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Capability Matrix: A Framework for Analyzing Capabilities in Value Chains

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Abstract

This paper develops a Capability Matrix for analyzing capabilities of developing country firms that participate in global and national value chains. This is a generic framework to capture firm-level knowledge accumulation in the context of global and local industrial constellations, by integrating key elements of the global value chain (GVC) and technological capabilities (TC) approaches. The framework can visually portray characteristics of firms' capabilities, and highlight a relatively overlooked factor in the GVC approach: local firms' endogenous learning efforts in varieties of relationship with lead firms.

Keywords: Capability Matrix, capabilities, value chains, lead firms, local firms
JEL classification: B41, L22, L60, O31

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1. Introduction

As globalization of economic activities has come to embrace the developing parts of the world, local firms in developing countries have confronted a rapidly changing environment. On the one hand, expansion of international trade and investment, driven particularly by powerful global firms, has opened up new opportunities for developing country firms to access markets, technology, and managerial know-how. On the other hand, developing country firms are facing challenges of ever more intense competition, both at home and abroad. One of the most pressing challenges for them, therefore, is to learn, acquire new capabilities, and innovate, so as to lay the foundation for improving long-term competitive performance. An increasing amount of research has been conducted in recent years to analyze the development of developing country firms within the new international context (Schmitz ed. [2004]).

Despite the growing interest of academics on this issue, one of the major obstacles confronted by researchers trying to undertake research in this area is the paucity of analytical tools that are designed to capture the dynamism of learning in firms in developing countries. Since learning and capability formation in developing country firms are difficult to capture using readily available statistics like R&D spending or the number of patents, researchers are normally required to undertake in-depth field research on developing country firms. The products that developing country firms produce or the markets they serve, however, are extremely diverse. Their learning and capability formation also take a myriad of forms, from minor improvements made to routine day-to-day operations to major projects for new product development. A big challenge for the fieldworkers, therefore, lies in coming up with an analytical tool that enables them to objectively capture and evaluate learning and innovations taking place in developing country firms. As will be argued in the subsequent sections of this paper, the existing global value chain (GVC) and

technological capabilities (TC) literature has shortcomings when it comes to providing an appropriate analytical tool to achieve this end.

This paper seeks to develop a framework for analyzing the firm-level capabilities of developing country firms that are engaged in varieties of international and domestic linkages. We aim to integrate the key elements of the two bodies of literature, i.e., GVC and TC approaches, together with another stream of literature on Japan's historical experience of industrial and technological development, for the purpose of developing a new analytical framework. This framework captures the local firms' accumulation of endogenous resources in the context of global and local industrial constellations that affect local firms' growth prospects in important ways. At the same time, the framework is designed for practical use by fieldworkers studying developing country firms.

The remainder of the paper is structured as follows. Section 2 reviews the three different streams of literature that are relevant for our framework. Section 3 presents the framework. Section 4 summarizes the main features of the framework and discusses its contributions.

2. Literature Survey

This section reviews the three streams of literature: the GVC literature, the TC literature, and the literature on Japan's historical experience of industrial and technological development.

2.1 The Global Value Chain Literature

The global value chain (GVC) literature, which uses the notion of *chains* to refer to the sequence of value adding activities to bring products and services to market, has provided useful insights into the changing patterns in which international production and trade are organized and coordinated.

In the GVC literature particular attention has been directed to how powerful

lead firms from developed countries *govern* the chains, which is usually expressed with the concept of *governance* of value chains. Governance implies that powerful lead firms set parameters for transactions: (1) what is to be produced, (2) how it is to be produced, (3) when it is to be produced, (4) how much is to be produced (Humphrey and Schmitz [2001]). Indeed, one of the key insights of the GVC literature is that vertical disintegration of transnational corporations, together with the growth of industrial capabilities in developing countries, have been accompanied with varieties of governance forms that fall between arm's-length markets and vertically integrated corporations (Gereffi, Humphrey and Sturgeon [2005: 79]). Furthermore, these governance forms matter "for understanding market access, the acquisition of capabilities, and the distribution of gains" (Schmitz [2006: 546]).

The conceptualization of value chain governance was advanced a step further by Gereffi, Humphrey, and Sturgeon [2005], who developed a simple and general framework to explain how governance types are determined. They isolate three fundamental determinants of governance types: (1) complexity of information exchanged in transactions, (2) codifiability of information exchanged, and (3) suppliers' capability base relative to the requirements of transactions. They argue that different combinations of the three variables result in five distinct types of governance. These are (1) market, (2) modular, (3) relational, (4) captive, and (5) hierarchy, in the ascending order of levels of inter-firm explicit coordination and power asymmetry between lead firms and suppliers.

An important by-product of the centrality of governance in the GVC literature is the tendency to regard developing country firms as subordinate agents that are compelled to operate and learn basically within the constraints of the parameters set by the lead firms. Despite the varieties of the governance types presented, the emphasis of the GVC literature has been on understanding the relationship between powerful global lead firms that seek to govern the chain and local suppliers (Schmitz [2006:547]).

More recently, a number of new research studies have directed attention to active and strategic actions of local suppliers and the dynamic evolution of the value chains initiated by local suppliers. Sturgeon and Lee [2005] analyzed how the

development of the North American and Taiwanese electronics industry has been driven by the virtuous cycle between lead firm strategic outsourcing and the development of supplier competencies. In this industry, increased supplier competencies and the formation of shared supply networks led to the lead firms' adjustments in their strategic outsourcing practices. Bazan and Navas-Aleman [2004] pointed out that Brazilian footwear suppliers, as they faced constraints to functional upgrading in the quasi-hierarchical chains controlled by the US buyers, took their own initiatives to work simultaneously in national chains where the relationship with the lead firm was more symmetrical and thus offered better chances of achieving functional upgrading.

The concept of *upgrading* has been used in GVC literature to analyze supplier competencies (see, for instance, Schmitz ed. [2004]). While the concept is rarely used with a clear definition, upgrading usually refers to the process in which firms engaged in GVCs increase the overall value added of their activities. Unlike the concept of technological capabilities, which is used for *firm-level* analysis of capability accumulation (see Section 2.2), the concept of upgrading is designed for *chain-level* analysis and places an emphasis on the advancement of the local firm's position *vis-à-vis the lead firm in the value chain concerned*. This is evident from Gereffi et al. [2001: 5]: "The concept of upgrading refers to several kinds of shifts that firms or groups of firms might undertake to improve their competitive position in global value chains." While the GVC literature often assumes upgrading to take place as a result of acquisition of new knowledge or resources by the suppliers, upgrading, literally defined, can also be achieved without accumulation of new knowledge or resource. For instance, an increase in value added may take place as a result of squeezing the labor cost (Morrison, Pietrobelli and Rabellotti [2008]) or decline in the prices of input materials.

Upgrading is typically classified into four types: (1) process upgrading (transforming inputs into outputs more efficiently by re-organizing the production system or introducing superior technology), (2) product upgrading (moving into more sophisticated product lines), (3) functional upgrading (acquiring new functions in the chain or abandoning existing functions to increase the overall skill content of activities), and (4) inter-sectoral upgrading (using the knowledge acquired in a particular chain to

move into different sectors) (Schmitz [2004: 7-8]).

Though not always made explicit, an important assumption that underlies the concept of upgrading is that the key for long-term sustainable growth of developing country firms is functional upgrading. On the one hand, production is seen as activities with low value added and low entry barriers, and therefore relatively easy even for developing country firms to enter. On the other hand, product planning, design and development, branding, and marketing are regarded as the high-value-adding core activities of global lead firms. This is why GVC studies often uses the phrase "climbing up the GVC ladder" to refer to the suppliers' shifting from production into other function(s) with higher value added (Kishimoto [2004: 246]).

Overall, the GVC literature has proved to be a useful analytical apparatus to classify and grasp the nature of industrial constellations and global, regional, and domestic linkages that developing country firms are engaged in. However, the approach falls short of providing a conceptual framework to analyze the process, mechanism and attainment of learning and capability formation in developing country firms. In particular, the literature offers very little with regard to the tools to analyze the developing country firms' strategic intents, which critically shape the firms' performance in learning and capability formation[1].

2.2 The Technological Capability Literature

The second key literature is the technological capability (TC) approach. This literature focuses on the very process of firm-level learning and technological development (Fransman and King ed. [1984]; Lall [1992]; Bell and Pavitt [1995]). Based on the assumption that acquisition of new machinery and equipment does not automatically result in high rates of productivity growth, the literature emphasizes the acquisition of capabilities to generate and manage technological change as a prerequisite for sustained dynamic efficiency (Bell and Pavitt [1995]). *Technological capabilities* are defined as the specialized resources, i.e., skills, knowledge and experience, as well as the

[1] A similar point is made by Morrison, Pietrobelli and Rabellotti [2008].

institutional structures and linkages which are needed to generate and manage technological change (Bell and Pavitt [1995: 78]).

For developing country firms that are not at the frontiers of technology, the process of building technological capabilities usually starts with importing and using technology developed elsewhere. This process is not as easy or simple as it might sound, as technological knowledge is not easily imitated by or transferred across firms. In other words, "(…) to gain mastery of a new technology requires skills, effort and investment by the receiving firm, and the extent of mastery achieved is uncertain and necessarily varies according to these inputs" (Lall [1992: 166]). The experience of developed and emerging countries shows that, having mastered the relatively simple imported technology, firms gradually start adapting and making minor improvements to the technology to meet the local needs, and eventually start to develop new technology of their own (Kim [1997, 2004]).

Following the early efforts to conceptualize the nature of technological capabilities and the mechanism of capability formation (e.g., Fransman and King ed. [1984]; Dahlman et al. [1987]; Lall [1987]), there have been attempts at generating more practical analytical tools and conducting empirical research on the capability formation of developing country firms. Particularly critical was Lall [1992], who classified technological capabilities by the functions they perform and by the levels of difficulty or complexity of technology. Lall [1992] categorized the functions of technological capabilities into investment (which was further broken down into pre-investment and project execution), production (further broken down into process engineering, product engineering, and industrial engineering), and linkages[2]; and classified the degree of complexity into simple-routine (experience-based), adaptive-duplicative (search-based), and innovative-risky (research-based).

The approach of presenting technological capabilities as two-dimensional matrices of functions and levels, pioneered by Lall [1992], has recently come to be

[2] While Lall [1992:167] only included two broad functional categories of capability in his matrix, namely investment and production, linkage capabilities are distinguished from production capabilities and are explicitly discussed as the third functional category of capabilities (Lall [1992:168]). We thus count Lall's category of functions as three.

increasingly popular. For the purpose of empirical analysis, functions and levels have been defined in greater detail specifically tailored to specific industries being studied. In particular, Figueiredo [2003, 2008] and Ariffin and Figueiredo [2004], in their study of innovative capabilities of firms in developing countries, classified the levels of innovative capabilities in fine detail.

While the TC literature provides useful insights into the nature and classification of firm-level technological capabilities and the mechanism of capability formation, the literature also has a serious shortcoming in that it leaves the local firms' relationships with customers or buyers out of the discussion. The literature offers very little regarding how customers or buyers assist or constrain the growth of developing country suppliers, one of the key insights of the GVC approaches discussed above.

2.3 Japan's Historical Experience of Industrial and Technological Development

Of the three streams of the relevant literature reviewed in this section, this third one is probably the least known in Western academia, primarily because the bulk of the literature is available only in Japanese. Nevertheless, the literature on Japan's historical experience of industrial and technological development provides critical insights on the development prospects of developing country firms.

One of the major contributions of this literature is in pointing out the critical importance of *production management* for the growth of manufacturing firms (Fujimoto [2001], [2007]). This is in contrast to the conventional tradition to regard technological development as the introduction of sophisticated machinery and equipment. While the scientific management of production processes originated in the US upon the advent of modern mass production, American companies did not explicitly distinguish between *hard* and *soft* elements of production. For American companies, scientific production management went hand in hand with the introduction of advanced machinery and equipment. It was the Japanese firms in the post-World War II period, when capital for investment in state-of-the-art machinery and equipment was in short supply, which focused on effective production management to achieve high productivity without

heavy investments in capital equipment. Based on a rich description and conceptualization of the activities and practices undertaken by Japanese firms at home and abroad, Itagaki ed. [1997], Schonberger [1982], and Abo ed. [1994] documented how the competitive performance of Japanese firms was achieved through effective production management on the shop floor and implemented via such techniques as lean production, *just in time* systems or *kanban*, and quality control (QC) circles.

In the present context, this literature is critical because it provides a clear definition and systematic classification of production technology. Suehiro [2008: 232] proposes a simple yet clearly defined typology of production technology as follows:

- Product technology: Technology born of research and development (R&D) to improve product structure, strength, and performance in terms of capacity, energy consumption, effectiveness, etc.;
- Production technology: 1) Processing and assembling technology to manufacture a product in conformity with specifications and instructions (in electronics and automobile industries), or 2) operating technology (in plant-type industries such as steel and chemicals); and
- Production management know-how: Technology to design and manage systems of production equipment, materials, parts, human resources (production workers, supervisors and engineers), and process manufacturing information.

To be more precise, production management is defined as "the skills required to improve product quality and production efficiency by developing the range of operators' skills or by improving plant layout and inventory handling" (Suehiro [2008: 232]). If the *hard* element of production technology directly deals with the operation of machinery and equipment, production management know-how can be labeled as the *soft* element of production technology that aims at effective management of the combination of the various elements of production: equipment, materials and components, human resources, and information.

In the context of developing countries, where local firms most often face a severe shortage of capital for investment in cutting-edge machinery and technology, it makes sense to distinguish between the hard and soft elements of production. Improving

production management is an important channel for boosting productive performance without large investments. While the Japanese production management techniques have already been adopted in many manufacturing firms in developing countries where Japanese foreign direct investment has played vital roles, they could be applied more generally to a wide range of developing countries.

2.4 Our Approach

As we just discussed, the GVC and TC approaches have their own contributions and drawbacks as analytical tools to capture the growth of developing country firms. Our approach is to bring together the critical elements of the two streams of literature and combine them with the literature on Japan's historical experience in industrial and technological development for the purpose of developing an analytical framework for fieldworkers undertaking research on the capability formation of developing country firms. Many of our arguments indeed coincide with Morrison, Pietrobelli and Rabellotti [2008], who also argued for integration of the GVC and TC approaches. However, we try to take the debate a step further by actually *showing* how the two approaches can be integrated in practice, presenting a new analytical framework.

3. Capability Matrix

This section sets out the Capability Matrix as a framework for analyzing capabilities of developing country local firms operating in the value chains. After presenting the basic structure and features of the Capability Matrix, the section discusses its theoretical contributions and applications.

3.1 Capabilities Consisting of Width and Depth

The Capability Matrix assesses capabilities at the firm level in two dimensions, the width of functions and the depth of capabilities. This is a simple, practical and

industry-neutral conceptual tool. It is based on three streams of literature, i.e. the GVC literature, the TC literature, and Japanese empirical studies on technological development.

Primarily drawing upon the TC literature, we define *capabilities* as resources needed to generate and manage technological change, including skills, knowledge, experiences, organizational systems, institutional structure and linkages. Capabilities are of firm-specific nature, and are a form of institutional knowledge accumulated within the firm over time (Bell and Pavitt [1995], Lall et al. [1994], Figueiredo [2003]).

The Capability Matrix has the following structure. The columns represent the *functional width* of capabilities. Functions in a firm's activities are aligned along the value chain from pre-production, production, to post-production. As a result, we can see how wide or narrow a range the firm's activities encompass along the chain of functions. The rows represent the *depth* of capabilities. Basic levels of capabilities are represented as shallow, and advanced levels as deep. This way of showing the levels of capabilities vertically follows the TC framework. Thus the structure of the Capability Matrix embraces the value chain perspective in the columns and the TC approach in the rows.

One of the unique features of the Capability Matrix is that it assesses the depth of capabilities for every function along the value chain and maps capabilities in a two dimensional surface of width and depth. The Capability Matrix can graphically portray the characteristics of the capabilities of an individual firm by showing the patterns of cells where the firm in question fulfills the function and meets the criteria of the levels of capabilities, and where it does not. By so doing, it highlights a variety of *shapes* of capabilities.

3.2 Functional Width of Capabilities

The first dimension of the Capability Matrix is the functional width of firm capabilities. In line with the concept of value chains, the columns constitute a chain of functions of firm activities, which encompass pre-production (market research, concept creation, product development and design), production, and post-production (branding and

marketing). By incorporating the value chain perspective, the Capability Matrix aims to capture the capability formation of local firms in their relationship with lead firms. The chain of functions in the columns reflects global industrial constellations where lead firms determine the functional width in which local firms operate.

There are various ways to categorize the functions of firms' capabilities. Table 1 shows the categories of functions adopted by the Capability Matrix in comparison with those in the TC and the GVC literature.

A generic framework of Lall [1992], which provided a basis for succeeding industry-specific frameworks in the TC literature, sets out three functions of firm-level technological capabilities: investment, production and linkages. Linkage capabilities refer to capabilities "to transmit information, skills and technology to, and receive them from, component or raw material suppliers, subcontractors, consultants, service firms, and technology institutions" (Lall [1992: 168]). Lall's conception of linkages thus includes linkages that a firm develops with any type of stakeholders. Lall chose the above three categories as "a basic core of functions … that have to be internalized by the firm to ensure successful commercial operation" (ibid.), but without a conscious design along with a flow of firm activities from upstream to downstream. Unlike the TC framework, the Capability Matrix explicitly adopts the notion of value chains in classifying functions.

Definitions of each function of the Capability Matrix are as follows. The pre-production function, called *planning*, is defined as the function to conduct market research, develop product concept, and develop and design a new product according to the needs of the market. The *production* function will be examined in the next paragraph. The post-production function, called *marketing*, is the function to market products so as to strengthen the relationship with customers, to develop the firm's own brand, and to explore markets. As shown in Table 1, planning and marketing functions in the Capability Matrix are mostly in line with their corresponding functions in the GVC literature, though the sub-functions are neither exhaustive nor restrictive.

As for the function of production, the Capability Matrix makes a key twofold distinction by dividing it into hard and soft aspects, which are referred to as

Table 1 Comparing Categories of Capability Functions

Literature	Industry	Function									
(1) TC literature											
Lall [1992]	General	Investment			Production				Linkages **		
		Pre-investment	Project execution		Process engineering	Product engineering	Indusrial engineering		Linkages within economy		
Figueiredo [2002]	Steel	Investment			Production				---		
		Decision-making and control	Project preparation and implementation		Equipment	Process and production organization	Product-centered				
Ariffin [2000]	Electronics		Project management		Equipment	Process and production organization	Product-centered		---		
Figueiredo [2008]	Electronics/ motorcycles		---		Equipment-related activities	Process and production organization	Product-centered		---		
(2) GVC literature											
General *	General		Product development	Design	Production				Branding	Marketing	
Kishimoto [2004]	Personal computers	Creating concepts and product planning	Product design and development		Managing supplier relations	Production control, QC, cost management	Assembly, production	Logistics (inventory control, delivery, repair service)	Own-brand marketing		
(3) Capability Matrix											
in this paper	General	Pre-Production <Planning>			Production				Post-Production <Marketing>		
		(market research, product development and design, etc.)			Equipment-related ／ Production management				(branding, marketing etc.)		

Source: By the authors.

Note: * Based on Gereffi and Korzeniewicz ed.[1994], Schmitz ed.[2004], and Kimura [2007].

** See footnote 2.

equipment-related and *production management* capabilities respectively. The equipment-related capabilities are defined as those to operate machinery and equipment to process inputs, and to maintain, design and manufacture machinery and equipment. The production management capabilities are those to arrange production activities efficiently and effectively so as to achieve targeted performance. The idea of distinguishing between hard and soft aspects of production activities stems from the Japanese literature reviewed in 2.3. In the context of developing countries where local firms most often face shortages of capital for investment in modern technology, it makes sense to distinguish soft elements that need smaller amounts of physical investment from hard elements needing much larger investment.

The distinction between the hard and soft aspects of production capabilities is a unique feature in the Capability Matrix. In the TC literature, though it might seem as if Lall's successors (Figueiredo [2002] [2008], Ariffin [2000]) distinguish between hard and soft aspects by classifying production activities into equipment (equipment-related activities) and process and production organization (Table 1), close examination reveals that soft and hard elements are intertwined in their analyses under the categories of equipment and process and production organization.[3] Meanwhile, the GVC literature does not adopt the notion of a hard-soft distinction in production activities. As will be discussed below, process and product upgrading in the GVC literature can be realized through efforts in either the hard or soft aspects of production activities.

3.3 Depth of Capabilities

The second dimension of the Capability Matrix is the depth of capabilities of local firms. Following Figueiredo [2008], we first introduce the distinction between the routine level and innovative level of capabilities. The former is the capability level to use the given or existing technologies, and the latter is that level to improve on the

[3] Moreover, categories of product engineering and product-centered capabilities in the TC literature contain product development activities. The Capability Matrix classifies product development as a part of the pre-production activities.

existing technology and generate technological changes (Table 2).

The routine level of capabilities is further divided into two: the level at which the firm is able to acquire and operate the existing technology and the level at which it can sustain operation and maintenance of the existing technology. This distinction follows most of the preceding studies in Table 2, and is also consistent with Suehiro [2000], who pointed out that the step-up from the basic operation level to the continuous maintenance level is the first major hurdle for the development of local firms in the developing countries[4].

The innovative level of capabilities is also divided into two: the level at which the firm is able to generate minor improvements to the existing technology and the level at which the firm is able to generate major innovation. This distinction follows Kritayakirana et al. [1989] and Thee [1997], who were influenced by the headstream of the TC literature (e.g. Fransman and King [1984]) and adopted simple categories to assess firm-level capabilities in Thailand and Indonesia. Interestingly, their categorization almost parallels categories adopted by studies on industry-level technological development: the framework of Hayashi ed. [1986] inductively generated from Japan's one century experiences of technological development and a dynamic cyclical model on the technology trajectory of Kim [2004] developed on the basis of the process and product innovation model of Utterback and Abernathy [1975].

The Capability Matrix thus adopts four categories of levels of capabilities that are simple and generic: (1) operational, (2) assimilative, (3) adaptive, and (4) innovative. Each level is defined as follows. The *operational* level is the level at which the firm is able to operate the existing technology. The *assimilative* level is the level at which the firm has mastered the existing technology and is able to maintain stable and continuous operation over time. The *adaptive* level is the level at which the firm is able to make minor yet original improvements to the existing technology. The *innovative* level is the level at which the firm is able to create something new with significant elements of originality and novelty compared to the existing technology.

Unlike the TC literature, which sets levels of capabilities by the degree of

[4] The second major hurdle is from design to home-manufacturing level.

Table 2 Comparing Categories of Capability Levels

Literature	TC Literature			Other references				Capability Matrix
	Lall [1992]	Ariffin and Figueiredo [2004]	Figueiredo [2008]	Kritayakirana et al. [1989]	Thee [1997]	Hayashi ed. [1986]	Kim [2004]	in this paper
Country	General	Malaysia/ Brazil	Brazil	Thailand	Indonesia	Japan	Korea	General
Industry	General	Electronics	Electronics/motorcycles	General	Motorcycles	General	General	General
Object of observation	Firms	Firms	Firms	Firms	Firms	Industries	Industries	Firms
Level of capabilities	Basic simple routine (experience-based)	Basic operation Level 1	Routine TC: Basic operation Level 1	Aquisitive	Operational	Operations	Acquisition	Operational
		Basic operation Level 2	Basic operation Level 2	Operative	Acquisitive	Maintenance	Assimilation	Assimilative
	Intermediate adaptive duplicative (search-based)	Basic innovative Level 3	Innovative TC: Basic innovation Level 3	Adaptive	Adaptive	Repairs and minor modifications	Improvement	Adaptive
		Intermediate innovative Level 4	Intermediate innovation Level 4		Design	Designing and planning		
			High-intermediate innovation Level 5					
	Advanced innovative risky (research-based)	Advanced innovative Level 5	Advanced innovation Level 6	Innovative	Innovative	Home manufacturing	Generation	Innovative
		Research-based innovative Level 6						

Source: By the authors.

complexity or difficulty of technology, the Capability Matrix designs levels on the basis of capability development from the learning of the existing technology to generation of original elements. We do not adopt the degree of complexity or difficulty of technology as the criteria of capability levels, because there is no universal tool that can assess the levels of complexity or difficulty in the absolute sense for all industries and products with varied attributes. For instance, for sophisticated products in cutting edge industries using advanced technology, even routine operation of the existing technology (i.e., the operational level) might be highly complex and difficult. Instead, the Capability Matrix emphasizes capabilities to generate elements of originality, because we consider making original improvements, rather than just producing as required, to be a key step for developing country firms on the development path toward innovation. The Capability Matrix gives more credit to a firm that makes minor yet original improvements to low-end products with mature technology than to a firm that has mastered sophisticated given technology.

Contrary to the conventional TC literature which regards the capability levels as a continuous sequence[5], the Capability Matrix acknowledges the possibilities that firms might bypass certain levels of capabilities or downgrade from a higher level to a lower level of capabilities, because such phenomena are observed in the field. Hayashi ed. [1986], based on the findings that individual skilled workers in China were capable of making modifications to product designs while the firms had not established maintenance standards, noted the possibility that Chinese firms had bypassed the level of maintenance that is equivalent of the assimilative level in the Capability Matrix. Fujita [2010] and Sato [2010], which use the Capability Matrix in analyzing local firm capabilities in the Vietnamese and Indonesian motorcycle industry, observe similar bypassing of the assimilative level in planning, equipment-related and marketing capabilities.

[5] For instance, Figueiredo [2008] assumes continuous capability accumulation and measures the speed of deepening through different levels of capabilities. One of the exceptions is Figueiredo [2002], which reported that a steel firm jumped to the advanced level of capabilities after insufficient mastery in the basic level and took a long time to return to and master the level of capabilities it had skipped.

3.4 Enriching the GVC and TC approaches

How can the Capability Matrix enrich the GVC and the TC approaches? The Capability Matrix, on the one hand, enriches the TC framework by incorporating the perspective of value chains in the analysis of local firm capability formation. In other words, the Capability Matrix underscores the importance of local firms' relationships with lead firms in determining local firms' capability formation. On the other hand, it also enriches the GVC approach by directing the focus to the capabilities of local firms or their endogenous learning efforts, which lie behind the phenomena of upgrading.

The difference between the concepts of capabilities and upgrading would need clarification. As reviewed in 2.1, the GVC literature uses the concept of upgrading in discussing the growth of local firms operating in the value chains. Upgrading is a chain-level concept and is loosely defined as the advancement of a local firm in its position vis-à-vis the lead firm in the value chain toward higher value-adding activities. In contrast, capability is a firm-level concept and refers to endogenous resources and knowledge accumulated in a local firm itself. The Capability Matrix is thus concerned with the whole activities of a specific firm which often participates in more than one value chain.

As the above definitions demonstrate, upgrading and capability formation are closely related. Upgrading may occur as a consequence of capability formation, and in this case the phenomenon can be observed by using the Capability Matrix. However, the two concepts are not entirely the same. On the one hand, upgrading does not necessarily occur as a consequence of the firm's capability acquisition. For example, process upgrading for higher efficiency could result from the firm's squeezing the cost of inputs such as raw materials and wages. Product upgrading via moving into products with increased unit values could be realized simply by using higher-end components and materials sourced from external suppliers. Inter-sectoral upgrading might be enabled by the existing capabilities that the firm had acquired from participation in the former value chain. Upgrading without additional capability acquisition does not change the map of capabilities in the Capability Matrix.

On the other hand, capability acquisition does not necessarily result in upgrading either. Let us assume that a local firm which previously outsourced maintenance of its machineries to an external service provider eventually learned to look after the maintenance on its own. This means that the firm's equipment-related capabilities improved from the operational level to the assimilative level. This phenomenon, however, cannot be recognized as upgrading because there is no change in the local firm's relationship with the lead firm in the value chain concerned. As an another example, let us consider the case in which a firm that had previously been engaged only in production activities acquired the capabilities to conduct product design or marketing and subsequently deepened its levels of design or marketing capabilities. If we follow the concept of upgrading, moving into pre- and post-production activities is a form of functional upgrading, but capability deepening in pre-production and post-production functions is not recognized by any of the four types of upgrading.

Thus the focus on capabilities in the Capability Matrix could provide a new perspective on the discussion of upgrading in the GVC literature. The Capability Matrix requires that upgrading that occurs as a result of capability acquisition and upgrading that does not occur as a result of capability acquisition should be clearly distinguished and that capability acquisition even without any change in the local firm's relationship with the lead firm should be identified.

3.5 Using the Capability Matrix

Table 3 is a prototype of the Capability Matrix. It sets out definitions of functions in the columns and levels of capabilities in the rows as presented in Sections 3.2 and 3.3. This is designed as a framework that can be used generally for firms in the manufacturing sector.

Table 3 A Prototype of the Capability Matrix

Depth (Level) \ Functional Width	Planning	Production		Marketing
		Equipment- Related	Production Management	
	Conduct market research, develop product concept, and develop and design a new product according to the needs of the market	Operate machinery and equipment to process inputs; maintain, design, and manufacture machinery and equipment	Arrange production activities efficiently and effectively so as to achieve targeted performance	Market products so as to strengthen the relationship with customers; develop own brand; explore markets
Operational: Operate the existing technology				
Assimilative: Master the existing technology and maintain the operation over time				
Adaptive: Make minor yet original improvements to the existing technology				
Innovative: Create something new with significant elements of originality and novelty compared to the existing technology				

(Source) By the authors.

Table 4 shows an example of the Capability Matrix to be applied to modern assembly industries[6] with criteria for each cell. The criteria contain some key indicators specific to modern assembly industries, such as recreation of design drawings in the planning function, and management of dies, molds, jigs and tools in the equipment-related function. Such key indicators might have to be modified when the Capability Matrix is applied to different types of industries.

In determining the criteria for the capability levels in Table 4, we introduced the distinction between local and global standards. The operational level is set at the level where local firms can fulfill the requirements of local standards posed by local customers, while the assimilative level is set at the level where local firms can fulfill the

[6] It covers any industries with many parts, such as machinery, metal-working, plastics, wood-working and so on. See Fujita [2010] and Sato [2010] for application to the motorcycle industry. They analyze the capabilities of local firms that supply motorcycle components to lead firms.

Table 4 Capability Matrix Applied to the Modern Assembly Industry

Functional Width / Depth (Level)	Planning	Production		Marketing
		Equipment-Related	Production Management	
Operational	Replication of an existing/given product in the domestic market by recreating the design drawings.	Basic operation of machinery and equipment, dies, molds, jigs, and tools to process components to the minimum level required in the domestic market.	Routine production management required in the domestic market.	Routine marketing methods/activities.
Assimilative	Replication of existing international-standard products by recreating the design drawings.	Processing components and manufacturing dies, molds, jigs and tools to the level required by foreign customers; maintenance and repair of machinery and equipment, dies, molds, jigs, and tools.	Maintaining stable production management fulfilling the levels required by foreign customers.	Adopting and stably managing improved marketing methods/ activities.
Adaptive	Making minor yet original improvements to the existing products.	Making minor yet original improvements to the existing machinery and equipment.	Making minor yet original improvements in production management so as to constantly boost its levels.	Making minor yet original improvements to marketing methods; developing brands recognized in the domestic market.
Innovative	Planning and designing of new products with significant elements of originality and novelty compared to the existing products.	Designing and developing new machinery and equipment with significant elements of originality and novelty.	Establishing a production management system so as to achieve the region's topmost level in production management.	New marketing methods with significant elements of originality and novelty to explore new markets abroad; establishing internationally recognized brands.

(Source) By the authors.

requirements of global standards posed by foreign lead firms. While we consider this distinction to be broadly applicable to a wide range of industries, it should be noted that the level of mastering the existing technology does not always correspond to global standards, and the correspondence depends on the configuration of the industry under study.

For practical use of the Capability Matrix in a field study, we would first observe the width of functions in which a firm operates, and assess the level of capabilities it has acquired. The cells would be colored if the firm met the criteria defined for each cell. The shape of the colored area that appears as a result of assessment visually displays a map of the capabilities of each individual firm. Figure 1 illustrates a few patterns. Pattern A is an example of wide and shallow capability formation. Pattern B shows narrow but deep capability formation. The result itself does not contain any judgment as to which pattern is more desirable. Rather, our focus is on the difference in the shapes of colored area, which expresses the difference in

Figure 1　Illustrative Usage of the Capability Matrix

Pattern A

Depth (Level) \ Functional Width	Planning	Production		Marketing
		Equipment	Production Management	
Operational		■	■	■
Assimilative				
Adaptive				
Innovative				

Pattern B

Depth (Level) \ Functional Width	Planning	Production		Marketing
		Equipment	Production Management	
Operational			■	
Assimilative			■	
Adaptive			■	
Innovative				

Pattern C

Depth (Level) \ Functional Width	Planning	Production		Marketing
		Equipment	Production Management	
Operational	■	■	■	■
Assimilative		■	■	
Adaptive	■		■	
Innovative				

(Source) By the authors.

characteristics of capabilities. This is what the Capability Matrix intends to highlight.

The Capability Matrix can be used in several ways. It can be used for assessing capabilities of one firm as well as comparing capabilities of more than one firm. In analyzing the capabilities of more than one firm, we can aggregate the results by calculating the percentage ratio of firms that have colored cells for each cell or compare the maximum levels reached among the firms. We can also use the Matrix in time-series analyses in order to illuminate the path of capability development over time, e.g. from pattern A to C, or from pattern B to C. In the context of value chain analysis, we can focus on firms which operate mainly in a specific type of value chain (e.g. captive type) and explore the relationship between capability formation and the type of value chain, or compare the results with firms in another type of value chain (e.g. relational type).[7]

[7] Fujita [2010] compares the maximum levels reached among firms participating in several types of value chains, while Sato [2010] aggregates the results of assessing the capabilities of firms operating in a specific type of value chain.

The main contribution of the Capability Matrix is in illustrating the multi-track concept of capabilities by displaying varieties of *shapes* of colored area. As the patterns in Figure 1 show, firms may have different shapes of colored area even when the total number of colored cells is the same. However, quantitative analysis that postulates the single-track concept of capabilities may also be possible, provided that sufficient consideration is taken. For instance, we could allocate one point to each colored cell so that the capabilities of the studied firm can be quantified in accordance with the total number of colored cells. Furthermore, the total number of points for each firm can be calculated by giving weights to each of the functions on the basis of the relative size of value added generated by the corresponding functions in the value chains.

4. Conclusion

The Capability Matrix developed in this paper offers a framework for analyzing firm-level capabilities of developing country firms that are engaged in varieties of global and domestic value chains. This two-dimensional matrix assesses firm capabilities in terms of functional width and depth at a particular point in time. It is a simple, practical, and industry-neutral framework that can be used to visually portray the status of a firm's capabilities in a variety of industries. It is designed as a tool for researchers undertaking field research on the development of developing country firms, and can also be applied to a variety of analytical approaches.

Our framework was to bring together critical elements of the GVC approach, the TC approach, and the literature on Japanese technological development. While the need to integrate the GVC and TC approaches has already been argued by other authors (Morrison, Pietrobelli and Rabellotti [2008]), this paper showed how the integration can actually be put into practice and makes it possible to overcome the shortcomings of the existing frameworks. On the one hand, the Capability Matrix enriches the GVC approach. In contrast to the GVC framework, which concerns the changes in the positions of local firms within the studied value chains in relation to lead firms regardless of whether the changes occurred as a result of the local firms' learning, the

Capability Matrix captures achievement of learning that extends across the whole range of activities undertaken by the studied firm. On the other hand, our framework also enriches the TC approach. By incorporating one of the central propositions of the GVC approach that value chains provide opportunities for as well as constraints on the growth prospects of developing country firms, the framework attempts to highlight the role of global and local industrial constellations in shaping the process of local firm capability formation.

The contribution of the Capability Matrix goes beyond providing an analytical tool. It highlights critical yet relatively overlooked factors that underlie the upgrading of local firms in GVCs: the local firms' strategic intents and endogenous efforts. Though not explicitly discussed in this paper, the Capability Matrix has an underlying proposition that local firms in developing countries are independent agents with the discretion to exercise their own strategies, including overall business strategies as well as specific learning strategies, which could significantly influence the learning outcomes.[8] As pointed out by Morrison, Pietrobelli and Rabellotti [2008: 51], there is a need for further conceptual and empirical work on how participation in GVCs contributes to local firm learning and innovation, and the Capability Matrix provides a powerful tool to achieving this end.

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