealing with a physical good that belongs to a manufacturing industry. If the medium is intangible or ephemeral, we are dealing either with a service (if its design information is functional) or software (if it is structural). In any case, design information is the major source of economic value added.

The design information of an artifact, like the genetic information of a living being, evolves over time through variation-selection-retention, which is decided by markets, societies, firms, engineers, and so on. Innovation, in the Schumpeterian sense (Schumpeter 1912/1934), is essentially the evolution of new design or a new combination of the functions and structures of an artifact (e.g., product, process, etc.) contributing to economic value added (Fujimoto 1999, 2007, 2012b).

To sum up, manufacturing, from the design information point of view, is broadly defined as those firm activities that create and control the *flow of value-carrying design information*. Said design information flows to customers through various productive resources deployed in factories, development centers, retail facilities, and so on. The places from which design information flows toward customers are called manufacturing sites (fields) or genba in Japanese.

As mentioned above, a firm's *manufacturing activities*, including development, production, purchasing, and sales, can be regarded as flows (creation and transfer) of value-carrying design information among productive resources (Fig. 4).

Within this framework, *product development* is the creation and verification of value-carrying design information. It is essentially a process of translation, going from the evaluation of future consumption processes and technological possibilities to product concept creation, product functional design, and product structural design, and ending with production process design and preparation. Each stage consists of repetitive problem-solving cycles involving designing-prototyping-testing steps (Clark and Fujimoto 1991; Thomke and Fujimoto 2000).

Production, in this context, is the repetitive transfer of product design information from the production process to the materials or work in process (i.e., the medium of the product). At each stage of the process, a fraction of the product's design information, stored in workers, tools, equipment, manuals, and other productive resources, is transferred to the materials or work in process and transformed into an actual product.

Purchasing means obtaining media (i.e., materials) for the product from outside firms. In many cases, the materials already embody partial design information, so purchasing activities often involve design information flows (Asanuma 1989; Clark and Fujimoto 1991). *Sales* is the transmission of the design information embodied in the products from the firms to the customers.

C*onsumption* of physical goods is another information-creation process related to the customers themselves, in which they use or operate the products and thereby convert their structures into their functions, which is then translated into the customers' own satisfaction or dissatisfaction. We may see this as the customers' self-

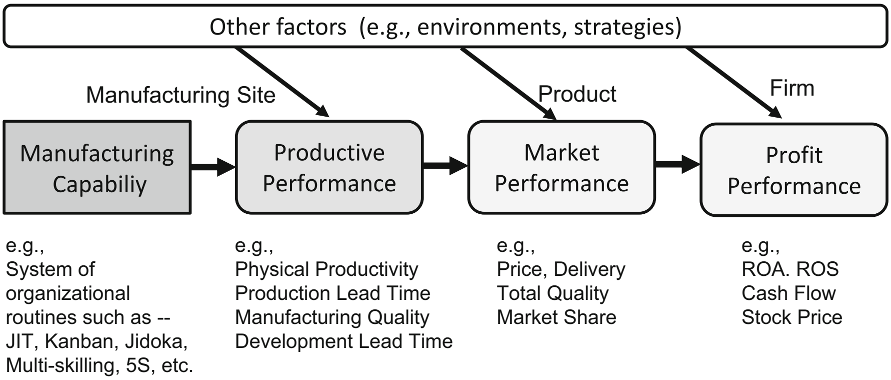

Fig. 5 Capability, competitiveness, and profitability

performed service activity, in which service means provision of value-carrying functions by the operators of certain structures.

2.3.2 Competitive Performance of Industries, Firms, and Sites

Let us focus on the manufacturing industries of trade goods for now. Generally speaking, *industrial competitiveness* refers to the productive or market performance of a certain set of products or sites belonging to the industry of a particular nation or region.

Competition here means a subject's efforts to be selected for a certain reward under either pre-determined rules and/or free choice on the part of the selector. Competition, in other words, is an interaction between mutually independent selectors and selectees. Thus, *competitiveness* (i.e., competitive performance) can be defined as *a selectee's ability to be selected by selectors* under the rule of independent choice.

In actual fact, there are at least three layers of competitive performance, depending upon what is selected by what: *profit performance of a firm, market performance of a product, and productive performance of a manufacturing field* (Fig. 5).

Profit performance refers to a firm's ability to be selected on the capital market (e.g., return on sales, return on assets, return on equity), or its attractiveness as a whole in the minds of investors. The level of *profit performance* is affected by the firm's productive and market performance, as well as by other environmental factors such as exchange rates, business cycles, and corporate strategic choices.

Market performance is a product's ability to be selected on the product market, or the attractiveness of the design information embodied in the product in question in the minds of customers. The product's ex ante market performance includes price, delivery time, and perceived product quality, whereas its ex post market performance is measured by its market share. We may also call market performance "surface-level competitiveness," as it is revealed on the surface level of the market that can be observed by customers.

On the other hand, *productive performance*, including productivity, lead times, yields, and defect rates, measures a genba's ability to be selected as a surviving facility by the firm itself. Thus, a firm's manufacturing sites compete to be selected by the top managers at the firm's headquarters.

The essential aspects of productive performance include efficiency, speed, and accuracy of design information flows across productive resources. Physical *productivity* is the process's efficiency in sending design information to the product. Production *lead time* is the product's efficiency in receiving design information from the process. Manufacturing *quality* is the accuracy of design information transmission from the process to the product.

Both productivity and lead time improve in proportion to *value-adding time ratios*, other things being equal. That is, physical productivity (i.e., units produced per person-hour) increases by N times when the ratio on the design-information-sending side (i.e., the percentage of design-information-sending time over the total operation time of a day) increases by N times, given the amount of the product's design information and the speed of its transmission. Likewise, production lead time (i.e., time elapsed between reception of the direct materials and completion of the product) is reduced to 1/N when the ratio on the design-information-receiving side (i.e., the percentage of design-information-receiving time over the same lead time) increases by N times. In both cases, the time during which information is *not* transferred from the process (e.g., workers, production equipment) to the product is called *muda* (waste) at the Toyota Motor Corporation (Ohno 1978).

In any case, the abovementioned productive performances are measured by the effectiveness of the flow of design information in the manufacturing sites. As indicated above in Fig. 5, the causal connection between a site's organizational capability and its productive performance is more direct than that between its capability and its products' market performance, as well as the firm's profit performance (Monden 1983; Shoenberger 1982; Womack et al. 1990; Fujimoto 1999).

We have so far discussed competitive performance at the level of firms (profit performance), products (market performance), and sites (productive performance). What about performance at the industry level? As mentioned earlier, an industry is a collection of manufacturing sites or their products, but not a collection of firms, which can be multi-industrial and/or multinational. Accordingly, it is not relevant to aggregate firms' profit performance at the industry level. An industry's ex post *market performance*, measured by market share, can be aggregated as a country's market share on the global market. As for ex ante market performance, such as price, total quality, and delivery, their distribution or average levels vis-à-vis rival countries may be used as summary indicators. An industry's *productive performance* indicators, such as productivity, lead time, and defect ratios, may also be captured as their distribution or average levels vis-à-vis rival countries (Womack et al. 1990; Clark and Fujimoto 1991).

2.3.3 Organizational Capabilities of Manufacturing Sites

Organizational capability is a concept developed in evolutionary economics and in the resource-based view (RBV) of firms in strategic management (Penrose 1959; Nelson and Winter 1982; Grant 2005; Fujimoto 1999). According to this view, a firm or one of its manufacturing sites is seen as a holder of firm-specific (or site-specific) organizational capabilities and managerial resources. Given the level of a firm's resources, its capabilities affect its competitive performance (e.g., productivity).

Organizational capability is an attribute of an organization, in that it is more than the simple sum of individual skills, and it affects interfirm differences in competitiveness and profitability in the long run. It influences, if not determines, the long-term survival rate of competing sites and firms. The organizational capability of a best-practice firm is difficult for other firms to imitate, so interfirm differences in competitiveness stemming from organizational capability tend to be sustainable over a long period of time. Organizational capability tends to be built up cumulatively by a firm rather than established through one major investment or acquisition. The process of capability-building is not always based on a deliberate planning process and may well be emergent (Mintzberg and Waters 1985) or evolutionary (Fujimoto 1999).

A firm's organizational capability may be found at the level of its headquarters (e.g., strategy formulation capability for creating a platform) or its manufacturing sites (genba). Although we discuss both types of capabilities in this book, let us focus on the latter for now. When a firm's organizational capability for controlling and improving the flow of value-carrying design information is found at the level of its manufacturing sites, we call it organizational capability in manufacturing, or simply *manufacturing capability*. It is a firm-specific or site-specific system of *organizational routines* that govern the design information flows among the site's productive resources.

As mentioned before, the physical productivity (the inverse of the labor input coefficient) of a manufacturing site is the efficiency of its design information flow to the market (Fujimoto 1999). It follows that the productivity of various factories or development projects differs depending upon the firm's technological choices and/or the sites' manufacturing capability (Womack et al. 1990; Clark and Fujimoto 1991). Our empirical analysis starts from the recognition of such interfirm and international differences in productivity within a global industry. Note that the standard (neoclassical) trade theories tend to assume that production functions (i.e., physical productivity) are identical across firms and national borders within an industry, which does not seem to be a realistic assumption in today's global competition.

The above view of industries can be seen as a dynamic interpretation of Ricardo's comparative advantage. Through their evolution, manufacturing routines and capabilities (e.g., the Ford system or the Toyota system) create international productivity differences across manufacturing sites (e.g., factories and projects) within the same industry (Fujimoto 1999). Indeed, we often find the productivity of a factory in one

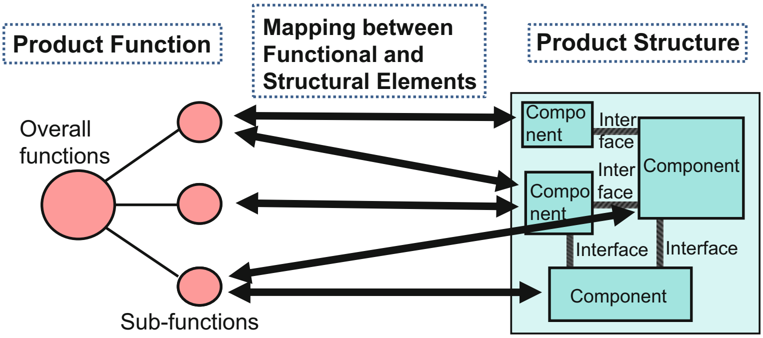

Fig. 6 Product architecture

country to be three or more times higher than that of a competing factory in another country that has adopted similar production technologies.

2.3.4 Architectures of Products and Processes

Let us now turn to the design attributes of value-carrying artifacts, including architecture and technology. *Architecture* is defined for any given artificial system (Simon 1969), including a product, use system, production process, platform, or business model. It refers to a formal pattern to link an artificial system's functional elements with its structural elements (Langlois and Roberstson 1992; Ulrich 1995). Thus, *product architecture* has to do with the engineers' basic way of thinking when they design the functions and structures of a new product. They may start from the product's overall functional requirements, derived from its concept, and deconstruct them into a set of subfunctions or functional elements. They then conceive the product's components, or structural elements, and map the relation between functional and structural elements. Thus, a product's architecture refers to a formal pattern of correspondence between its functional and structural elements (Fig. 6).

To the extent that the product's functional and/or structural elements are interdependent, the components (i.e., structural elements) need *interfaces* with other components, through which signals and energy flow for mutual adjustment. After completing a basic design of this sort, engineers can move on to the detailed design of each component.

Likewise, *process architecture* refers to the correspondence between the functional/structural elements of a product and its production process's structural elements. The concept of process architecture is important particularly in non-assembly-type industries, such as chemicals, steel, and other material industries, whose products are monolithic and difficult to deconstruct into discrete components.

The overall picture of product-process architecture may be illustrated by a matrix of product functions, product structures, and production process structures (Fig. 7).

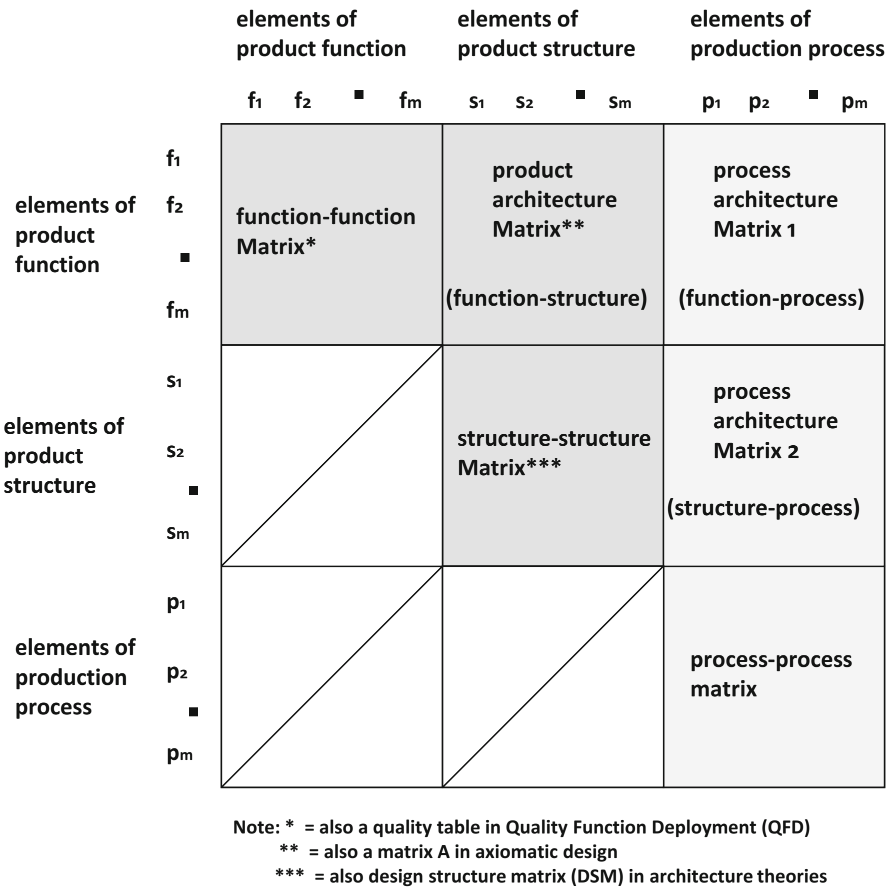

Fig. 7 Overall picture of product-process architecture

2.3.5 Basic Types of Architectures: Modular, Integral, Open, and Closed

There are certain basic types of architecture: modular versus integral and open versus closed (Ulrich 1995; Fine 1998; Baldwin and Clark 2000; Fujimoto 2007). *Modular architecture*, in its pure form, refers to a one-to-one correspondence between functional and structural elements. The parameters for components or production processes can be designed and operated relatively independently from one another, with less coordination among them. The *interfaces* among such components can be simplified and standardized, so "mix and match" of structural elements can generate variety within the total system (e.g., product) without sacrificing functionality. In other words, a modular product is *coordination-saving*.

Integral architecture, by contrast, is characterized by a many-to-many correspondence between a product's functional and structural elements. The designs of product components tend to be specific to each variation of the product. Such components must be optimized to the complete product through mutual adjustments of functional-structural design parameters. In other words, an integral product is *coordination-intensive*. "Mix and match" is difficult and so is the use of many common components without sacrificing the functionality and integrity of the whole product (Fig. 5). The same kind of classification also applies to process architecture (Fujimoto 2007).

We can describe purely modular and purely integral cases by using the axiomatic design framework (Suh 1990). In this context, the design process is described as the design engineers' effort to identify and solve a simultaneous equation $\mathbf{Ax} = \mathbf{y}$, where $\mathbf{y}$ is a vector of functional requirements, $\mathbf{x}$ refers to structural design parameters, and $\mathbf{A}$ is a matrix representing causal relations between $\mathbf{x}$ and $\mathbf{y}$. Engineers identify functional requirements $\mathbf{y^*}$ given by customers and try to acquire causal knowledge $\mathbf{A}$ by learning from existing systems, accessing the scientific knowledge base, or conducting physical or virtual simulations. They then try to find the best-effort solution $\mathbf{x^*}$ by combining existing components or creating new types of parts.

In this axiomatic design framework, which assumes linear relations between an artifact's structural and functional parameters, a new product's architecture is summarized in the content of matrix $\mathbf{A}$, which represents causal relations, where a_{ij} is a nonzero coefficient (Fujimoto 2007).

Modular **Integral**

$$\mathbf{A} = \begin{bmatrix} a_{11} & 0 & \cdots & 0 \\ 0 & a_{22} & & \\ \vdots & & \ddots & \\ 0 & & & a_{mm} \end{bmatrix} \qquad \mathbf{A} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1m} \\ a_{21} & a_{22} & & \\ \vdots & & \ddots & \\ a_{m1} & & & a_{mm} \end{bmatrix}$$

Let us look at the open/closed axes. *Open architecture* is a type of modular architecture in which "mix and match" of component designs is technically and commercially feasible not only within a firm but also across firms because certain industry-standard (i.e., open) interfaces are established among them. *Closed architecture*, on the other hand, is the case where a given component is functionally/structurally connectable to other components only within a certain firm's boundaries because its inter-component interfaces are firm-specific.

By combining the modular-integral axis and the open-closed axis described above, we can identify three basic types of product architecture (Fig. 8): (1) open-modular (open), (2) closed-modular, and (3) closed-integral (integral).

As an ideal type, *open-modular* architecture is characterized by industry-standard interfaces that are shared by relatively functionally complete components (with one-to-one correspondence between their functions and structures) designed by different firms; *closed-modular* architecture features firm-specific common components that can be connected only to other components whose interfaces are designed by the same firm; lastly, *closed-integral* architecture entails a collection of optimally designed product-specific (i.e., customized) components with complex many-to-many connections among their functions and structures.

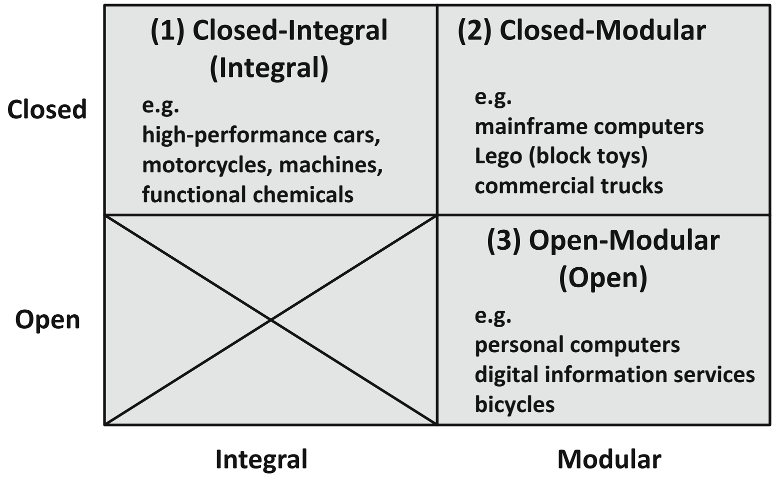

Fig. 8 Basic types of product architecture

The above design-information view of products, processes, sites, and industries naturally leads us to adopt an architectural approach to industrial classification based on architectures rather than a more traditional one relying on specific technologies. This architectural framework may provide additional insights into matters concerning intra-industry trade and a reinterpretation of the theory of comparative advantage, which is discussed next.

2.4 Architectural Positioning Strategy

2.4.1 Internal and External Architectures

The issue of strategic choices with regard to architectural positioning is another key aspect in our evolutionary analysis of firms and industries. When we analyze a firm's architectural positioning strategy for certain products, components, or platforms, we have to start from the notion that a complex artifact can be described as the hierarchy of a system with subsystems, sub-sub systems, and so on (Simon 1969; Langlois and Robertson 1992). Let us assume that the firm in question is engaged in a certain product category, which can be described as a three-layer hierarchy: a system S, subsystems S_i, and sub-sub systems s_{ij}. Let us also assume that this company develops and produces subsystem S_1 by manufacturing or purchasing its sub-sub systems s_{1j} and selling S_1 to the assembler of the total system, S (Fig. 9).

In this case, the architecture of subsystem S_1 regarding its functions and structures (i.e., sub-sub systems s_{1j}) may be called the *internal architecture* of S_1, whereas the internal architecture of the total system S (in its part corresponding to S_1) may be regarded as the *external architecture* of S_1.

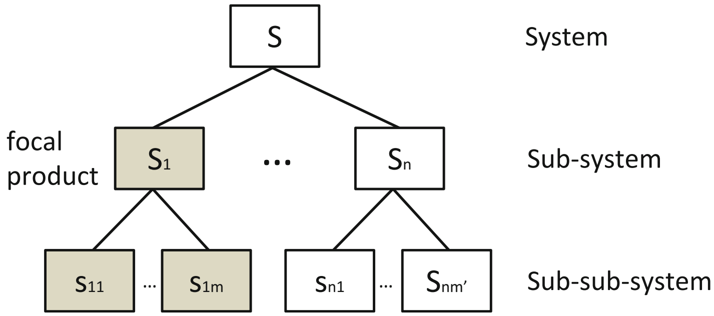

Fig. 9 The hierarchy of artifacts

If the external architecture of S_1 is relatively integral, S_1 will be more likely to be *S*-specific, or more *customized* to the design of *S* as a total system. Conversely, if its external architecture is relatively closed-modular or open-modular, S_1 will be more likely to be a customer-firm-specific *common part* or *industry-standard part*, respectively.

2.4.2 Architectural Positioning Matrix

Based on this distinction between the internal and external architecture of focal system S_1, we may analyze the integral/modular architectural positioning of S_1 by using a simple 2x2 matrix with four basic cells regarding strategic positioning: *integral-inside-integral-outside* (I-I), *integral-inside-modular-outside* (I-M), *modular-inside-integral-outside* (M-I), and *modular-inside-modular-outside* (M-M).

Different innovation/production/pricing/sales strategies may be applied to different cells. For example, price leadership or aggressive innovations to compensate for high unit costs will be crucial in the I-I strategy; sales and cost leadership with scale and learning effects will be key in the I-M strategy; solution business by sales engineers and direct selling will be effective in the M-I strategy; and simple production scale or profit-seeking of remaining players will be the best approach in the M-M strategy (Fig. 10).

Similarly, we can create a matrix to analyze internal/external and closed/open architectures, with the following architectural positioning strategies: *closed-inside-closed-outside* (C-C), *closed-inside-open-outside* (C-O), *open-inside-closed-outside* (O-C), and *open-inside-open-outside* (O-O) (Fig. 11).

Among these choices, the strategy most often adopted by the so-called platform leaders (e.g., Apple, Google, Amazon, Facebook, Intel, Microsoft, etc.) is *closed-inside-open-outside* (C-O). In order to understand the considerable impact of this C-O strategy, we need to explore the mechanisms of the cumulative network effect (network externality; Katz and Shapiro 1985) with complementary goods in the open-inside-closed-outside platform, which consists of closed-inside-open-outside core products.

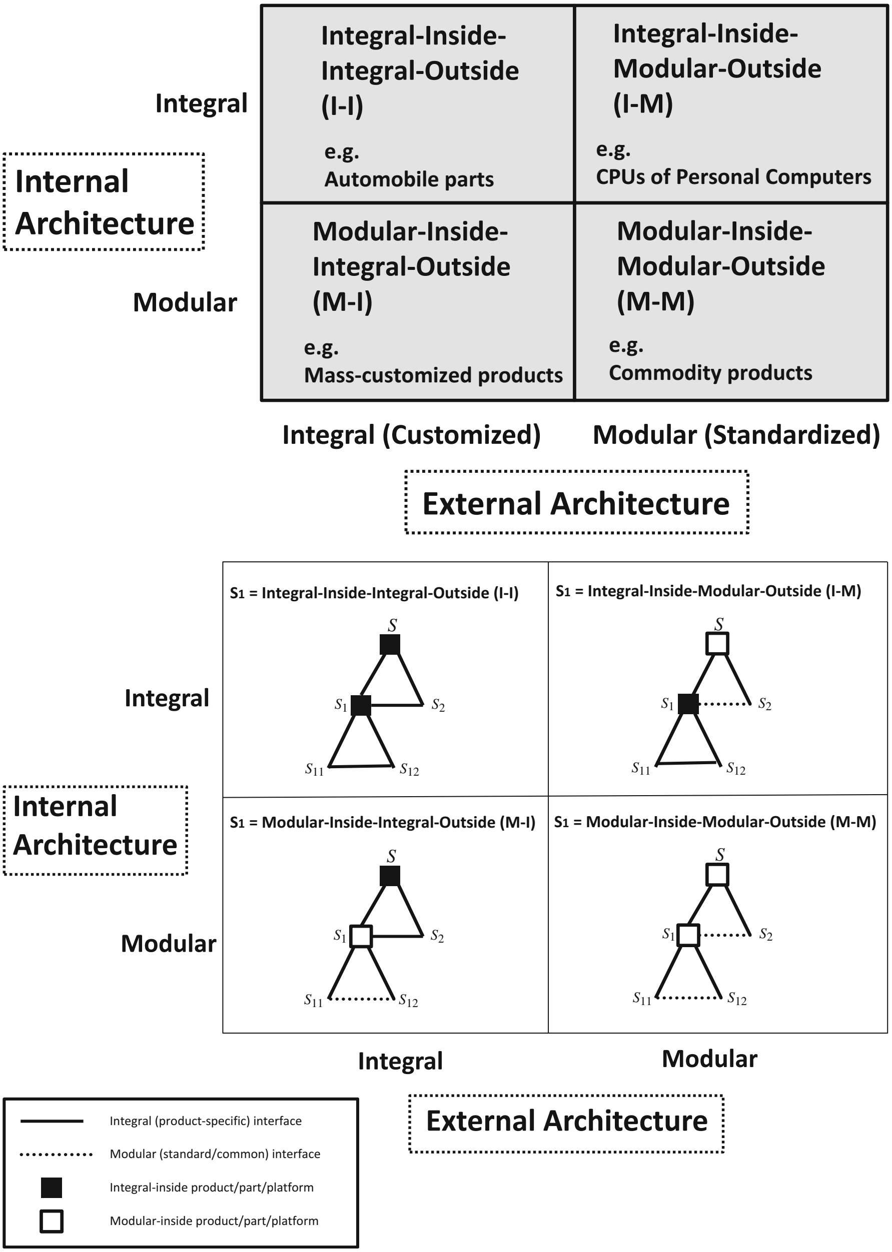

Fig. 10 Architectural positioning strategy (1) (integral/modular)

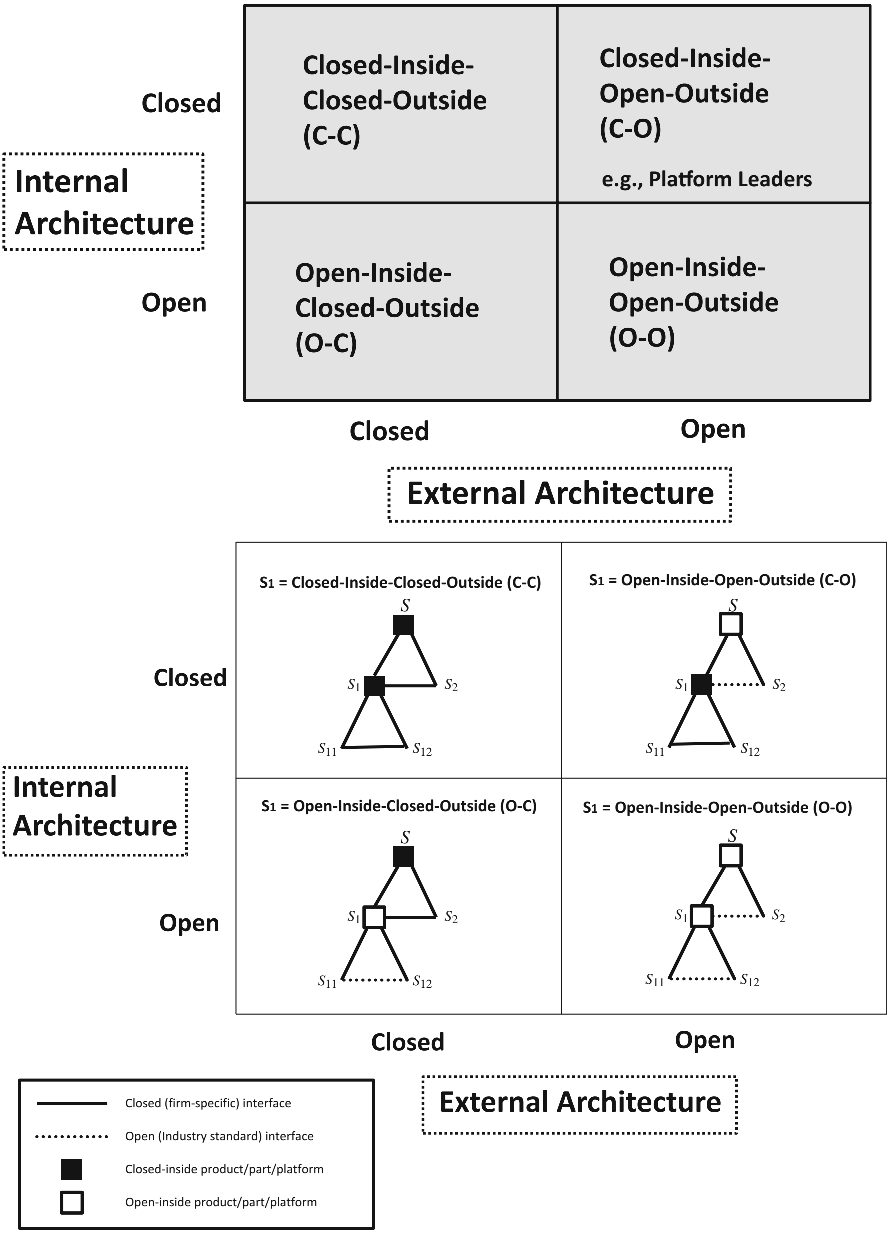

Fig. 11 Architectural positioning strategy (2) (closed/open)

2.4.3 Competition Among Open-Inside Platforms

Suppose that there is a technologically superb firm that has a broad range of deep systemic and component knowledge. In conventional inter-product competition, the high-tech firm in question will try to enclose all of its proprietary technologies and knowledge and maximize its product's market share by making the most of its technology-driven product competitiveness.

However, when the firm aims to become a platform leader, its strategy can be very different (Gawer and Cusumano 2002; Chapter "Capability Building and Demand Creation in 'Genba-Oriented Firms'"), as explained below:

(i) When the firm in question (from now on, the "core firm") finds that it possesses a core technology for an artifact with potentially open-modular architecture and network externality with complementary goods and promising markets, it tries to create an industry-standard interface, or open interface, around this key technology, which other firms will adopt.
(ii) The core firm further tries to make the "core area" within the newly established standard interface closed-inside-open-outside while also rendering the design information and technological knowledge inaccessible from outside the core firm by simply hiding them or protecting them by means of patents.
(iii) The core firm capsules its core technology in its "closed" area in the form of key components (e.g., CPUs for personal computers), core complementary goods (e.g., smartphone terminals), fundamental operating software (e.g., OSs for personal computers or smartphones), communication equipment (e.g., base stations for mobile phones), developmental services, communication/transaction services, etc., from which it earns revenues.
(iv) On the other hand, the core firm deliberately makes the design information and technological knowledge of the "peripheral area" outside the industry-standard interface open to other firms, so that the latter can develop complementary goods with open-outside architectures relatively easily by using the now accessible design/technological information. In this way, technological barriers to entry in the peripheral area become significantly lower, and many firms may enter this area.
(v) The core firm tries to preserve its technological leadership by monopolizing the design information in the core area, managing and maintaining the open interface, and making the design information in the peripheral area open and attractive to many existing or potential manufacturers/developers of complementary goods.
(vi) If the above efforts by the core firm are successful, cumulative network effects among core products/components/software and complementary goods and services may bring about rapid market growth for this network of products, components, software, and services, which we may call *platform* (Katz and Shapiro 1985; Brandenburger and Nalebuff 1996; Gawer and Cusumano 2002).

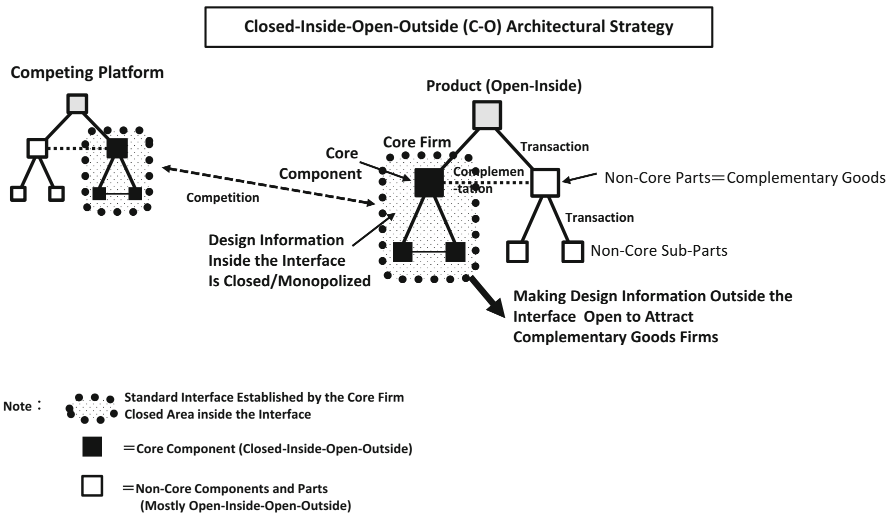

Fig. 12 Platform strategy by the key component firm

(vii) If the platform in question monopolizes the industry, we may regard this platform with open-inside architecture as an industry in a broad sense. If there are competing platforms that are functionally similar (e.g., Google versus Apple in smartphones), we may regard them as an industry with multiple and mutually competing platforms with open-inside architectures. Thus, an industry, in the broad sense of the word, consists of either competing products or competing platforms. Figures 12 and 13 illustrate the cases of core component and core product.

Thus, by introducing the concepts of hierarchies of artifacts, internal/external architectures, and open/closed architectures, our framework of competitiveness/capability/architecture can cover both conventional inter-product competition and newer inter-platform competition. In the former case, capability-building capabilities and design-based comparative advantages are the key elements to understand the dynamics of industrial competition. In the latter case, capabilities for creating and managing industry-standard interfaces and open-inside platforms, as well as cumulative network effects among complementary goods and services, are the main success factors for the platform-leading firms and the platforms themselves.

2.4.4 Product-Based Industry and Platform-Based Industry

When a set of products and components evolves into a platform created by the core firms (i.e., the platform-leading firms), which establish their industry-standard interfaces, a question arises as to how we should redefine an industry comprising the said platform. Conventionally, an industry consists of a set of products of similar design

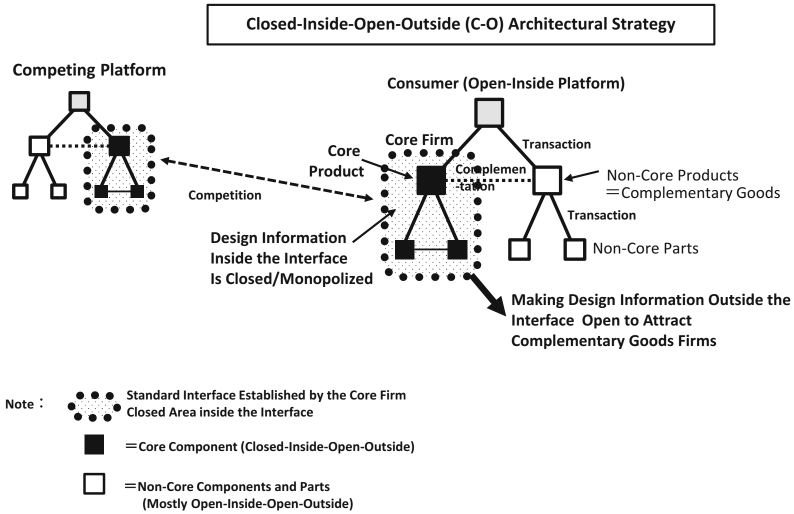

Fig. 13 Platform strategy by the key product firm

or functions competing with each other, as well as of the components and materials that their producers purchase. In other words, the products and components in an industry are mutually connected through competition or transaction.

On the other hand, a platform with open-modular architecture and network effects among complementary goods consists of products and components that are interconnected not only through competition and transaction but also through complementation (Brandenburger and Nalebuff 1996). Therefore, when a platform extends beyond a conventional industry, or a collection of functionally similar products and components, should we also call the set of industries interconnected via said platform "an industry"?

We believe that there should be two different definitions, i.e., the conventional *product-based definition of an industry* and the newer *platform-based definition of an industry*. That is, when an open-modular platform with standard interfaces encompasses multiple product-based industries, for instance, A and B in Fig. 14, we may redefine them as a single platform-based industry that includes both product-based industries A and B.

In the present book, an *industry* is understood as a collection of design information assets (e.g., products, components, services) that are networked or interconnected along three axes, i.e., transaction, competition, and complementation (see Fig. 14). When the products and components are not only competing with but also complementary to each other, we call such a network of products a *platform*. An industry can also be defined in terms of manufacturing sites and firms that are buying/selling, competing, and cooperating with each other. When such relations include "symbiosis" between complementary goods and their producers, we may call this industry an *ecosystem* (Iansiti and Lavien 2004). Hence, the definition of industry adopted here is rather broad.

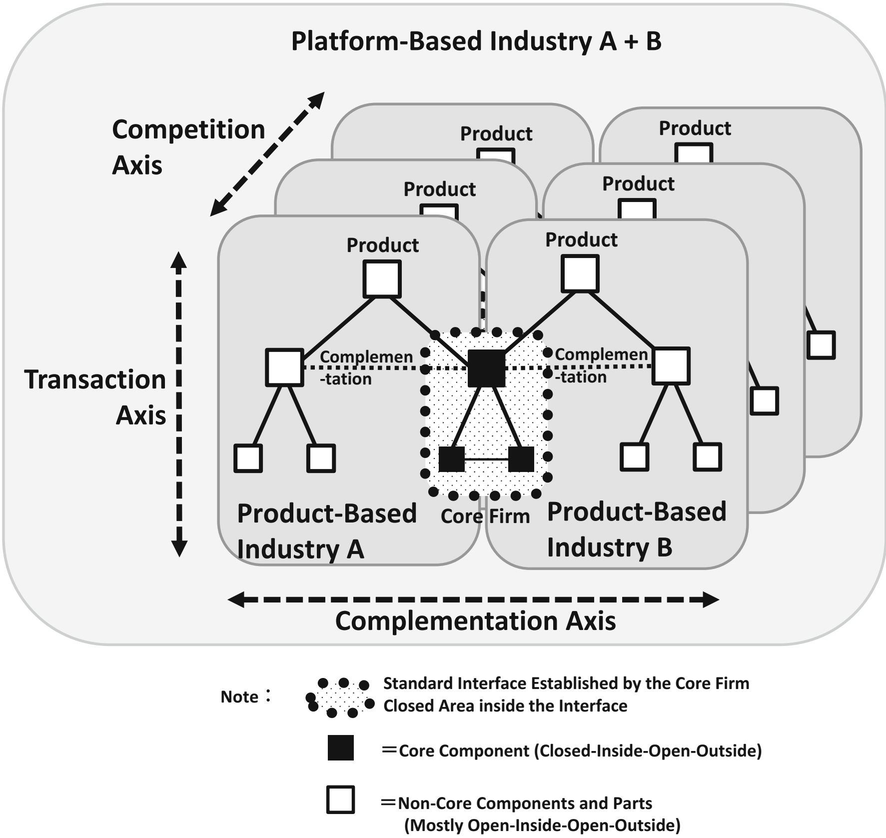

Fig. 14 Two definitions of an industry: product-based and platform-based

3 Implications and Conclusions

3.1 *Summary of the Evolutionary Framework*

The present chapter illustrated a field-based or site-based evolutionary framework for analyzing competition dynamics among sites, industries, and firms. This *field-based evolutionary framework of capability-architecture fit* may give us additional insights to better understand the general industrial dynamics of the early twenty-first century on a global scale.

After defining the competitive performance of industries, the capability of manufacturing sites (genba), and the architectures of products and processes, we illustrated the basic logic of *design-based comparative advantage* by connecting these factors (Fujimoto 2007, 2012b; see Fig. 2 again): the dynamic fit between a certain type of genba organizational capability, which has emerged in a given country, and a certain type of product architecture, which has evolved over time, tends to result in higher competitive performance of design locations in terms of comparative design costs.

Organizational capability in manufacturing is defined as a system of organizational routines that collectively control and improve the flow of design information to customers (Nelson and Winter 1982; Clark and Fujimoto 1991). To the extent that an organization is a system of coordinated activities (Barnard 1938), key dimensions of its capability will naturally include degrees and types of *coordination*. The evolutionary logic is also introduced here to explain why different types of organizational capabilities are unevenly accumulated in different countries and regions (Fujimoto 1999, 2007, 2012b, 2014).

The concept of *architecture* is defined as a formal pattern for coordinating the functional and structural design elements of an artifact, including product and process (Ulrich 1995; Fujimoto 2007). A product/process with integral architecture is coordination-intensive, whereas a product/process with modular architecture is coordination-saving, as mentioned earlier.

It follows from the above argument that a country's patterns of comparative advantage in design may be influenced by a certain fit between the *coordination capabilities* of its manufacturing sites (genba) and the *coordination intensities* of products and processes, both of which evolve over time. Specifically, a country whose industrial sites are relatively rich in coordination capabilities for evolutionary reasons, such as postwar Japan, might have a comparative advantage in design in relatively coordination-intensive products or those with integral architectures. Conversely, a country whose industrial sites have historically emphasized specialization-standardization-simplification of their products, processes, components, and their interfaces—such as the USA, whose industries grew rapidly, thanks to a massive inflow of immigrants—might have a comparative advantage in design in relatively coordination-saving products or those with modular architectures.

The present framework follows the general logic of comparative advantage theories, which emphasize country-industry fit and relative productivity advantage across countries. In addition, it adopts the design-based concepts of comparative advantage by integrating the design view of manufacturing into existing trade theories. In this context, both capabilities and architectures are treated as endogenous and dynamic. Hence, our approach assumes that a certain evolutionary process will result in the uneven distribution (i.e., endowment) of a given organizational capability across countries and firms. History does indeed matter.

The view of design-based comparative advantage also postulates that organizational capabilities are more difficult to move across borders than capital, goods, and services, even in our age of globalization, and that they tend to become country-specific. A country's capability-building environment (e.g., resource scarcity), the intensity of its industry's capability-building competition, and its firms' capability-building capability (i.e., evolutionary capability; Fujimoto 1999) all affect the prevalent nature of the capabilities of its manufacturing sites or genba.

The evolutionary view of architectures also argues that a product's overall *macro-architecture* is selected ex post by markets and society, whereas its *micro-*

architectures tend to be generated ex ante by engineers (Fujimoto 2012b). When a product must meet demanding functional requirements and/or strict constraints (e.g., safety and environmental regulations), its macro-architecture tends to become integral, other things being equal. By contrast, when the requirements and constraints are less strict, it tends to become more modular. Thus, a product's architecture is not a given—it evolves through micro-macro loops of design selections by engineers and markets.

Thus, the framework of design-based comparative advantage tries to explain why certain products are imported or exported within a global system of intra-industry trade of differentiated products, which is the overall trend of the twenty-first century.

3.2 Comparative Advantage in Production/Design Cost

In this introductory chapter, we argued that industries and firms are both a collection of sites engaged in providing certain products and that the products' market performance and the firms' profitability are both affected by the productive performance (i.e., deep-level competitiveness) of such manufacturing sites. We also pointed out that the value added of a product dwells in its design information.

The capability-architecture view of industrial performance adopted here is, in a sense, a reinterpretation of the Ricardian theory of comparative advantage. It extends the concept of comparative cost from production to design, so that it becomes a theory of comparative design cost. This implies that David Ricardo's classical theory of international trade, with certain modifications by modern economists such as Sraffa and Shiozawa (e.g., the multifactor multi-country version of Ricardo's comparative cost analyses), may be realistic enough to explain twenty-first-century trade phenomena in Japan and across the world (Sraffa 1960; Shiozawa 2007).

We predict that industries and industrial sites are more likely to be selected and thus survive when they build certain organizational capabilities and produce or develop products with appropriate architectures. Similarly, firms will be more likely to survive and grow when they choose a profitable mix of products and their architectures, as well as competent sites and their locations. In the following chapters, we will often use the abovementioned keywords: *industrial competitiveness*, *organizational capabilities*, and *product architectures*.

Theoretically, the framework of international industrial competitiveness put forward in this book may be regarded as a dynamic application of the Ricardian comparative advantage theory to design costs and locations, i.e., *design-based comparative advantage*. This approach starts from field observations of *industrial sites*, in which value-carrying design information flows toward the markets, evaluates the *organizational capabilities* that control or improve the value flows, identifies the *architectures* of products and processes, and analyzes the dynamic fits between architectures and capabilities and their impact on the *competitive performance* of sites, products, firms, and industries.

Thus, by dynamically reinterpreting the classical concepts of comparative advantage and by applying them not only to production costs but also to design costs, this volume will try to explain what has happened to various industrial sectors in postwar Japan, in terms of economic growth, labor shortage, yen appreciation, capability-building, international competition during the Cold War, global competition after the Cold War, and relative wage/productivity divergence and convergence vis-à-vis other advanced/emerging nations.

3.3 Evolution of Industries, Firms, and Sites

The evolutionary framework adopted here will also illustrate the growth and changes of national and global economies, industries, firms, and sites seen as interrelated dynamic processes.

First, the evolution of the capabilities of manufacturing sites (genba) causes productivity growth and differences, which influence country A's average productivity in industry X through market selection of high-productivity sites within the country.

Second, different industries in country A, with different patterns of capability-building processes and design architectures, display different levels of relative productivity vis-à-vis the industries in competing countries B and C.

Third, the resulting profile of the relative productivity ratios of industries X, Y, and Z between competing countries A and B affects relative wage ratios between the two countries (Fujimoto and Shiozawa 2011–2012). In other words, the profile of all industries' relative productivity ratios vis-à-vis competing countries affects the relative wage ratio.

Fourth, as a result of the relative productivity and wages mentioned above, the relative costs and prices of industries X, Y, and Z in the competing countries are revealed. In the long run, following the logic of Ricardian comparative advantage, the industrial portfolios of countries A, B, and C emerge through selection by the global markets of "comparatively advantageous industries," which have higher relative productivity ratios vis-à-vis rival countries rather than other domestic industries.

However, the industrial structures of trading countries may constantly change to the extent that, as *capability-building competition* among sites and firms continues, their products' design attributes (e.g., architecture) change. For instance, while the relative wage ratio between two countries may change, as their all-industry profiles of relative productivity ratios mentioned above change, further changes in relative productivity ratios may, in turn, change the patterns of comparative advantage. If the relative productivity ratios of industry X in countries A and B converge faster than the relative wage ratios in the same two countries, due to technological standardization, lower-wage country B may gain a comparative advantage vis-à-vis country A, thereby shifting its status from importer to exporter in industry X, as Akamatsu's *flying geese* theory or Vernon's product cycle theory suggest (Akamatsu

1962; Vernon 1966). This is not always the case, though, as the international trade situation in the 2010s indicates—international wage gaps may decrease faster than physical productivity gaps between two countries (e.g., China and Japan).

Fifth, in order to secure profits and growth, manufacturing firms worldwide will try to select certain advantageous combinations of products and locations by moving and expanding across countries and industries. Multinational firms may find overseas locations for their manufacturing sites by balancing two principles, i.e., physical proximity to markets and comparative advantage. Therefore, a firm's business structure will evolve through selection of advantageous industries, products, architectures, technologies, site locations, and so forth.

It ought to be noted that the above account follows the Ricardian logic of classical economics, which argues that normal (natural) prices are determined by unit labor cost, or by the combination of labor productivity (labor input coefficients) and hourly wages. Additionally, the evolutionary analysis of firms and industries presented here essentially follows the assumption of classical economists (or their prominent successor P. Sraffa) that prices and volumes of a given product are determined separately (Sraffa 1926, 1960; Shiozawa 2007).

3.4 Between New and Old Theories

The early twenty-first century is the age of truly global competition, environmental and energy constraints, rapid changes in digital and other technologies, increasing numbers of demanding customers, parallel advancements in product commoditization and differentiation, rapid changes in relative wages and productivity across borders, and high levels of socioeconomic uncertainty. To the extent that the above is true, the concepts of comparative advantage and industrial performance and their evolution will continue to be key to sustaining or improving our children's living standards and quality of life.

Some may argue that we need newer theories able to handle the new realities of the twenty-first century. In fact, in analyzing open architecture platforms in digital industries, we will apply newer economic concepts, such as complementary goods, network externality, and inter-platform competition. In this particular area, we certainly need to introduce new economic concepts for new realities.

At the same time, we have also explored an alternative idea—returning to the older theories of the nineteenth century, namely, classical economic theories, and modifying them to fit the realities of the current global economy. More specifically, our work tries to start from the classical (Ricardian) trade theory and then reinterprets it dynamically to explain the rapid changes in relative wages and productivity (Fujimoto and Shiozawa 2011) and to incorporate the concept of product design and architecture into it (Fujimoto 2007, 2012b). Consequently, this chapter proposes a field-based evolutionary framework of capability-architecture fits to analyze industrial performance, i.e., the concept of design-based comparative advantage (Fig. 2).

It is worth noting that the present framework of dynamic and design-based comparative advantage is, in many ways, complementary to existing trade theories. Indeed, the neoclassical (Heckscher-Ohlin-Samuelson) theory, the product-cycle (flying geese) theory (Akamatsu 1962; Vernon 1966), the new trade theory (Helpman and Krugman 1985), and the new-new trade theory (Melitz 2003) all capture certain important aspects of today's industrial competition and trade dynamics.

However, in order to understand the trade phenomena of the post-Cold War era, when minute-level intra-industrial trade of highly differentiated goods is common and relative wages and productivity of individual sites are changing rapidly worldwide, we would need additional insights that may borrow ideas from other schools and disciplines, including the concept of comparative cost from classical economic theories, of system emergence from evolutionary economics, of organizational capabilities from strategic management, of product architecture from design-artifact theories, and of monozukuri (manufacturing as design flow) from technology and operations management (Fujimoto 1999, 2007, 2012a; Fujimoto and Shiozawa 2011–2012; Mintzberg and Waters 1985; Nelson and Winter 1982; Penrose 1959; Shiozawa 2007; Simon 1969; Sraffa 1960; Ulrich 1995). What we need in this context seems to be a dynamic and interdisciplinary framework that can capture the essence of the multifaceted entity called *genba*.

Appendix: The Case of Postwar Japan—Capability-Building and Architectural Fit

By applying the capability-architecture framework to the case of Japanese industries in a dynamic way, this book will argue that postwar Japanese industries tended to possess a rich endowment of coordinative capabilities (e.g., teamwork of multi-skilled engineers/workers), mostly due to certain historical reasons, and that Japan's *coordination-rich* industries typically enjoyed design-based comparative advantage in *coordination-intensive* products (Fujimoto 2014). In other words, we assume that Japan's industrial innovations mainly developed in industries with relatively *integral* (i.e., coordination-intensive) architectures, including automobiles and functional chemicals, rather than those with modular (i.e., coordination-saving) architectures, such as digital products and software.

Using the above evolutionary framework of industry performance, let us look at the history of Japanese manufacturing industries (i.e., trade goods) after World War II. To briefly describe the *postwar history of Japan's genba*, we have divided this period into roughly 20-year spans (1950–1970, 1970–1990, 1990–2010, 2010–; see Table 1).

(i) Following a period of turmoil immediately after World War II, the beginning of the Cold War and Japan's strategic geographical position brought about opportunities for rapid economic growth at an unexpectedly early stage. In the 1950s

Table 1 A postwar history of genba (manufacturing sites) in Japan

Period (roughly)	Characteristics	Consequences in genba (manufacturing sites)
1945–1950	Beginning of the Cold War	Capability rebuilding of genba starts (QC, etc.)
1950–1970	High growth without immigrants	Emergence of genba coordination capabilities through “economy of scarcity” (e.g., Toyota system)
1970–1990	International competition during the Cold War (among advanced nations)	Productivity/quality improvements overcoming yen appreciation and oil crises, trade friction
1990–2010	Global competition after the Cold War (with low-wage emerging nations)	The Dark Ages of Japan’s genba in trade goods, capability-building unable to overcome wage handicap
2010–prediction	Global competition with richer emerging nations	Japan’s capability-building genba may have better chances of survival as wage gaps narrow

and 1960s, the “economy of scarcity” forced many Japanese factories and sites to develop coordination-rich manufacturing capabilities based on the teamwork of multi-skilled employees. This historical imperative subsequently brought about Japan’s comparative advantage in coordination-intensive (i.e., integral architecture) goods, such as small cars and analog consumer appliances.

(ii) In the 1970s and 1980s, internal and international competition became tougher due to yen appreciation and slower economic growth, but many of Japan’s manufacturing sites (monozukuri genba) accelerated their efforts in capability-building and productivity increases to overcome these handicaps. As a result, many Japanese manufacturing industries enjoyed competitive advantage and Japan’s trade surplus expanded, which created trade friction and a boom in the Toyota production (lean production) system in and outside Japan. This was the era of international competition between advanced nations during the Cold War.

(iii) In the 1990s and 2000s, however, the competitive environment surrounding Japan’s industrial sites changed drastically. As the Cold War ended, highly populated low-wage countries like China started to enter the global market as major exporters. China’s typical wage rate in the 1990s was, roughly speaking, one-twentieth that of Japan, due partly to what A. Lewis might describe as “unlimited supplies of labor” from China’s agricultural inland provinces to industrializing coastal areas (Lewis 1954). Thus, many of Japan’s manufacturing sites in trade goods sectors found that their advantage in physical labor productivities (i.e., labor input coefficients) did not help them maintain their Ricardian comparative advantages in production costs. Besides, the wave of digital innovations since the mid-1990s created major market shifts from coordination-intensive analog products to coordination-saving (i.e., architecturally open-modular) digital products, where Japan's relatively coordination-rich sites could not maintain their design-based (i.e., architecture-based) comparative advantage (Fujimoto 2007, 2012b).

As a result of the abovementioned changes in global competitive environment and product technologies in the electronics industry, and continuing post-bubble recession and yen appreciation, Japan's manufacturing sites (genba) faced a "Dark Ages" period during most of the 1990s and 2000s. This was particularly true in the digital electronics sector, in which China, Korea, and Taiwan became major exporters, whereas some of Japan's most prominent factories were closed down despite severalfold increases in labor productivity. However, Japanese factories in the trade goods sector continued their capability-building efforts, further improved productivity, and many of them survived the "Dark Ages," particularly in coordination-intensive (i.e., integral architecture) products, including fuel-efficient cars, sophisticated industrial machinery, highly functional chemicals, steel, and so forth. Indeed, Japan maintained a trade surplus for much of this period.

Nonetheless, the competitive situation is now changing worldwide. As we enter the next 20 years (2010–), we can already observe significant changes in the shape of global competition, including a rapid increase in wage rates in China and other emerging countries (Thailand, Indonesia, India, and others). The wage-related handicap that Japan's trade goods sectors labored under for many years has diminished somewhat since the beginning of the 2010s. Accordingly, although no nation can escape country-level changes in industrial structure driven by dynamic comparative advantage, the chances that Japan's domestic factories persevering in their capability-building efforts can survive will increase in the coming years. In this sense, many of Japan's high-productivity manufacturing sites are gradually moving past their worst period, i.e., the end of the post-Cold War era.

Yet, this may be the time of darkness before the dawn, in which observers and decision makers may make major mistakes, as they overlook the abovementioned changes and assume an overly pessimistic view that the gloom of manufacturing industries in high-wage advanced nations will continue forever. Some managers in Japan's large enterprises have considered only short-term cost data, de-emphasized their domestic factories' productivity advantages, and ignored their potential for further productivity increases, erroneously closing down factories that could have survived with proper measures. Some media sources and scholars are also responsible for spreading unduly pessimistic views, predicting the hollowing out of Japan's manufacturing sector as a whole. These are erroneous interpretations that ignore both the genba's realities and the theoretical principles of comparative advantage. If all managers in Japan's trading sectors were to follow the advice of such commentators, the result might indeed be the hollowing out of the entire manufacturing sector as a self-fulfilling prophecy—the result of human error rather than of global competition.

This is why we need a solid theoretical-analytical framework for evaluating industrial performance and its potential in each sector or product. The author believes that this framework should be based on field observations and industrial data, as well as the logical integration of various disciplines, including classical trade theories, design-architecture theories in engineering, and evolutionary views of capability-building.

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