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Empirical Analysis of the Hypothesis of Architecture-based Competitive Advantage and International Trade Theory

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March 2006

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Abstract: In this paper, we propose an *architecture-based hypothesis of comparative advantage*, which predicts that a good "fit" between "*organizational capacities of manufacturing*" that companies have built up over their histories and *product-process architecture* (i.e., basic design concepts for product function, structures and processes), tends to result in international competitiveness. Therefore, we attempt an empirical analysis that the net exports of Japan are relatively "Integral type".

Concretely, we make an architecture spectrum indicator by the principal component analysis based on the answers to a corporate questionnaire (33 companies and 254 products) executed in cooperation with the Ministry of Economy, Trade and Industry. We also show the integral degree and the modular degree of each product

Next, we performed regression analysis of the export ratio and the architecture spectrum indicator by the assembly-industry products, and by the process-industry products. The result supported the above-mentioned proposition. Moreover, for assembly-industry products a statistically significant result is obtained even by the regression analysis that includes the labor intensity variable. These results show that "The export ratio tended to rise both as the integral *architecture indicator* increases and as the labor intensity levels rise for the assembly-industry products, where global competitiveness is strong". These results have the possibility of suggesting a new development direction in international trade theory.

Keywords: Architecture, comparative advantage, integral architecture indicator, export competitiveness, labor intensity

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1. Introduction

In this brief memo, we examine an *architecture-based comparative advantage hypothesis* which predicts that, for Japanese manufacturing firms, "*integral architecture*" products with more complex function-structure relationships tend to result in higher export ratios. These products tend to be manufactured by exploiting *integration-oriented (i.e., integrative) organizational capability* of manufacturing, which relies on teamwork of multi-skilled workers, a traditional strength of the post-war Japanese manufacturing firms compared with those other countries. Our data analysis indicates that, in the area of assembled products in particular, production bases located in Japan are still enjoying export competitiveness in labor-intensive integral architecture products.

2. A New Approach to Explain Industrial Competitiveness

What industries will survive in 21st-Century Japan, and what will the country import and export? For Japanese industrialists and policy makers, this is simultaneously an old and new question. In fact, Japan saw the following gravity shifts in its industrial structure from the Meiji Period into the Showa Period:

agriculture → manufacturing → service industries;
light industries → heavy industries;
materials → processing and assembly;
low added-value industries → high added-value industries;
labor-intensive → capital-intensive → knowledge/technology-intensive industries.

Since the 1990s, however, Japan has entered a phase of its history that is marked by a declining population. This situation begs the following questions: Which types of goods and services should Japan see at its "strengths" and how should it invest its limited human resources amid fierce industrial competition in East Asia? Surprisingly, there have been no clear answers. Although there are vague suggestions that Japan should move toward technology-intensive industries, IT-based industries, or high service industries, the reality is that digital-network goods and services (particularly software) have largely been dominated by the United States. Besides, certain technology-intensive products—such as memory semiconductors and DVD players, for which Japan has been expected to have competitive advantage, are seeing larger shares taken by such countries as South Korea, Taiwan, and China. As a result, Japanese industrialists tended to be unsure which industrial sectors will maintain competitive advantages in the future. This situation is leading to the emergence of pessimistic views that smack of overreaction, including opinions that "China poses a threat to Japan" and that "most of Japan's industries are hollowing out."

In order break out of this bind, Japan will need to revisit its development and production sites and discuss "a shop-floor-based view of industries" as a way of reorganizing its competitive strategies with an open mind. This process will involve reconfirmation of Japan's strengths and weaknesses without adhering excessively to existing industrial classifications.

From this standpoint, the University of Tokyo's Manufacturing Management Research Center attempted to engage in analysis of "manufacturing in a broad sense," which reinterprets companies' development and production activities as the flow of "creation and transfer of design information" toward the customers. Furthermore, we propose an *architecture-based hypothesis of comparative advantage*, which predicts that a good "fit" between "*organizational capacities of manufacturing*" that companies have built up over their histories and *product-process architecture* (i.e., basic design concepts for product function, structures and processes), tends to result in international competitiveness.

In general, when there is good fit between a nation's characteristics and an industry's characteristics, the industry tends to enjoy competitive advantages in that country. Ricardo's Theory of Comparative Advantage implied that "good fit" is translated into relatively high labor productivity vis-a-vis other countries. Neoclassicists such as Heckscher, Ohlin and Samuelson advocated that countries having larger endowment of a certain production resource (for example, labor-rich countries) will have better fit with industries that use this particular resource (for example labor-intensive industries) assuming that productivity is identical across the countries.

However, as was stated above, various phenomena that are difficult to explain using existing theoretical frameworks have been emerging in recent years. These phenomena include Japan's being surpassed apparently by East Asian countries in some technology-intensive product sectors.

3. Export Competitiveness of Japan's Integral Architecture Products

Here, we take note of "fit between organizational capacity and architecture" as seen from our observations of manufacturing activities on the shop floor. Specifically, it is thought that Japanese manufacturing firms, facing high economic growth amid shortages of work force, materials and money, tended to engage in economically rational long-term transaction/long-term employment. As a result, they built organizational capability that emphasizes teamwork among stable multi-skilled workforce, or “integrative organizational capability of manufacturing,” which raised their productivity and quality simultaneously.

On the other hand, it was thought that there are two basic types of product-process architecture:

- “Integral architecture” with complex interdependence between product functions and product structures (such as automobiles, etc.);
- “Modular architecture” in which the relationship between a product’s functional and structural elements have a simple and clear one-to-one correspondence (such as personal computers, etc.).

It was also thought that Japan, which is a country with a high endowment of “integrative organizational capability” among its firms, tends to have a competitive advantage in “integral architecture” products – a prediction based on our “architecture-based comparative” hypothesis.

So then, can this new approach to industrial competitiveness demonstrate additional explanatory power for the reality of Japan’s industrial competitiveness? Although our research is still at the exploratory stage, Manufacturing Management Research Center (MMRC) at Tokyo University conducted a survey analysis of selected Japanese manufacturing firms in cooperation with the Ministry of Economy, Trade and Industry (METI). The survey targeted both assembled products and processed products (chemicals, etc.), including automobiles, household appliances, electronics, parts, industrial machines, chemicals, iron and steel, fibers, and food and drink（Refer the appendix 1 about industrial division and the size of the sample） Although a portion of this analysis was included in the 2005 “White Paper on Manufacturing,” this memo will present some of our newer results of our analyses at MMRC.

4. Outline of the Survey on Architecture-based Competitive Advantage

The survey analysis gained responses based on five-step Likert-scale evaluation by employees who are in charge of those products in question. It asked those company personnel in charge of products for their subjective evaluations of 12 items as elements of “integrative/modular architecture indicators”; these items included “Is part design conducted specially for the specific product?” and “Do inter-component interfaces use company-specific designs?”

The 12 question, plus 1 (overall evaluation 13) items are shown as follows.

＜Questionnaire＞

1. This product mainly consists of parts or materials with customized (product-specific) design.
2. Interfaces that link the components of this product are custom-designed (product- specific).
3. Interfaces that link the components of this product are firm-specific (used only in this company).
4. In order to achieve total performance of this product, design parameter of its components must be precisely fine-tuned (mutually adjusted).
5. Total quality of this product cannot be achieved by mix-and-match of pre-designed components (e.g. generic parts, common parts, carry-over parts).
6. The product faces strict constrains in terms of size and weight, which results in inter-dependence between design parameter of the components, (e.g. parts interference and weight balance).
7. The product requires close collaboration of component design or material design between the assembler and the suppliers.
8. In order to satisfy its customers, the product needs to achieve more than one performance requirement at the same time.
9. The product needs precise adjustment of process design parameters to the change and variance of its materials or upstream products.
10. The product cannot achieve high total product quality by mix-and-match of the standard production equipment (it requires customization of the equipment).
11. The main production process of this product is designed or manufactured by this company (in-house equipment).
12. In order to achieve the required performance, this product needs precise mutual adjustment of control parameters between its production processes.
13. Overall evaluation of product/process architecture based on questions 1-12

（Note.1） Scale 5: Very true, 4: Rather true, 3: Neutral, 2: Not so true, 1: Not true at all

（Note.2） Assembly-industry products are answered from Questionnaire1 to Questionnaire13, Process-industry products are answered from Questionnaire7 to Questionnaire13.

The results were aggregated by multi-variable statistical analysis (e.g., principal component analysis), then indicators that express the level of “integral-ness” (or, conversely, level of modularity) of the products’ architecture were prepared.

Next, the procedure and the result are shown.

Table 1　Principal Components Analysis（1）(Assembly Products : 173 Samples)

Table 1　Principal　Component　Analysis(1)

	First Principal Component	Second Principal Component
Cumulative Contribution Ratio	0.39	0.51
Question		
1(1)	0.786	0.113
1(2)	0.630	0.210
1(3)	0.576	0.056
1(4)	0.698	0.244
1(5)	0.675	0.203
1(6)	0.503	0.293
1(7)	0.540	0.238
1(8)	0.663	0.201
1(9)	0.252	0.672
1(10)	0.238	0.776
1(11)	0.266	0.664
1(12)	0.071	0.869

（assembly-industry products case）

It is a result of the principal component analysis on 173 assembly-industry products products that shows in Table 1. Two principal components have been extracted at the stage of cumulative contribution ratio 0.51.

The first principal component is composed by (1) - (8).　The second principal component is composed by (9) - (12). The lower 1(1) -1(12) of the cumulative contribution ratio shows the element procession of the question vote of (1) - (12) (After Varimax rotation). In question (1) - (8), the value with the first principal component is higher, and it can be thought the question item that depends on the first principal component. When the questions are summarized, the first principal component is thought to be a factor of "Architecture of the product design".

Question (9) - (12) indicates the value with higher second principal component, and is thought to be a question item that depends on the second principal component. It is thought "Architecture of the production process" factor from the content of the question.

The correlation analysis result of the overall evaluation (13) and the principal component factor is the following.

Correlation coefficient of the first principal component factor and overall evaluation: 0.721

Correlation coefficient of the second principal component factor and overall evaluation: 0.452.

Therefore, the first principal component is thought the factor of "Architecture of the product design", and a suitable factor for showing the characteristic of the integral modular degree of the assembly-industry products. Moreover, because the correlation of the principal component factor and the overall evaluation is the highest, the first principal component factor is defined (In the meaning that the integral degree rises when the numerical value rises), "Integral architecture indicator". In addition, sets of these first principal component factors (173 products) are defined as the architecture spectrum of the assembly-industry products.

The architecture spectrum of the assembly-industry products (173 products) is as shown in Figure 1 and Table 2.

Figure 1. Architectural Spectrum (173 Assembly products)

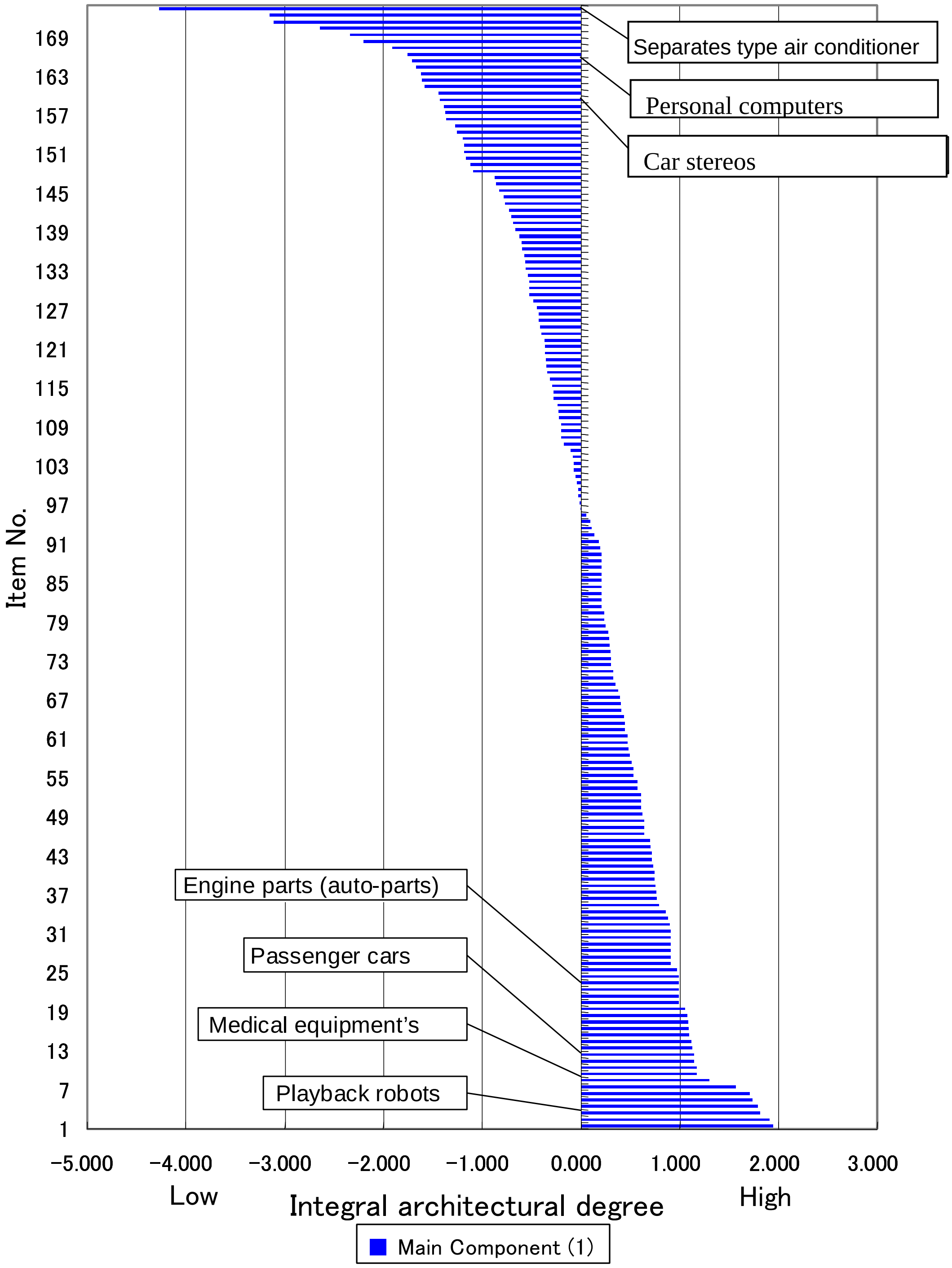


Table 2 Integral architecture indicator and Item name (assembly-industry products)

Item Number	Item Name	Integral Archtecture Degree
(1)High Degreed Integral Archtectyure Products		
1-5	Playback robot, Cellular telephones,Color rolled film, Automobile air conditioners,Electric switching systems	2.290 - 1.309
6-10	Liquid crystal televisions,othersIC,Chassis and Body parts(Automobile parts), Large passenger cars,Small passenger cars	1.303 - 1.207
11-15	Motorcycles(More than 125ml),Medical equipment's,Medical equipment's,Small passenger cars,Large passenger cars	1.207 - 1.124
16-20	Precision measuring machines and instruments,Magnetic tapes,Other semiconductor parts,Switches,External storage	1.110 - 1.032
21-25	Automobile air conditioners,Engine parts(Automobile parts),Bearings,Industrial use equipment,Plate making machinery	1.016 - 1.016
26-30	Engine generators for general use,Engine parts(Automobile parts),Terminal equipment,Steam turbines for industry,Small capacity motors	0.959 - 0.908
31-35	Injection molding machinery,Other electronics parts,Diesel engines for marine,Internal combustion engines for industry,Chassis and Body parts (Automobile parts)	0.845 - 0.825
36-40	Engine parts(Automobile parts), Color televisions(FPD),Other electronics parts,Engine parts(Automobile parts),Car navigation systems	0.820 - 0.733
41-45	Semiconductor characteristic measuring equipment,Internal combustion engines for industry,Connectors,Small passenger cars,Large passenger cars	0.728 - 0.703
46-50	Large trucks,Small trucks, Engine parts(Automobile parts),Small passenger cars,Large passenger cars	0.703 - 0.703
51-55	Bearings,Looms,Airplane,Other batteries,Other photographic film	0.703 - 0.677
(2)Midium Degreed Integral Archtectyure Products		
56-60	Cranes,Engine parts(Automobile parts),Fork lift trucks,Other Fine ceramics	0.648 - 0.592
61-65	Refrigerators with freezer,Quarts crystal units,Engine parts(Automobile parts),Industrial rubber products,Drive, transmission and Control parts (Automobile parts)	0.587 - 0.530
66-70	Printing machinery,Electro magnetic relays,Steam turbines for industry,Other Fine ceramics,Other photographic film	0.502 - 0.479
71-75	Software products,Polyurethane foam,Engine parts,Oil hydraulic equipment's,Suspension and Brake parts(Automobile parts)	0.440 - 0.371
76-80	Suspension and Brake parts(Automobile parts),transportation system,Other electronis parts,Cellular telephones,Electric test and measuring equipment	0.359 - 0.277
81-85	Industrial rubber products,Input-output units,Water tube boilers,Steel bridge,Automobile air conditioners	0.271 - 0.187
86-90	Suspension and Brake parts(Automobile parts),Plastic film and plastic sheets,Electronic circuit boards,Microwave ovens,Other Wrapping and packing paper	0.143 - 0.069
91-95	Color televisions,Plastic pipes,Synthetic fiber fabrics (Filament),Other baterries,Washing machines	0.065 - 0.048
96-100	Compressor,Elevators,Reaction vessels,Other chemical machines,Other airplane parts	0.046 - -0.013
101-105	Plastic plates,Drive, transmission and Control parts(Automobile parts),Shovel type excavators,Battery driven type watch (Complete),Color sensitized paper	-0.040 - -0.114
106-110	Mechanical presses,Special purpose machinery,Other chemical machines,Software products	-0.122 - -0.192

Table 2 Integral architecture indicator and Item name (assembly-industry products) (continue)

Item Number	Item Name	Integral Archtecture Degree
(3) Low Degreed Integral Archtectyure Products		
111−115	DVD−Videos,Chassis and Body parts (Automobile parts) ,Digital cameras,Motorcycles(Less than 125ml),Facsimile machines	−0.208 − −0.241
116−120	Packaged type air conditioners,Steel vessel,Steel vessel,Modular installation machine,Separate type air conditioners	−0.304 − −0.389
121−125	Flat−panel display manufacturing equipment,Grinding machinery,Engine parts (Automobile parts,Other household electrical appliances,Color rolled film	−0.390 − −0.455
126−130	Stamping dies,Engine parts (Automobile parts),Chassis and Body parts (Automobile parts),Chassis and Body parts (Automobile parts),Other Color film	−0.462 − −0.485
131−135	Automatic highrised warehouses,Fork lift trucks,Separators,Rubber hoses,Water tube boilers	−0.504 − −0.586
136−140	Video cameras,Industrial rubber products,Programmable controllers,Rubber tires for automobiles,Rubber tires for automobiles	−0.593 − −0.698
141−145	Personal handy phone system,,Chassis and Body parts (Automobile parts) ,General purpose computers,Other foods,Other electronics parts	−0.739 − −0.849
146−150	Quarts crystal units,Other foods,Machining centers,Plastic reinforced products,Software products	−0.868 − −1.077
151−155	Car navigation systems,Pumps,Other Seasoning,Frozen cooking food,Mechanical parkings	−1.148 − −1.386
156−160	Electronic circuit boards,Safety glass,Car stereos,Steam turbines for industry,Electric test and measuring equipment	−1.475 − −1.735
161−165	Personal computers,Steel bridge,Personal computers,Fixed capacitors,Software products	−1.790 − −2.064
166−170	Power conversion equipment,Weekly magazine,Condensing units,Separate type air conditioners,Rubber beltings	−2.071 − −2.673
171−173	Sheet glass, Steel vessel,Other Machine tool	−2.747 − −3.469

(**process-industry products case**)

It is a result of the principal component analysis on 81 process-industry products that shows in Table 3. Two principal components have been extracted at the stage of accumulation contribution rate 0.71.

The first principal component is composed by (10) - (12).　The second principal component is composed by (7) - (9). The lower 1(7) -1(12) of the cumulative contribution ratio shows the element procession of the question vote of (7) - (12) (After Varimax rotation).

It is question (12) that it is the nearest "Function and structural definition" as the question on "Production process architecture" of the process-industry products. In question (12), it is a question item of "Mutual adjustment between in-house processes for the function achievement" of having to

Table3　Principal Components Analysis（2）
（Process Industry Product : 81 Samples）

	First Principal Component	Second Principal Component
Cumulative Contribution Ratio	0.43	0.71
Question		
1(7)	−0.037	0.711
1(8)	0.033	0.850
1(9)	0.497	0.629
1(10)	0.887	0.117
1(11)	0.818	−0.331
1(12)	0.833	0.307

adjust the parameter mutually between equipment and to design best, and it is the first principal component for the function demonstrating. Moreover, manufacturing facilities are not the mixtures (question (10)) but in-house production or equipment (question (11)) to apply. They are the first principal component for that. This might be appropriate points.

The second principal component is composed of question. Question (7) is a joint development with the supplier. Question (8) is a complexity of the demand performance. Question (9) is a material and process synchronization. If these common features are said, it is "There is a possibility that the factor of mutual adjustment between the processes of the material mixes".

It is named "Mutual adjustment between the processes and the material for the function achievement" factor if forced to say with the second principal component of the process-industry product. However, the element procession of question (9) can point out a high numerical value of 0.497 it and the considerable synchronization with the first principal component.

In the process-industry products, even the character of single purpose products produced as the one (solid and liquid, etc) the first principal component is a suitable factors for showing the characteristic of the integral modular degree.

Moreover, the first principal component factor is defined from correlate about the principal component factor and the overall evaluation the highest, it is "Integral architecture indicator" of the process-industry products (In the meaning that the integral degree rises when the numerical value rises).

Sets of these first principal component factors (81 products) are defined as the architecture spectrum of the process-industry products.

The architecture spectrum of the process-industry products (81 products) is as shown in Figure 2 and Table 4.

Figure 2. Architectural Spectrum (81 process products)

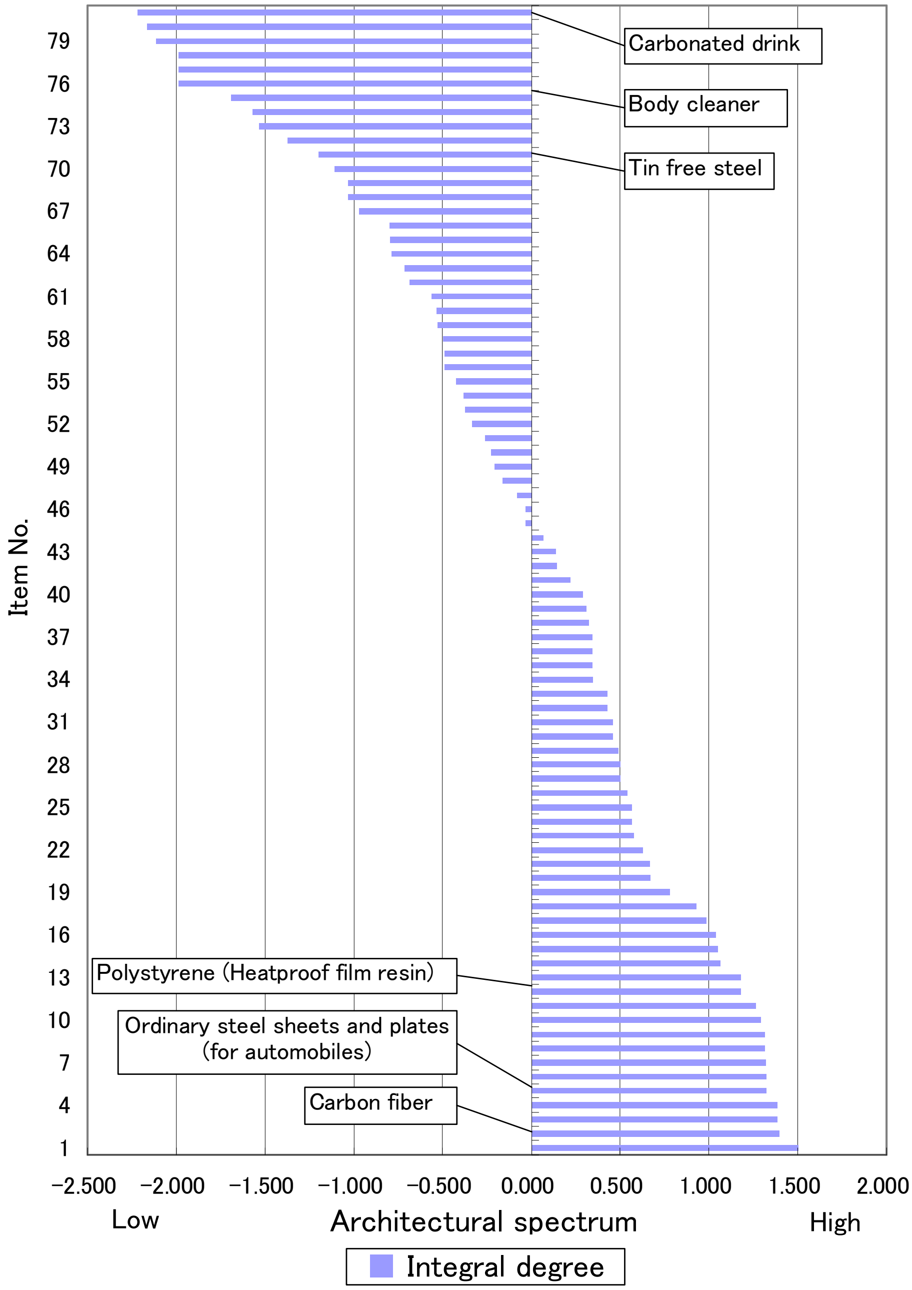


Table 4 Integral architecture indicator and Item name (process-industry products)

Item Number	Item Name	Integral-Architectural-Frequency		
(1)Items with high Integreal-Architectual-frequency				
1-5	Copper electric wires, Carbon Fiber, Synthetic fiber fabrics (Filament), Glass products, Synthetic rubbers	1.503	-	1.325
6-10	Ordinary steel sheets and plates, Other foods, High speed steel cutting tools, Sheet glass	1.323	-	1.291
11-15	Plastic material for building Glass products, Polystyrene, Special hot rolled steel products, Other IC parts	1.263	-	1.049
16-20	Chassis and Body parts, Cemented carbide tips, Plastic formed products, Other Fine ceramics, Suspension and Brake parts	1.038	-	0.671
21-25	Epoxy resin, Refractory brick, Other Plastic, Aluminum rolling products, Electrolytic copper	0.665	-	0.565
(2)Items with medium Integreal-Architectual-frequency				
26-30	Tin plates, Non-woven fabrics, Glass fiber wool products, High speed steel cutting tools, Medical products	0.543	-	0.459
31-35	Medical products, Synthetic fiber fabrics (Filament), Other non-steel metal, Parts and accessories of boilers, Suspension and	0.459	-	0.343
36-40	Engine parts, Drive, transmission and Control parts, Polyamides resin(Molding materials), Polyfluorocarbon resin, Plastic film and plastic sheets	0.343	-	0.293
41-45	Cement, Synthetic fiber fabrics (Filament), Other IC parts, Glass products, Sodium hydroxide	0.221	-	-0.035
46-50	Polyvinyl chloride, Other IC parts, Polystyrene, Whisky, Medical products	-0.035	-	-0.228
(3)Items with low Integreal-Architectual-frequency				
51-55	High speed steel cutting tools, Whisky, Electronic circuit boards, Powder metallurgical products (Machinery materials), Sodium hydroxide	-0.258	-	-0.423
56-60	Skin cream products, Powder metallurgical products (Machinery materials), bear, Copper electric wires, Phenol-formaldehyde resin	-0.491	-	-0.533
61-65	Sparkling Liqueur, Small capacity motors, Phenol-formaldehyde resin,Other Liqueur(fruit wine), Medical products	-0.561	-	-0.795
66-70	Ordinary steel sheets and plates, Coffee・Tea type Beverage, Body cleaner, Coffee・Tea type Beverage, Food oil	-0.798	-	-1.109
71-75	Other Liqueur(fruit wine), Body cleaner, Tin free steel, Aluminium cans for beverage	-1.199	-	-1.690
76-81	Liqueur, Spirits, Spirits, Liqueur, Phenol-formaldehyde resin, Carbon Fiber	-1.988	-	-2.218

(regression analysis)

At the same time, the level of labor intensity (i.e., labor distribution rate)—which is a standard in conventional trade theory—was also observed.

The survey also inquired about export ratios as an indicator of international competitiveness. Furthermore, the “integral architecture indicators” and labor intensity were statistically examined, through regression analysis, both separately and simultaneously to determine any correlation with export ratios. The results are as shown in the Table5.

Table5 Summary of regression analysis of export ratio
(Integral architecture indicator and labor intensity)

The type of product	Dependent Variable (Y)	Independennt Variable (X): Integral Architecture Indicator	Labor Intensity	Constant	Adjusted R-squared	Sample Size
assembly product	Export Ratio	0.1221 (2.48)*		0.358 (8.94)	0.091	52
	Export Ratio		0.702 (2.01)*	0.267 (4.04)	0.062	52
	Export Ratio	0.1310 (2.78)**	0.770 (2.43)*	0.236 (3.75)	0.178	52
process industry product	Export Ratio	0.1184 (4.06)**		0.1888 (6.84)	0.324	43
	Export Ratio		0.2056 (0.88)	0.1268 (6.84)	0.005	43
	Export Ratio	0.1195 (4.42)**	−0.0314 (0.16)	0.1944 (4.31)	0.307	43

Note:t−value in parenteses. * Statisticaliy significant at 5% level. ** Statisticaliy significant at 1% level

The export ratio was dependent variable (Y), the integral architecture indicator, and the labor intensity were independent variable (X) and the regression analysis was executed. However, there were 31 products that there are no answers in the amount of production and exports of 173 products in the assembly-industry products. 14 per 81 products did not have the answer in the process-industry products. These were removed from the sample of the regression analysis (Refer to appendix 2 for the regression analysis of this sample size).

The data of t the level of the labor intensity was defined from four question items of the following question groups that prepared it by a corporate questionnaire.

(1) Product sales (2) Purchase raw material expense of product (3) Subcontract expense of product (4) Total employer payment of product

The amount of the additional value and the level of the labor intensity (i.e., labor distribution rate) were defined from the following calculation.

The result of the correlation analysis of the overall evaluation question (13) and the principal component factor of the process-industry products is following.

Correlation coefficient of the first principal component factor and overall evaluation: 0.678

Correlation coefficient of the second principal component factor and overall evaluation: 0.521

Therefore, the first principal component is "Architecture of the production process" factor as for the process-industry products.

Additional value amount = sales-purchase raw material expense-subcontract expense

The level of the labor intensity (i.e., labor distribution rate) = total employer payment/additional value amount

The regression analysis of Table5 was executed by 43 samples in the process-industry products and 52 samples in the assembly-industry products because there was no answer in total employer payment.

First, the level of the integral architecture indicators showed a positive correlation with export ratio for both assembled and processed products, and had a high level of statistical significance (estimated error rate of 1% or less). This result is consistent with our hypothesis that, for Japan manufacturing firms with team-oriented organizational capability, the more integral their products are, the higher their export competitiveness. Furthermore, it was recognized that there is a positive correlation in the area of assembled products even in simultaneous analysis with level of labor intensity, indicating robustness of the explanatory power of the architectural indicators.

Secondly, although the labor intensity indicator did not show a clear trend in the area of processed products, it did have a positive correlation in assembled products with a reasonably high level of statistical significance (5% level). This means that, in the area of assembled products, export competitiveness is high when labor intensity is high.

In the following, the scatter chart of the export ratio and the integral architecture indicator of the assembly-industry products and the process-industry products are shown.

Figure 3 Export Ratio and Integral Architecture Indicator Scatter chart (1)
（assembly-industry products ： 52sample）

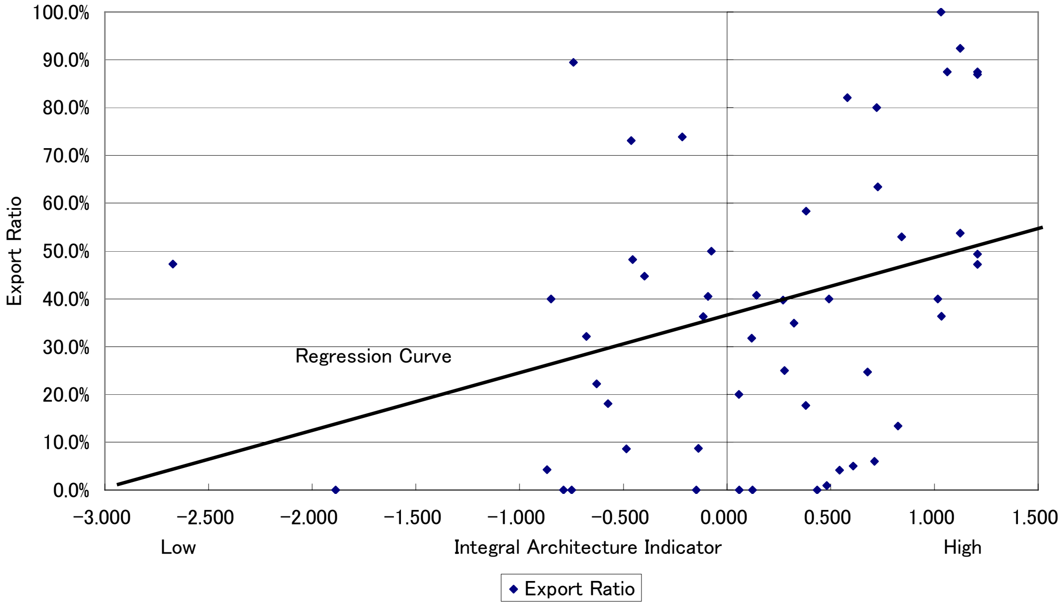
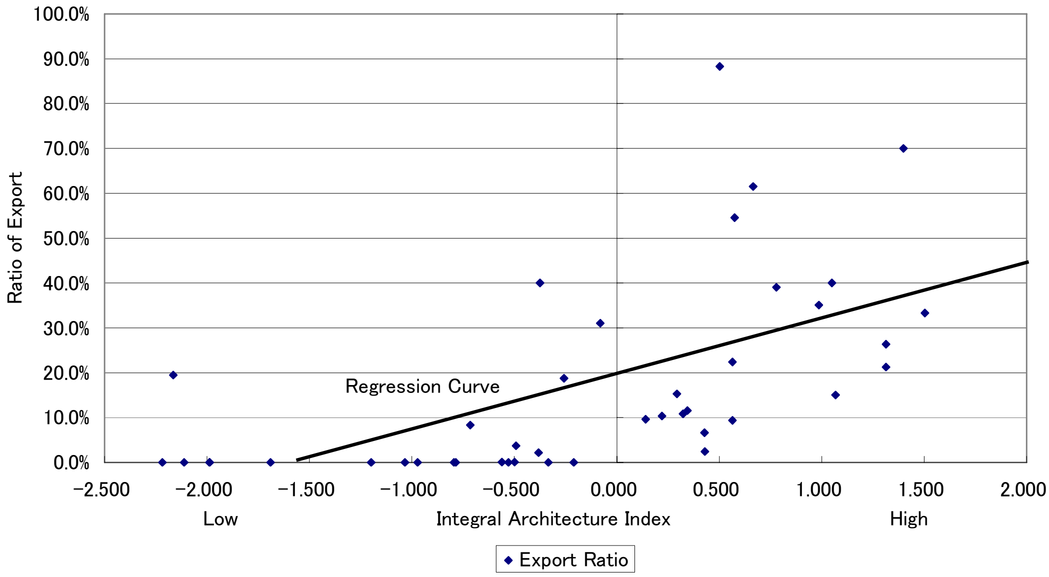


Figure 4 Export Ratio and Integral Architecture Indicator Scatter chart (2)
（Process-Industry products ： 43sample）



5. Japan’s Strength Based on Multi-skilled Labor Force

Because Japan’s labor endowment is obviously lower than that of its largest trading partner, China, the finding that Japan’s assembled products have higher export competitiveness when they are more labor-intensive may come as a surprise. However, it should be noted that "labor forces" may include both multi-skilled labor forces that are fostered by long-term employment on the one hand, and single-skilled labor forces with short-term employment on the other hand. The above statement gains thus coherence if it is remembered that Japan may have a rich supply of people belonging to the multi-skilled type of labor force, compared even with China. In fact, as is typified by the Toyota Production System, workplaces in Japan's assembly industries that foster multi-skilled workers and economize capital equipment are indeed highly competitive.

The above conclusions are still provisional. It will be necessary to make comparisons with various research projects conducted in the past, to elaborate observation methods, and to conduct additional tests with more samples. However, at the very least, the conclusions appear to support the idea that shop-floor-based theory of the industry—i.e., "competitive advantage based on the fit between organizational capacity and architecture"—which had rather been overlooked heretofore, can be added to theories that explain industrial competitiveness of nations.

Finally, we would like to discuss the practical implications of these results. First, when a country's industries tend to have integrative organizational capability of manufacturing that is tempered through capability-building competition based on long-term employment/transaction, locating integral architecture products domestically gives the relevant location export competitiveness and facilitates sustainability within the country. Of course, overseas production of integral architecture products will increase from the additional principle of "producing products wherever their market exists." However, even when looking at overseas sales ratios that include such overseas production, our statistical analysis indicates that the more integral the products' architecture, the higher the ratio of overseas sales.

Second, Japanese companies must not be lax in fostering a multi-skilled workforce. Even if companies are forced to increase their non-fulltime personnel as a response to sales volume fluctuations caused by Japan's recession and low growth throughout the 1990s, they must make a full effort to ensure that these non-fulltime employees are at least multi-skilled to a certain extent.

Of course, actual industrial structure is a joint result made up of the capability-building efforts of manufacturing firms, their strategic choices, environmental changes, and other inside and outside factors. Thus, the above-mentioned results point only to one of many factors influencing industrial competitiveness. However, in answer to the question "What products does Japan tend to have an advantage in?" it is likely appropriate to say architecture-based theory of international competitive advantage must be established when companies make decisions regarding decent factory locations.

Appendix 1: Industrial division and product items

254 Products of 33 Companies., 10 Industries.

・Steel and Steel Products, Non-ferrous metals and products, Other metal products （18 items）

・General machinery （40 items）

・Household electrical appliances, Electronic and communication equipment, Other electric machinery （41 items）

・ Parts and accessories of electric and electronic equipment （19 items）

・ Cars and auto parts （39 items including 10 auto items ）

・ Other transportation equipment and repairing （12 items）

・ Other machines and instruments （2 items） (Other machines and instruments :Precise machine Office machinery, Optical instruments Watch and Clocks)

・ Chemical products, Ceramic, stone and clay products （48 items）

・ Foodstuffs and feeds for animal poultry, Fabricated textile products, Pulp, paper, and paper products （32 items）

・ Other manufactured products and Software products （5 items）

Appendix 2: Regression Analysis of the export ratio and the integral architecture indicat or.

In the regression analysis, independent variable (Y) is the export ratio and dependent variable (X) is an integral architecture indicator. However, the product that there are no answers in the amount of production and exports included 31 products of 173 products in the assembly-industry products, 14 products in 81 products in the process-industry products. So, we removed these from the sample of the regression analysis.

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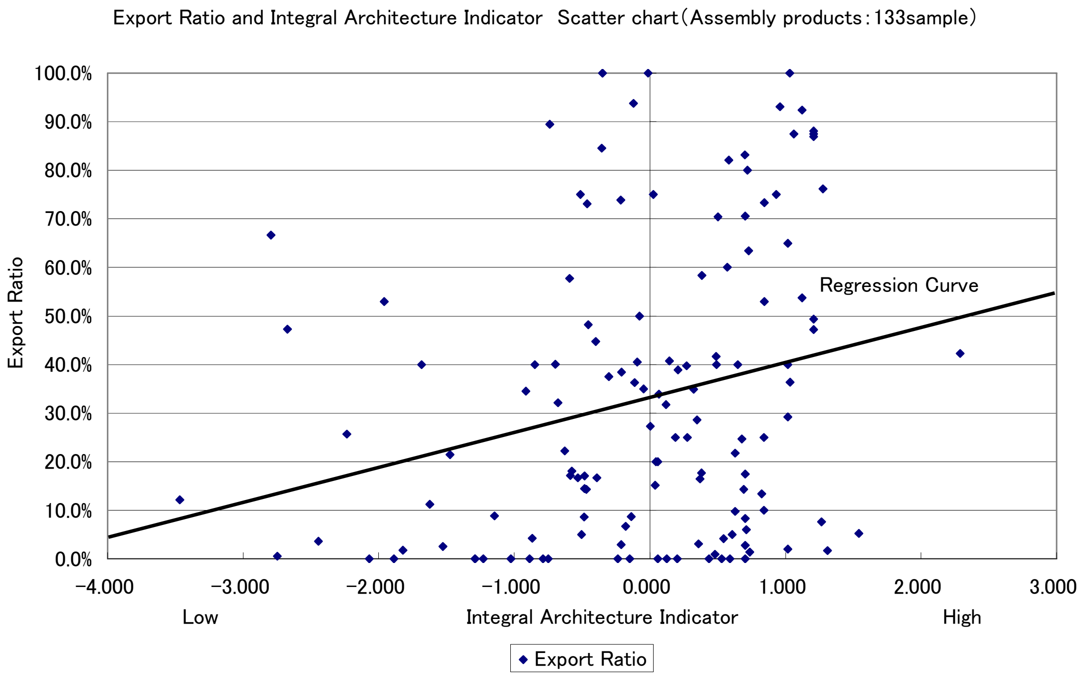
Export ratio and Integral Architecture Indicator Scatter chart(1)（Regression Analysis of Assembly-industry products：133sample）

$$Y = \underset{(2.89)^{**}}{0.0739} * X + \underset{(13.1)^{**}}{0.336}$$

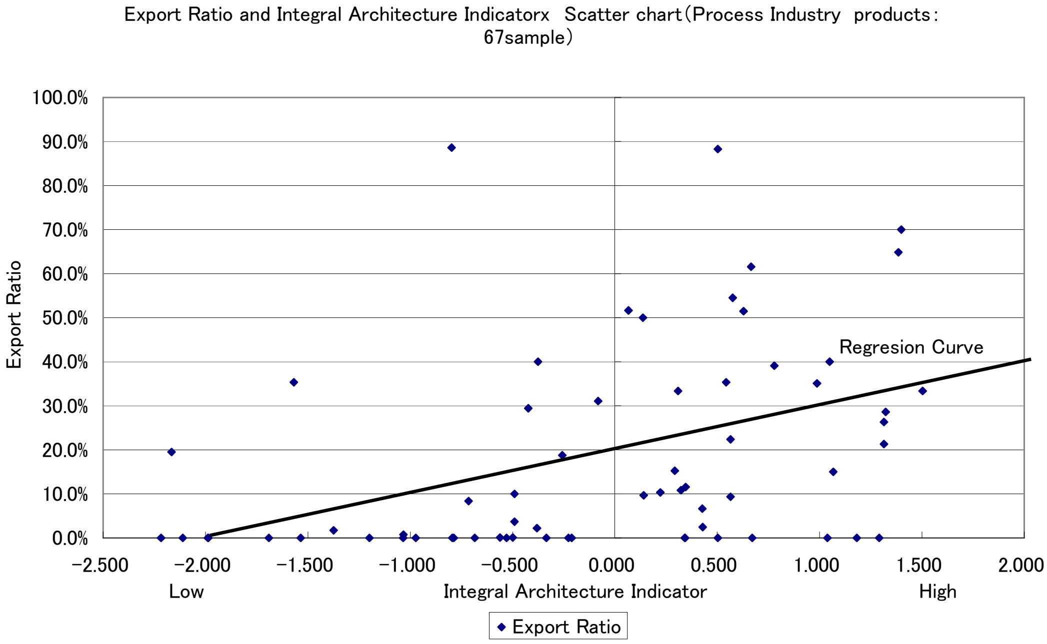
(N=133 Adjusted R-squared:0.052)
(t-value in parentheses. **Statistically significant at 1% level)



Ratio of Export and Integral Architecture Indicator Scatter chart(2)（Regression Analysis of Process-industry products：67sample）

$$\underset{(3.33)^{**}}{Y = 0.0871*} X \underset{(7.05)^{**}}{+0.186}$$

(N=67 Adjusted R-squared:0.133)
(t-value in parentheses. **Statistically significant at 1% level)



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