Kindai Management Review Vol. 2, 2014 (ISSN: 2186-6961)

A Genba-Based Evolutionary Approach for Analyzing Industrial Performance: The Effect of Dynamic Fit between Capabilities and Architectures

Takahiro Fujimoto

University of Tokyo, Japan

Abstract

This paper explores an analytical framework that may give us some additional insights for understanding the trade and industrial dynamics of the early 21st century—*a field-based evolutionary framework of capability-architecture fit*, which applies the classical concept of Ricardian comparative advantage to design costs and locations. This framework starts from field observations of *genba*, or an industrial site in which value-carrying design information flows toward the markets, evaluates the *organizational capabilities* that control or improve the value flows, identifies *architectures* of its products and processes (i.e., formal pattern linkages between their functional-structural design elements), and *competitive performance* of sites, products, firms and industries. By dynamically reinterpreting the classical concepts of comparative advantage and applying them not only to production costs but also to design costs, this paper tries to explain what has happened to the trade goods industrial sector of postwar Japan in terms of economic growth, labor shortages, 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.

Keywords: *industrial performance,* monozukuri *(manufacturing), design-based comparative advantage, history of genba, Japanese industries, David Ricardo*

INDUSTRIAL COMPETITIVENESS: A MISSING LINK OF MODERN ECONOMICS

Industry worldwide in the early part of the 21st century may be characterized in various ways—intensifying post-Cold War global competition that involves both advanced and emerging nations; trends toward freer trade through various bilateral and multilateral agreements; explosive growth of goods and services that use digital-networking technologies; stricter constraints regarding environmental protection and energy conservation; the growing complexity of artifacts that deal with such constraints; coexistence of a high degree of price competition in commodity-type goods and product differentiation in brand-conscious goods; increasing technology market uncertainties and volatilities that firms face; and the higher instability and influence of global financial networks on industries.

One of the propositions derived from the above characterization is that international *industrial performance* (*competitiveness*) based on the concept of comparative advantage, devised in the19th century by David Ricardo and others (Ricardo, 1817), still matters in this century. It is also important to note that improvement of physical productivity (i.e., labor input coefficients), the ultimate generator of industrial comparative advantage and national standards of living (Smith, 1776), occurs in industrial sites, or genba in Japanese, including factories, development centers, shopping stores, service facilities and farmland. An industry is nothing but a collection of industrial sites (genba) of a similar kind.

In the 18th and 19th centuries, major works of classical economists, including Adam Smith, David Ricardo and Karl Marx (Marx, 1867), tended to make rich descriptions and analyses of "industries" based on field observations (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 neo-classical school) tended to deemphasize the concept of "industry" and "sites," while pursuing such mathematical-theoretical sophistication as the general equilibrium theory that assumes profit maximization at the firm level. This meant that mainstream economics tended to neglect 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, Jones, & Roos, 1990; Clark & Fujimoto, 1991).

Indeed, the concept of comparative advantage of industries, both Ricardian and neo-classical, continued to be the key to understand the freer trade systems of the 21st century. Newer approaches like product lifecycle (flying geese) theory, new trade theory and new-new trade theory certainly provided additional explanatory powers for understanding today's trade phenomena that involve emerging nations, foreign direct investment, product differentiation and economy of scale (Akamatsu, 1962; Vernon, 1966; Helpman & Krugman, 1985; Melitz, 2003). Without introducing the concept of *design* of the 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 vice-versa.

Besides, some 20 years after the end of the Cold War and the abrupt entrance of gigantic low-wage countries like China, the average wage in such emerging countries finally started to soar, as the period of "unlimited supply of labor" (Lewis, 1954) is ending. This may be a good time to introduce a certain dynamic and field-based version of Ricardian-Sraffian trade theory for analyzing 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 & Shiozawa 2011).

Against this background, this paper sketches out an evolutionary framework for analyzing industrial performance by introducing such concepts as *manufacturing (*monozukuri*) as design information flow*, genba *as value-creating site*, *evolution of organizational capabilities*, *evolution of product-process architectures*, *dynamic fit of capabilities and architectures*, and multi-layer concepts of industrial performance (see Fujimoto, 2007 and 2012b for details).

ECONOMY, INDUSTRY, FIRM AND SITE

In order for us to conduct empirical research on industrial performance, we must modify our analytical framework of industrial analysis from that which mainstream economics has adopted, the "economy-industry-firm" paradigm (Figure 1, (1)), to a more realistic one, the "economy-industry/firm-site framework (Figure 1, (2)). The former certainly has significant theoretical value as it is a critical foundation of the general equilibrium theory on the supply side, but it cannot capture some critical parts of the reality in today's global competition and international trade dynamics. So, from the empirical point of view, this paper adopts the latter or *field-based view of industries*.

In the current framework, a national economy, on the supply side, is a collection of domestic industries, and an industry is a collection of value-adding sites (e.g., factories, product development projects, and service facilities) that share similar product-process design information. A firm, on the other hand, is a collection of sites and headquarters that are controlled by the same capital. Today's

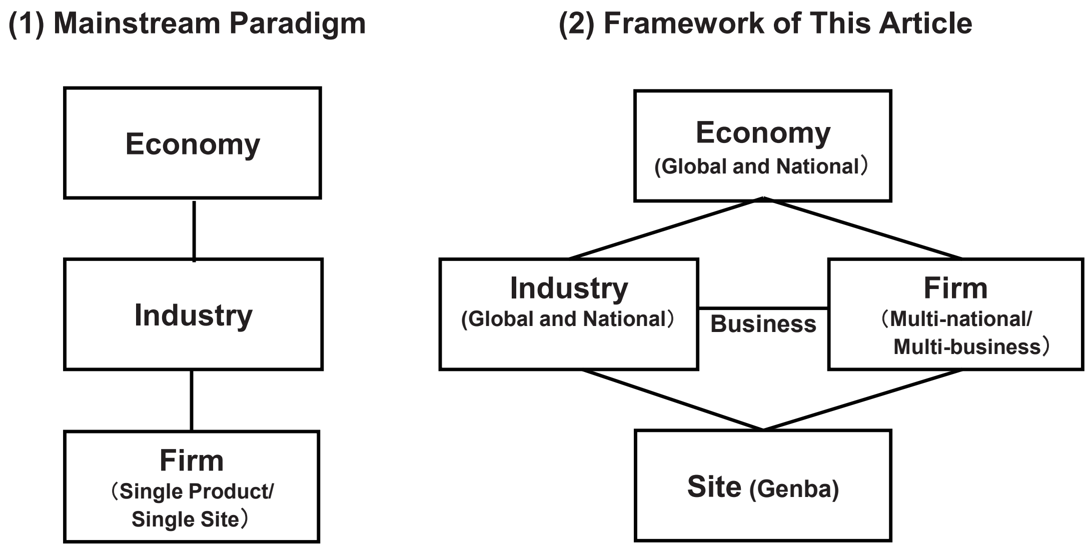


Figure 1: Economy, Industry, Firm and Site

firms are in many cases multi-national and multi-industrial, whereas local industries, by definition, stay within a country's borders. Thus, the world economy may be composed in part of global firms, whereas a national economy consists of local industries.

In any case, the most basic value-adding units of the economy are the sites or genba. In addition, economies, industries, firms and sites all evolve over time (Nelson & Winter, 1982; Fujimoto, 1999, 2012a). We will therefore start from field observation and integrate the evolutionary analyses of firms and industries by focusing on the common component of the two—industrial sites (genba), including factories, and development projects.

CAPABILITY: THE ARCHITECTURE-PERFORMANCE FRAMEWORK

The field-based framework for analyzing industrial performance and trade structures proposed in this paper is based on an evolutionary framework of *design-based (architecture-based) comparative advantage*, which predicts that certain dynamic fits between manufacturing capabilities and product-process architecture tend to result in international competitive advantage of an industry (Figure 2: See also Fujimoto, 2007).

The proposed framework includes the following components: (1) the design-based concept of *manufacturing* in a broad sense (monozukuri in Japanese), which reinterprets firms' 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 country characteristics and product attributes creates competitive advantage of a given product in a given country (Ricardo, 1817; Fujimoto & Shiozawa, 2011); (3) the *evolutionary theory of organizational capabilities*, which explains ex-post rational objects without fully depending upon ex-ante rational reasoning (Fujimoto, 1999); and (4) the concept of *product-process architecture*, originating from a theory of axiomatic design in engineering (Suh, 1990; Ulrich, 1995).

Overall, both organizational capabilities of the manufacturing sites (genba) and architecture of the artifacts (products and processes) collectively and dynamically influence performance (competitiveness) of the industry in question, which is illustrated in the central triangular part of Figure 2.

Note here that both capabilities and architectures are treated as endogenous rather than exogenous factors. This implies that both capabilities and architectures can change as their interactions with environmental factors change. There is no such thing as Japan-specific capability or automobile-specific architecture in a static sense, as it is a result

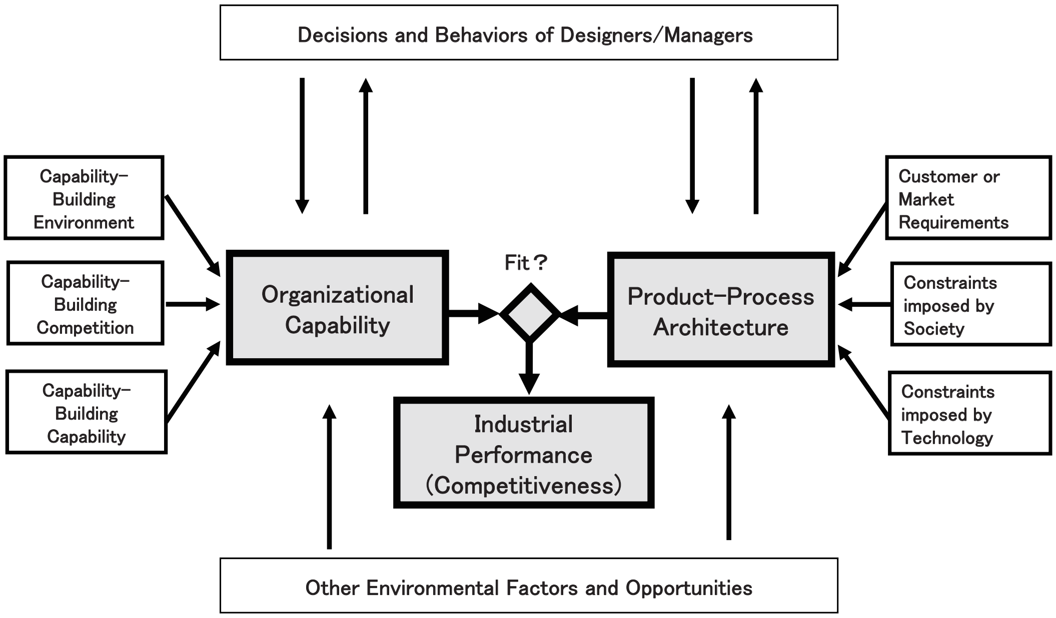


Figure 2: Field-Based View of Industrial Performance: Design-Based Comparative Advantage

of historical evolution of the entire industrial system.

Let us now briefly look at each component of this framework. 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 that order.

MANUFACTURING AS DESIGN INFORMATION FLOWS BETWEEN PRODUCTIVE RESOURCES

Starting from the above-mentioned framework of analyzing industrial performance, our next question is, what are the key concepts that all industrial sites (genba) have in common? Here, we adopt the design-based concept of manufacturing (Fujimoto, 1999, 2007) or monozukuri. According to this view, 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 artifact (Simon, 1969) that exists inside the manufacturing sites is nothing but a combination of value-carrying design information and its medium.

Thus, the common factors that we observe 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; (iii) the site's performance measured as effectiveness of the flows.

In this context, 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 which consists of design information and its medium, following Aristotle's logic of form and material. 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 locations—the notion of design-based comparative advantage, which is discussed below.

If the medium of the product in question is tangible, it is a hardware good that belongs to a manufacturing industry. If the medium is intangible or ephemeral, it is a service (if its design information is functional) or software (if it is structural). In any case, design information is the major source of

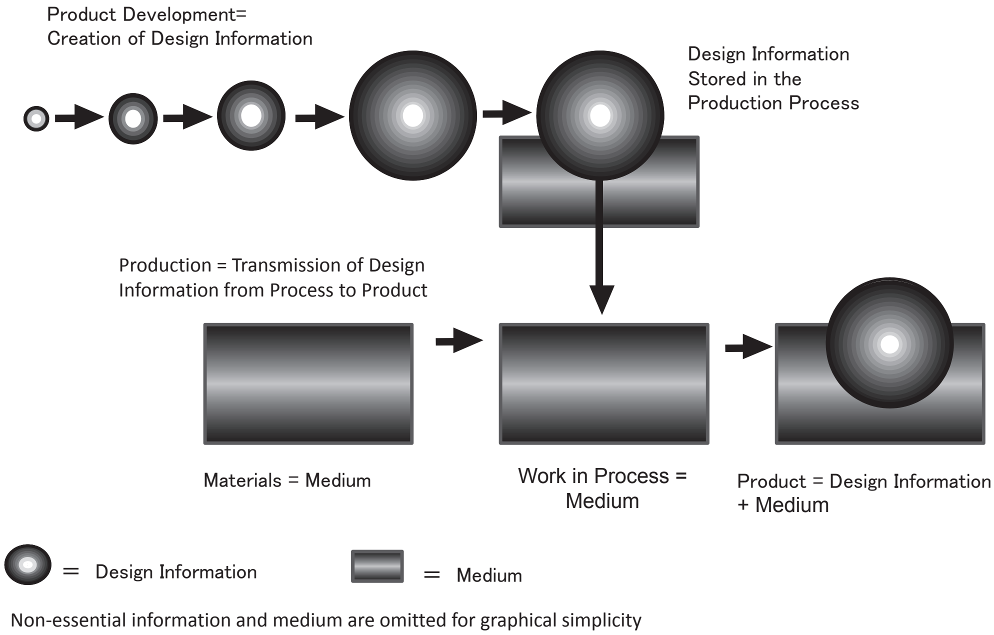


Figure 3: Production and Development as Design Information Processing

economic value added.

Design information of an artifact, like genetic information of a living thing, evolves over time through variation-selection-retention, which is made by markets, societies, firms and engineers. Innovation, in the Schumpeterian sense (Schumpeter, 1912/1934), is essentially the evolution of new design, or the new combination of functions and structures of an artifact (e.g., product, process, etc.) that contributes to economic value added.

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

A *productive resource* (Penrose, 1959), such as workers, equipment, die, tool, standard operating procedure, digitized design file, raw materials, work-in-process, prototype or engineering drawing, 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 its media.

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 between productive resources (Figure 3).

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

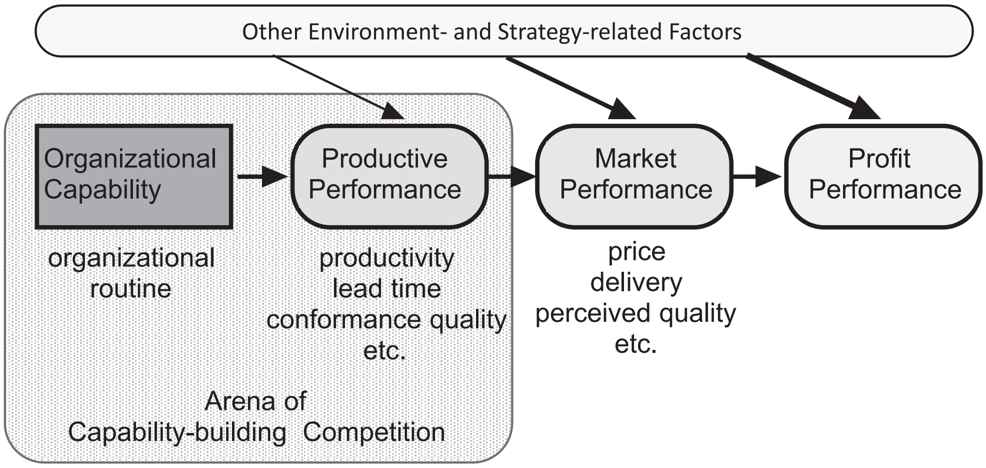


Figure 4: Capability, Competitiveness and Profitability

Fujimoto, 2000).

Production, in this context, is the repetitive transfer of the 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 design information stored in the 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 & Fujimoto, 1991). *Sales* is the transmission of the design information embodied in the products from firms to customers.

Consumption is another information-creation process by customers themselves, in which they use the product as a structure, realize its functions, and create satisfaction or dissatisfaction in their own minds. We may see this as the customer's self-service process of manipulating the product's structures for generating its functions.

COMPETITIVE PERFORMANCE OF INDUSTRIES, FIRMS AND SITES

Let's focus on manufacturing industries of trade goods for now. Generally speaking, industrial competitiveness means industrial sites' collective performance for winning in international competition. *Competition* here means a subject's effort 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.

It is important here to note that 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* (Figure 4; Fujimoto, 2007)

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

Market performance is a product's ability to be selected in the product market, or 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 top managers at the headquarters of the firm.

The essential aspects of productive performance include efficiency, speed and accuracy of design information flows across productive resources. *Productivity* is the process's efficiency of sending design information to the product. Production *lead time* is the product's efficiency of 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 as *value-adding time ratios*, or percentage of the time in which design information flows from the process to the product in the total operation time or lead time, other things being equal. The time during which information is NOT transferred from the process to the product is called *muda* (waste) at Toyota Motor Corporation (Ohno, 1978).

In any case, productive performance is measured by effectiveness of the flow of design information in the manufacturing sites. As indicated in Figure 4, organizational capability in manufacturing is more directly connected to productive performance than to market performance or 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 level of an industry? 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 multi-national. Accordingly, it is not relevant to aggregate firms' profit performance at the industry level. An industry's *market performance*, measured by market share, can be aggregated as a country's market share in the global market. As for price, 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 ratio, may also be captured as their distribution or average vis-à-vis rival countries (Womack et al., 1990; Clark & Fujimoto, 1991).

ORGANIZATIONAL CAPABILITIES OF MANUFACTURING SITES

Organizational capability is a concept developed in evolutionary economics and resource-based view (RBV) of the firm in strategic management (Penrose, 1959; Nelson & Winter, 1982; Grant, 2005; Fujimoto, 1999). In this view, a firm or its manufacturing site is illustrated as a holder of firm-specific (or site-specific) organizational capability or a system of *organizational routines* that govern flows of the value added (i.e., design information) that link the productive resources.

Organizational capability is regarded as specific to a firm or a group of firms. It is an attribute of organization in that it is more than a simple sum of individual skills. It affects inter-firm differences in competitiveness and profitability in the long run. It influences, if not determines, the long-term survival rate of competing sites and firms. Organizational capability of a best-practice firm is difficult for other firms to imitate, so inter-firm differences in competitiveness stemming from organizational capability tend to be sustainable for a long time. Organizational capability tends to be built up cumulatively by a firm rather than established by one major investment or acquisition. The process of capability building is not always based on a deliberate planning process: it may well be emergent (Mintzberg & 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), but it may also be concentrated in the manufacturing field. 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 (genba), we may call it organizational capability in manufacturing, or simply *manufacturing capability*.

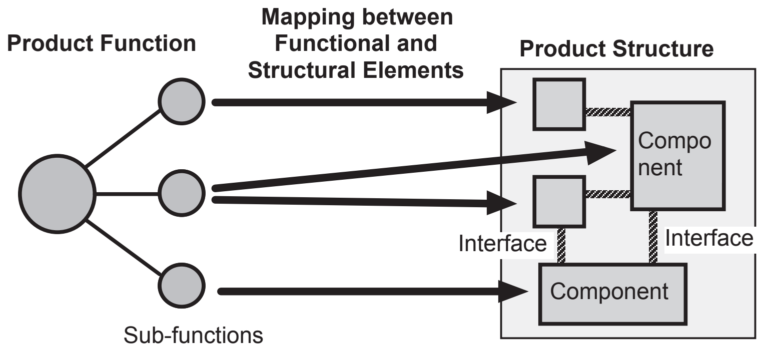


Figure 5: Architecture of a Product

Note again that we are focusing on manufacturing industries of trade goods, although the same logic can be applied to the service sector in many respects. A manufacturing site (genba), in this context, is a place where value-carrying design information flows to the market. The flow is governed by technologies and routines. A system of routines that effectively govern the design information flow may be called organizational capability in manufacturing, or more simply, *manufacturing capability*. Firms select core technologies, while their sites (genba) accumulate manufacturing capability, which in turn affects productivity of the sites.

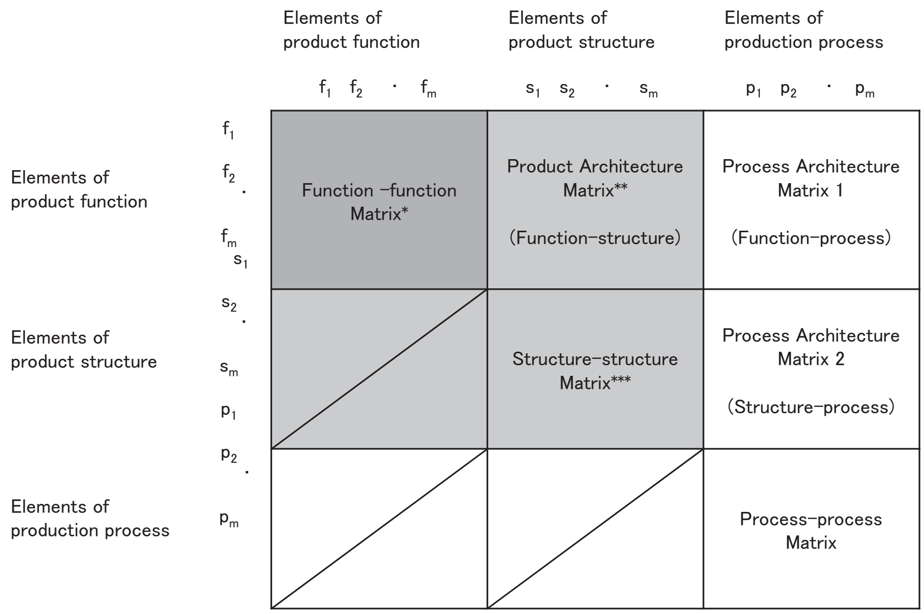
The physical productivity (inverse of labor input coefficient) of a manufacturing site means the efficiency of the design information flow to the market (Fujimoto, 1999). It follows that the productivity of different factories or development projects may differ depending upon the firm's technological choices and/or the sites' capability building (Womack et al., 1990; Clark & Fujimoto, 1991). Our analysis starts from the recognition of such inter-firm and international differences in productivity within a global industry. Note that the standard (neo-classical) 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 Ricardian comparative advantage. Manufacturing routines and capabilities (e.g. the Ford System or the Toyota System), through their evolution process, create international productivity differences between factories and projects within the same industry (Fujimoto, 1999). Indeed, we often find productivity of a factory in country A to be three or more times higher than that of its competing factory in country B which has adopted similar production technologies.

ARCHITECTURES OF PRODUCTS AND PROCESSES

Architecture is defined on any given artificial system (Simon, 1969), including a product, use system, production process or business model. It means a formal pattern of linking an artificial system's functional elements to its structural elements (Langlois & Roberstson, 1992; Ulrich, 1995). Thus, *product architecture* implies the basic way of thinking in the minds of engineers when they design functions and structures of a new product. They may start from the product's overall functional requirement derived from its concept, and then deconstruct this requirement into a set of sub-functions or functional elements. They then conceive of the product's components or structural elements and map those functional elements to the structural elements. Thus, a product's architecture means a formal pattern of correspondence between its functional and structural elements (Figure 5).

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



Note: * = also a quality table in Quality Function Deployment (QFD)
** = also matrix A in axiomatic design
*** = also design structure matrix (DSM) in architecture theories

Figure 6: Overall Picture of Product-Process Architecture

of each component.

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

The overall picture of the product-process architecture may be illustrated by a matrix of product functions, product structures and production processes (Figure 6).

There are certain basic types of architecture: modular versus integral, and open versus closed (Ulrich, 1995; Fine, 1998; Baldwin & Clark, 2000; Fujimoto, 2007). *Modular architecture*, in its pure form, represents 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 each other with less coordination between them. The *interfaces* between 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, represents a many-to-many correspondence between the product's functional and structural elements. Designs of the components tend to be specific to each variation of the product. Such components must be optimized to the whole product by mutual adjustments of functional-structural design parameters. In other words, an integral product is *coordination-intensive*. Mix and match are difficult, and so is the use of many common components without sacrificing functionality and the integrity of the total product (Figure 5). The same kind of classification applies also 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 design engineers' efforts to identify

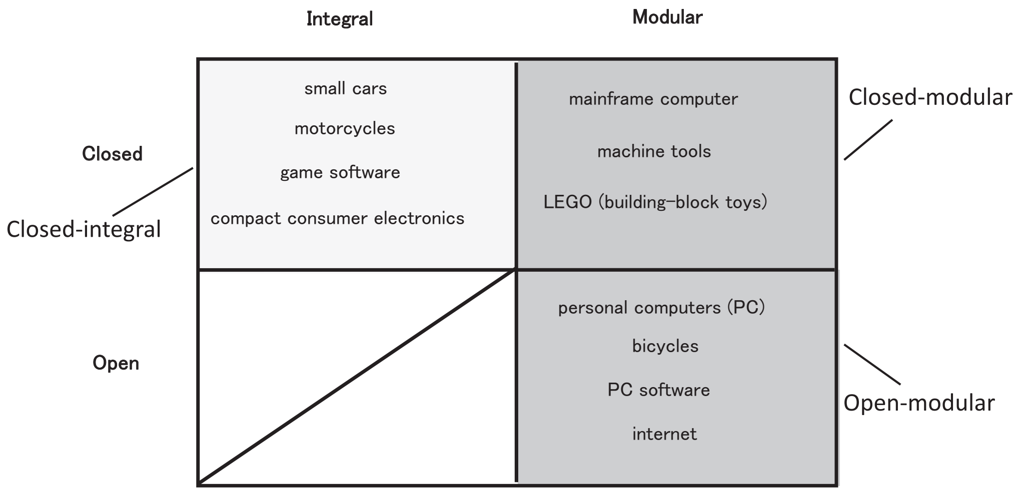


Figure 7: Three Basic Types of Product Architectures

and solve a simultaneous equation $Ax=y$, where y is a vector of functional requirements, x refers to structural design parameters and A is a matrix representing causal relations between x and y. Engineers identify functional requirements y* given by customers and try to acquire causal knowledge A by learning from existing systems, accessing the scientific knowledge base or conducting physical or virtual simulations. They then try to search for the best effort solution x* by combining existing components or creating new forms of parts.

In this axiomatic design process, a new product's architecture is summarized in the content of matrix A that represents the causal relations, where a_{ij} is a non-zero coefficient (Fujimoto, 2007).

Modular

$$\mathbf{A} = \begin{bmatrix} a_{11} & 0 & \cdots & 0 \\ 0 & a_{22} & & \\ \vdots & & \ddots & \\ 0 & & & a_{mm} \end{bmatrix}$$

Integral

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

On the other hand, *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. *Closed architecture* is the case where mix and match of independently designed components is possible only within a single firm, as the interface designs are common only within that firm. Closed architecture products may be either modular or integral.

By combining the modular-integral axis and the open-closed axis described above, we can identify three basic types of product architectures (Figure 7): (1) *open-modular* (open), (2) *closed-modular* and (3) *closed-integral* (integral).

The above-mentioned design-information view of products, processes, sites and industries naturally leads us to the architectural approach to industrial classification based on architectures rather than specific technologies, which is the traditional way. This architectural framework may provide additional insights to the questions regarding intra-industry trade and reinterpretation of comparative advantage theories, which is discussed next.

DESIGN-BASED COMPARATIVE ADVANTAGE

Having defined competitive performance of industries, capability of manufacturing sites (genba), and architectures of products and processes, we can now illustrate the basic logic of *design-based comparative advantage* by connecting these factors (Fujimoto, 2007, 2012b; see Figure 2 again): the dynamic fit between a certain type of genba's organizational capability which has emerged in a country on the one hand, and a certain type of product's architecture that has evolved over time on the other, tends to result in higher competitive performance of locations of design in terms of comparative design cost.

Note again that *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 & Winter, 1982; Clark & 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 for explaining why different types of organizational capabilities are unevenly accumulated in different countries and regions (Fujimoto, 1999, 2007).

The concept of *architecture* was also defined as a formal pattern of coordinating 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 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 rapidly grew with a massive inflow of immigrants, might have a comparative advantage in design in relatively coordination-saving products or those with modular architectures.

The framework of this paper follows the general logic of comparative advantage theories, which emphasizes the country-industry fit and relative productivity advantage across countries. In addition, it adopts the design-based concepts of comparative advantage by infusing the design view of manufacturing into existing trade theories.

Both capabilities and architectures are treated as endogenous and dynamic here. It assumes that a certain evolutionary process results in uneven distribution (i.e., endowment) of a given organizational capability across the countries and firms. History matters.

The view of design-based comparative advantage also assumes that organizational capabilities are more difficult to move across borders than money, capital, goods and services even in the era of globalization, and that they tend to become country-specific. A country's capability-building environment (e.g., resource scarcity), 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 are generated ex-ante by engineers (Fujimoto, 2012b). When the product faces 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 the micro-macro loops between design selections by engineers and markets.

In this way, the framework of design-based comparative advantage tries to explain why certain products are imported or exported within the framework of intra-industry trade of differentiated products, which is the overall trend of the 21st century.

A DYNAMIC INTERPRETATION OF RICARDIAN COMPARATIVE ADVANTAGE

The capability-architecture view of industrial performance that this paper has adopted is, in a sense, a reinterpretation of the Ricardian theory of comparative advantage by extending the concept of comparative cost from production to design—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 multi-factor multi-country version of Ricardian comparative cost analyses) may be realistic enough to explain the 21st century's trade phenomena in Japan and the world (Sraffa, 1960; Shiozawa, 2007).

However, this paper's framework has so far been rather static regarding capability-architecture fit. The next section will therefore sketch out a dynamic reinterpretation of Ricardian comparative advantage, which is applied not only to production sites but also to design sites. In other words, starting from the international productivity differences that David Ricardo assumed some 200 years ago (Ricardo, 1817), we may illustrate the evolution of economies, industries, firms and sites as an inter-related process.

First, the evolution of manufacturing site capabilities causes productivity growth and differences, which influences country A's average productivity in industry X through market selection of high-productivity sites inside the country.

Second, different industries in country A, with different patterns of capability-building processes and design architectures, show different levels of relative productivity vis-à-vis those 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 & Shiozawa, 2011). In other words, the profile of all industries' relative productivity ratios vis-à-vis competing countries determines 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 between 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 global markets' selection of "comparatively advantageous industries" that demonstrate 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* between sites and firms continues, the 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 between the same two countries due to technological standardization, lower-wage country B may newly gain comparative advantage vis-a-vis country A and thereby shift from importer to exporter status in industry X, as Akamatsu's "flying geese" theory suggested (Akamatsu, 1962). This is not always the case, though, as the international trade situation in the 2010s suggest—international wage gaps may decrease faster than physical productivity gaps between two countries (e.g., China and Japan).

Fifth, manufacturing firms worldwide, in order to secure profits and growth, 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—physical proximity to markets and comparative advantage. In this way, a firm's business structure will evolve through the selection of advantageous industries, products, architectures, technologies, site locations and so forth.

It is important to note again that the above story follows the Ricardian logic of classical economics that normal (natural) prices are determined by unit labor cost, or the combination of labor productivity (labor input coefficients) and hourly wages. Additionally, the evolutionary analysis of firms and industries presented here basically follows the assumption of classical economics (or its prominent successor P. Sraffa) that prices and volumes of a given product are determined separately (Sraffa, 1926, 1960; Shiozawa, 2007), as opposed to the neo-classical (general equilibrium) assumption of simultaneous price-volume determination.

SOME REALITIES OF CLASSICAL ECONOMICS IN THE 21ST CENTURY

The choice of classical economics as the basis for the evolutionary analysis of industry performance is empirical rather than theoretical. Empirically at least, the practices that we observe in today's manufacturing industries simply fit the classical models better.

In the Japanese auto industry, for example, a manufacturing firm may set the price/cost target of a new product prior to its production by applying the "target costing" method, which explores a realistic combination of the product's design information, price, profit margin, unit cost and life-time sales volume by rationalizing its design (i.e., value engineering). Note here that, at this developmental (pre-production) stage, the relationship between the target cost and cumulative volume follows the logic of increasing return (i.e., long-term economy of scale) because each project incurs fixed costs for product development.

Once production starts, however, the product's normal price is basically fixed, similar to the assumption of the "cost-plus" principle. Then manufacturing firms try to make accurate forecasts for the next months' sales, set the master production schedules accordingly and maximize their efforts to sell out all the products that were actually produced (Sraffa, 1926). When finished goods inventories are piling up or slow to move, price discounts may be offered, which generates a gap between the normal price and the market price, but the former is still relatively stable. Quite simply, these practices in the real world, which includes firms and factories and development projects, are closer to what classical economics has assumed for a long time.

Also, classical trade theories (Ricardian in particular) can, in many cases, better explain the reality of global industries, such as the large international differences in both productivity and wages between advanced and emerging countries. At the beginning of the 21st century, for instance, average wages in China's major exporting factories in the machinery industry were less than one-twentieth of those in Japan, while Japanese factories' productivity was in many cases three or more times higher than that of its Chinese counterparts. The standard models of neoclassical trade theories, which assume internationally identical production functions, are rather remote from the above reality on the shop floor.

As mentioned earlier in this paper, the concepts of "industry," "industrial performance" and "industrial structure" have been long neglected or deemphasized in mainstream neoclassical theories. Industrial organization analysis is virtually an applied microeconomics and inter-industrial analysis by input-output tables supplements macroeconomics, but economic analyses of industrial structures and performance have not been actively carried out in today's mainstream economics, with some exceptions in trade theory and industrial agglomeration studies.

Classical economists, by contrast, have tended to emphasize the concept of industry in the context of theories of value, industrial structure, trade, distribution, industrial agglomeration, economic development and so forth. As we move into the 21st century, in which free trade and intra-industrial trade have become more prevalent, we may need to pay more attention to a certain reality of classical economics regarding the evolutionary analysis of industries.

THE CASE OF POSTWAR JAPAN: CAPABILITY-BUILDING AND ARCHITECTURAL FIT

Applying the above-mentioned capability-architecture framework to the case of Japanese industries in a dynamic way, this paper will argue that postwar Japanese industries tended to possess a rich endowment of coordinative capabilities (e.g., teamwork of multi-skilled engineers/works) mostly for certain historical reasons, and that Japan's *coordination-rich* industries tended to enjoy design-based comparative advantage in *coordination-intensive* products. In other words, we assume that Japan's industrial innovations tended to be more active 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 package software.

Using the above-mentioned evolutionary framework of industry performance, let's analyze a

Table 1: A Postwar History of Genba (Manufacturing Sites) in Japan

Period (roughly)	Characteristics	Consequences in Genba (Manufacturing Sites)
1945-1950	The Beginning of the Cold War	Capability-Rebuilding of Genba Starts (QC, etc.)
1950-1970 (50's -60's)	High Growth without Immigrants	Emergence of Genba's Coordination Capabilities due to By "Economy of Scarcity" (e.g., Toyota System)
1970-1990 (70's -80's)	International Competition during the Cold War (among Advanced Nations)	Productivity /Quality Improvements Overcoming Yen Appreciation and Oil Crises Trade Friction
1990-2010 (90's -00's)	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- (10's-) Forecast	Global Competition with Richer Emerging Nations	Japan's Capability-Building Genba May Enjoy Higher Chances of Survival as Wage Gaps Naoorw

postwar history of Japanese manufacturing industries (i.e., trade goods). To briefly describe the *postwar history of the Japanese genba*, we have divided this period into roughly 20-year spans (1950–70, 1970–90, 1990–2010, 2010–; See Table 1).

(1) 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 timing. In the 1950s and 1960s, the "economy of scarcity" forced many Japanese factories and sites to build up 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.

(2) 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 at 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.

(3) In the 1990s to 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's, due partly to what A. Lewis might describe as "unlimited supplies of labor" from its agricultural inland provinces to industrializing coastal areas (Lewis, 1954). Thus, many of Japan's manufacturing sites in the trade goods sectors found that their advantages 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 above-mentioned changes in the global competitive environment and product technologies in the electronics industry, and the continuing post-bubble recession and yen appreciation, Japan's manufacturing sites (genba) faced a "Dark Ages" period during much of the 1990s and 2000s. This was particularly so in the digital electronics sector, in which China, Korea and Taiwan became major exporters, whereas some of Japan's major factories were closed down after increasing their labor productivity several-fold. 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. Japan maintained a trade surplus for much of this period.

The competitive situation is changing worldwide, however. Now that we enter the next 20 years (2010–), we are already observing significant changes in the form 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 started to alleviate somewhat in the past few years. Although no countries can escape the country-level changes in industrial structure driven by dynamic comparative advantage, the chances that domestic factories continuing capability-building efforts can survive will increase in the coming years. In this sense, many of Japan's high-productivity manufacturing sites are gradually getting away from their worst period—the end of the post Cold War era.

However, this may be a situation of darkness before dawn, in which many observers and decision makers tend to make major mistakes, as they overlook the above-mentioned changes and assume an overly pessimistic view that the dark night will continue forever. Some managers in Japan's large enterprises look only at short-term cost data, deemphasize their domestic factories' productivity advantages and ignore 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 of the Japanese manufacturing sector, which predict the hollowing-out of Japan's manufacturing sector as a whole—erroneous views 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 be a hollowing-out of the entire manufacturing sector as a self-fulfilling prophecy—the result of human error rather than 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 it 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.

OLD THEORIES FOR NEW REALITIES

To the extent that the early 21st century is the era of truly global competition, environmental and energy constraints, rapid changes in digital and other technologies, an increasing number of demanding customers, parallel advancement of product commoditization and differentiation, rapid changes in relative wages and productivity across borders and high levels of socioeconomic uncertainty, the concepts of comparative advantage and industrial performance and their evolution will continue to be the keys for sustaining or improving our children's living standards and quality of life. And yet, mainstream economists, while purifying their theories toward the general equilibrium paradigm, have tended to avoid incorporating the apparently messy concept of industries and manufacturing sites (genba) and their performance into their theoretical core. As a result, we are currently observing certain gaps between the economic theories of the 20th century and the industrial realities of the 21st century.

Some may argue that we need newer theories that can handle the new realities of the 21st century. In this paper, though, we have explored an alternative idea—returning to the older theories of the 19th century, namely classical economic theories, and modifying them for the realities of the current global economy. More specifically, this paper tried to start from classical (Ricardian) trade theory, reinterpreted it dynamically to consider the rapid changes in relative wages and productivity (Fujimoto & Shiozawa, 2011), and incorporated the concept of product design and architecture into it (Fujimoto, 2007, 2012b). Consequently, this paper proposed a field-based evolutionary framework of capability-architecture fits for analyzing industrial performance—the concept of design-based comparative advantage (Figure 2).

Note that this framework is by no means a substitutive one; rather, it is complementary to existing theories of trade. Indeed, the neo-classical (Heckscher-Ohlin-Samuelson) theory, the product-cycle (flying geese) theory (Akamatsu, 1962; Vernon, 1966), the new trade theory (Helpman & 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 in highly differentiated goods is common and relative wages/productivity of individual sites are changing rapidly worldwide, we would need additional insights that may borrow some ideas from other schools and disciplines, including the concept of comparative cost from classical economic theories, system emergence from evolutionary economics, organizational capabilities from strategic management, product architecture from design-artifact theories, and monozukuri (manufacturing as design flow) from technology and operations management (Fujimoto, 1999, 2007, 2012a, 2011b; Fujimoto & Shiozawa, 2011; Mintzberg & Waters, 1985; Nelson & 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 some essence of this multi-faceted entity or "genba."

REFERENCES

Akamatsu, K. (1962). A historical pattern of economic growth in developing countries. *The Developing Economies*, 1 (Supplement s1), 3–25.

Asanuma, B. (1989). Manufacturer-supplier relationships in Japan and the concept of relation specific skill. *Journal of the Japanese and International Economies*, 3, 1–30.

Baldwin, C. Y., & Clark, K. B. (2000). *Design rules: The power of modularity*. Cambridge, MA: MIT Press.

Barnard, C. I. (1938). *The functions of the executive*. Cambridge, MA: Harvard University Press.

Clark, K. B., & Fujimoto, T. (1991). *Product development performance*. Boston, MA: Harvard Business School Press.

Fine, C. H. (1998). *Clockspeed: Winning industry control in the age of temporary advantage*. Reading, MA: Perseus Books.

Fujimoto, T. (1999). *The evolution of a manufacturing system at Toyota*. Oxford, UK: Oxford University Press.

Fujimoto, T. (2007). Architecture-based comparative advantage: A design information view of manufacturing. *Evolutionary and Institutional Economics Review*, 4, 55–112.

Fujimoto, T. (2012a). Evolution of firms and industries. *Evolutionary and Institutional Economics Review*, 9(1), 1–10.

Fujimoto, T. (2012b). An economic analysis of architecture and coordination: Applying Ricardian comparative advantage to design costs and locations. *Evolutionary and Institutional Economics Review*, 9(1), 51–124.

Fujimoto, T., & Shiozawa, Y. (2011). Inter and intra company competition in the age of global competition: A micro and macro interpretation of Ricardian trade theory. *Evolutionary and Institutional Economics Review*, 8(1-2), 193–231.

Grant, R. M. (2005). *Contemporary strategy analysis* (5th ed.). Oxford, UK: Blackwell.

Helpman, E., & Krugman, P. (1985). *Market structure and foreign trade: Increasing returns, imperfect competition and the international economy*. Cambridge, MA: MIT Press.

Lewis, W. A. (1954). Economic development with unlimited supplies of labour. *Manchester School*, 22, 139–191.

Marshall, A. (1890). *Principles of economics*. London, UK: Macmillan.

Marshall, A. (1919). *Industry and trade*. London, UK: Macmillan.

Marx, K. (1867). *Das Kapital I*.

Melitz, M. J. (2003). The impact of trade on intra-industry reallocations and aggregate industry productivity. *Econometrica*, 7, 695–725.

Mintzberg, H., & Waters, J. A. (1985). Of strategies, deliberate and emergent. *Strategic Management Journal*, 6(3), 257–272.

Monden, Y. (1983). *Toyota production system: Practical approach to production management*. Norcross, GA: Industrial Engineering and Management Press.

Nelson, R. R., & Winter, S. G. (1982). *An evolutionary theory of economic change*. Cambridge, MA:

Harvard University Press.
Ohno, T. (1978). *Toyota seisan hoshiki* [The Toyota production system]. Tokyo, Japan: Daiyamondo-sha.
Penrose, E. T. (1959). *The theory of the growth of the firm*. Oxford, UK: Basil Blackwell.
Ricardo, D. (1817). *On the principles of political economy and taxation*. London: John Murray.
Schumpeter, J. A. (1912/1934). *The theory of economic development*. Cambridge, MA: Harvard University Press.
Shiozawa, Y. (2007). A new construction of Ricardian trade theory: A many-country, many-commodity case with intermediate goods and choice of production techniques. *Evolutionary and Institutional Economics Review*, 3(2), 141–187.
Shoenberger, R. (1982). *Japanese manufacturing techniques: Nine hidden lessons in simplicity*. New York, NY: Free Press.
Simon, H. A. (1969). *The science of the artificial*. Cambridge, MA: MIT Press.
Smith, A. (1776). *An inquiry into the nature and causes of the wealth of nations*.
Sraffa, P. (1926). The laws of returns under competitive conditions. *Economic Journal*, 36(144), 535–550.
Sraffa, P. (1960). *Production of commodities by means of commodities: Prelude to a critique of economic theory*. Cambridge, UK: Cambridge University Press.
Suh, N. P. (1990). *The principles of design*. New York, NY: Oxford University Press.
Thomke, S., & Fujimoto, T. (2000). The effect of "front-loading" problem-solving on product development performance. *Journal of Product Innovation Management*, 17, 128–142.
Ulrich, K. T. (1995). The role of product architecture in the manufacturing firm. *Research Policy*, 24(3), 419–440.
Vernon, R. (1966). International investment and international trade in the product cycle. *The Quarterly Journal of Economics*, 80(2), 190–207.
Womack, J., Jones, D. T., & Roos, D. (1990). *The machine that changed the world*. New York, NY: Rawson Associates.

Dr. Takahiro Fujimoto is Professor at the Faculty of Economics, University of Tokyo, Japan