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Product Architecture and Human Resource Management: Comparing Japanese, Chinese, and Korean Firms Based on a Questionnaire Survey

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Abstract

Using data from a questionnaire survey focusing on firms from Japan, China, and South Korea, this paper empirically examines the complementarity between product architecture and human resource (HR) management. The results of the analysis can be summarized as follows. First, in Japan and Korea, firms were more or less evenly divided between those employing a modular and those employing an integral architecture. On the other hand, in China, more firms employed a modular architecture. Second, with regard to HR management practices and customs, there were differences in the emphasis of internal training of new graduates and the emphasis of mid-career recruitment. Japan and China are at the two extremes, with firms in the former tending to emphasize the recruitment of new graduates and firms in the latter emphasizing mid-career recruitment, while firms from Korea were in-between, but closer to Japan. Third, we found that, in Japan, development performance was significantly higher when product architecture and HR management were appropriately combined. However, we did not find such significant effect for the case of Korea and China. And fourth, we found that when we drop the assumption that the relationship between the combination of product architecture and HR management on the one hand and development performance on the other is linear and examine the non-linear effect of the former on the latter, both in Japan and Korea, the more that firms approach the best combination, the more their development performance increases.

1. Introduction

Since the publication of the seminal study by Ulrich (1995), there has been a burgeoning interest in the role of product architecture, resulting in a growing body of empirical research focusing on this key concept. The term product architecture is typically understood to refer to the way products as a system are divided into subsystems and how the interfaces among these subsystems are defined (see, e.g., Baldwin and Clark 2000, Fujimoto 2001). Product architectures can be divided into two broad categories: when the combination of parts and components is determined in advance and parts and components are combined according to these rules in the development and production process, the product architecture can be described as "modular;" on the other hand, when the rules of combining parts and components are not determined in advance and parts and components as well as departments within the firm are adapted to each other in the development and production process, the product architecture is labeled as "integral."

In addition, architectures can also be distinguished in terms of whether they are "closed" or "open." In the case of a closed architecture, the design rules for interfaces between parts are specific to a particular firm, while in the case of an open architecture, design rules are generic, transcending the boundaries of a firm. Fujimoto (2004) argues that firms from the United States tend to be strong in open, modular architectures, while Japanese firms have a competitive edge in closed, integral architectures. Based on these considerations, there has been growing interest in the role of product architecture in the product development process not only from a micro-level perspective, but also on an industry- or country-level (see, e.g., Fujimoto and Shintaku 2005).

Research along these lines undertaken to date, however, has the following shortcomings. First, while existing studies on product development have produced important results on the links between product architecture and the organizational design for product development activity, and on the product development process itself, little has been said on the human resources that propel this process forward.

Major representative studies on product development include those by Clark and Fujimoto (1991) and Nobeoka (1996), who conduct international comparative research on product development mainly at car manufacturers, and those by Chesbrough et al. (2006) and Gawer and Cusumano (2002) focusing on innovation in Europe and the United States. Yet, none of these studies consider the crucially important issue of how the human resources actually in charge of product development such as engineers are managed.[1] The purpose of this paper is to fill this gap and examine the management of the human resources in charge of product development.

Second, studies on the relationship between product architecture and firm competitiveness tend to pay insufficient attention to the question of what kind of human resource (HR) management should be adopted for a given architecture or, put differently, the complementarity between product architecture and HR management. Assuming that Fujimoto's (2004) observation that U.S. firms tend to be stronger in open modular architectures, while Japanese firms have a competitive edge in closed integral architectures, is correct, this still raises the question with what kind of institutions and practices these product architectures need to be combined in order to yield results. This issue has been addressed in recent years in the field of organizational economics in studies such as Milgrom and Roberts (1992) and Roberts (2004). What is missing, however, are quantitative analyses that take full advantage of this research and examine whether product architecture and HR management stand in a complimentary relationship to each other.

Against this background, the aim of this paper is to do exactly that: i.e., to empirically examine the complementarity between product architecture and HR management. The remainder of the paper is organized as follows. The next section describes the survey from which the data for the analysis are derived and provides an outline of the data. Section 3 then provides an overview of product architectures and

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[1] As far as we are aware, the only existing study addressing this issue is Kono (2009). Examining human resource training through the dispatch of guest engineers from parts makers to final assemblers in the car industry, she looks at the issue of product architecture from the perspective of parts makers. While the present study focuses not on suppliers but final producers, looking at inter-firm relationships is something we would like to focus on in future research.

HR management practices in the three countries. This is followed, in Section 4, by our empirical analysis on the complementarity of the two and their effect on product development performance. Section 5 concludes.

2. Survey methodology and data

The data used in this paper are based on a questionnaire survey focusing on firms in Japan, China, and South Korea. The questionnaire consists of exactly the same questions for all three countries. The survey was implemented through careful translation and reverse translation and a revision of the questionnaire form after conducting a preliminary test survey.

Target firms in Japan consisted of private-sector firms with 185 or more employees belonging to the manufacturing and software industries. Firms were chosen from across Japan, with sample firms drawn from the business information database of Tokyo Shoko Research, Ltd. The survey was conducted as a postal survey between March 1 and March 12, 2010. Details on the number of firms contacted, the number of firms responding, and the response rate are shown in panel (a) of Table 1. [2]

Target firms in South Korea consisted of private-sector firms in manufacturing (with 300 or more employees) and the software industry (with 150 or more

[2] The response rate at 3% is extremely low. There are likely two reasons for this. The first is that a considerable number of firms contacted (especially small and medium ones) probably do not have internal product development capabilities and, strictly speaking, should have been screened out. According to the 2008 *Report on the Survey of Research and Development* (Statistics Bureau, 2008), the percentage share of firms that “not only conduct so-called ‘research’ but also engage in activities aimed at technological improvements and the development of products as well as production and manufacturing processes” was 12.8% in the manufacturing sector (11.5% for firms with 1-299 employees, 54.0% for firms with 300-999 employees, and 81.8% for firms with 1,000 or more employees). For the information and communications industry, the overall average was 6.7% (6.1% for firms with 1-299 employees, 12.3% for firms with 300-999 employees, and 56.7% for firms with 1,000 or more employees). The second possible reason is that the questionnaire consisted of two steps, where, after the head of the personnel department had replied to the section on the personnel system and HR management, the questionnaire needed to be forwarded to the head of the product development department to reply to the section on product development. Due to this complication, it was likely difficult for large firms with several establishments (for example, firms whose headquarters were in Tokyo but their product development department was in Osaka) to reply to the questionnaire.

employees).[3] Firms were chosen from across Korea, with sample firms drawn from the 2008 *Basic Survey of Establishments*. The survey was conducted in the form of interviews conducted by specialized interviewers and the survey period was July 8 to October 4, 2010. Details on the number of firms contacted and the number of firms responding are provided in panel (b) of Table 1.

In our survey on China, we were unfortunately unable to cover the entire country due to budget limitations and therefore focused on firms in four regions, namely, Shanghai, Beijing, Guangzhou, and Shenzhen. Sample firms were drawn from the *Yearbook of Chinese Companies* for Shanghai and a list of companies provided by the State Administration for Industry and Commerce for Beijing, Guangzhou, and Shenzhen. Firms were chosen on the basis of random sampling. The survey was implemented in the form of interviews at the firms conducted by interviewers specializing in company surveys. The survey period was August 14 to October 15, 2010. Details on the number of firms contacted and the number of firms responding are provided in panel (c) of Table 1.[4]

3. An overview of product architectures and HR management in the three countries

3.1 Product architecture

As stated at the outset of this paper, product architectures can be distinguished in terms of whether they are modular or integral. In the former case, there is more or less

[3] It should be noted that because the 2008 *Basic Survey of Establishments* which we used to draw our sample is the 2008 edition and because of subsequent changes in the number employees, the sample of manufacturing firms contains firms with fewer than 300 employees.

[4] The average response rate was 19.0% and therefore considerably higher than in Japan. The reason is that the survey was conducted through company visits by interviewers specializing in company surveys. The structure of the questionnaire, asking the head of the HR department about the personnel system and HR management and the head of the product development department about product development, was the same as in Japan.

a one-to-one relationship between a particular function and a particular part. On the other hand, in the latter case, the relationship between particular functions and parts is more complex. Yet, while such distinctions are easy to make in theory, finding appropriate indicators that can be used for empirical analysis is not that simple. Therefore, in our questionnaire survey, we included the following question:

"*In the development of your main product or information system, what approximately is the percentage of man-hours, as a share of overall development man-hours up until mass production commenced, spent on optimizing the design parameters of the 'key component' in order to achieve the desired function?*"

The aim of this question was to determine whether the percentage was relatively low, in which case the relationship between the function and the part is relatively simple, indicating a modular architecture, or whether it was relatively high, suggesting that the relationship between the function and the part is relatively complex, indicating an integral product architecture.[5] More specifically, we divided the distribution of answers into quartiles and classified firms falling into the first and second quartiles as employing a modular architecture and those falling into the third and fourth quartiles as employing an integral architecture.

The results are shown in Table 2. As can be seen, in Japan and Korea, firms were more or less evenly divided between those employing a modular and those employing an integral architecture. On the other hand, in China, more firms employed a modular architecture.

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[5] In this context, it is useful to briefly discuss the study by Kishi and Fujimoto (2010), who constructed a product architecture index using data on 97 products by 19 Japanese firms. To do so, they prepared 13 questions on product architecture characteristics and asked respondents to reply on a scale from 1 (=Fully disagree) to 5 (=Fully agree). For 89 of the 97 products, respondents answered with 4 or 5, indicating that the product architecture was integral. Apart from potential sample selection bias, a possible reason why products with an integral architecture appear to make up by far the largest share may be that the questions contained expressions that may have led respondents to reply in a certain way, such as the parts underlined in the following statements that respondents had to rate: "You cannot make a <u>decent</u> product appealing to customers by mixing standardized and custom parts and components" and "In order to achieve the required functionality, it is necessary to <u>meticulously</u> adjust the governing parameters of the production process to each other." Thus, while the study by Kishi and Fujimoto (2010) provides many important insights, we did our best to use neutral expressions in our survey questions.

Next, let us look at what type of firms tend to employ what type of product architecture. Starting with Japanese firms (panel (a) of Table 2), we find that firms employing integral architectures tend to be medium and large firms with 500 or more employees. By industry, software firms are more likely to employ modular architectures. Next, the situation for Korean firms is shown in panel (b). In Korea, whether firms belong to the machinery manufacturing sector or not has no bearing on whether they adopt an integral architecture. Finally, in China (see panel (c)), it is manufacturing firms other than machinery-related ones that tend to employ integral architectures, while firms in the software industry tend to employ modular architectures.

What are the implication of the above results? First, comparing the three countries, the findings suggest that in Japan and Korea, there is a relatively even split between firms employing a modular product architecture and firms employing an integral product architecture, whereas in China, a larger share of firms employ a modular architecture. An additional finding – which is not shown here to conserve space – is that Chinese firms display a strong inclination toward open interfaces. This result is close to Fujimoto and Shintaku's (2005) hypothesis that manufacturers in China tend to use quasi-open architectures (however, whether architectures are "quasi-open" is not something we can empirically confirm with the data used in this study).

However, second, we find that in China, as well as in Japan and Korea, even in the same industry and among firms of the same size, there is considerable variation in the use of modular and integral architectures and it cannot be said that a particular product architecture is dominant. That is to say, product architecture is not something that is exogenously determined by, for example, industry characteristics, but instead is strategically chosen by firms depending on a number of factors at a particular time.

3.2 HR management

Let us now turn to HR management practices and customs and see how large the differences among the three countries are. We start by looking at differences in recruitment methods, that is, whether firms tend to place greater emphasis on the internal training of new graduates or on mid-career recruitment. The results are shown in Figure 1, which suggests that Japan and China form the two ends of the spectrum, with firms in the former emphasizing the recruitment of new graduates and the latter emphasizing mid-career recruitment, while Korea falls between the two, although it lies closer to Japan.

Next, we turn our attention to how firms promote skill development by focusing on the emphasis they place on on-the-job training (OJT) and off-the-job training (off-JT). As shown in Figure 2, almost 100% of firms in Japan replied that “guidance and instruction by older colleagues and superiors” (which is thought to be a typical example of OJT) is “effective,” while the share among Korean and Chinese firms was only about 85–90%. That being said, it is clear that the large majority of firms from all three countries regard OJT as important. Where they differ, however, is in their attitudes to off-JT, which we measure in terms of firms’ response to the importance they attached to sending employees to graduate school: whereas very few Japanese firms consider this as effective, a considerable share of Korean and, especially, Chinese firms do (see Figure 3).

How should we interpret the different attitudes to skill development? It is likely that they are closely related to the issue of whether firms emphasize internal training of new graduates or mid-career recruitment. Expressed more generally, one could say that the difference reflects differences in attitudes toward investment in skills via the internal or the external labor market.

According to the theoretical analysis by Morita (2001), which aims to compare the situation in Japan and the United States, this difference in attitudes can be explained as follows. If innovation in a particular industry is incremental, the firm-specificity of technology increases. Employees are trained in this firm-specific technology through OJT, as a result of which the firm-specificity of skills also increases. The increase in firm-specificity of skills lowers employee turnover, which in turn raises firms’ demand for investment in skills. This kind of logic results in the equilibrium observed in Japan.

In contrast, when firms are not engaged in incremental innovation, the firm-specificity of technology and employees' skills is likely to be low, leading to higher employee turnover and low investment in skills through OJT. This would describe the equilibrium in the United States. Thus, it is the existence of these different equilibria the explains the different attitudes to skill development.

This logic can also be applied to the differences between China and Korea, where external labor market-orientation is high, and Japan, where this orientation is low. As the results of case studies conducted for three products (cell phones, LCD TVs, and information systems) in the three countries (see Tsuru and Morishima 2011) also made clear, employee turnover of engineers is high in China, followed by Korea, and is extremely low in Japan. Moreover, as seen in Figure 1, the emphasis on mid-career recruitment follows the same order, with Chinese firms putting greatest emphasis on mid-career recruitment, followed by Korea and then Japan. In contrast, the emphasis on OJT is in exactly the opposite order, with Japan followed by Korea and then China. Summing up the results, with regard to Chinese firms it could be said that although they stress OJT, they also put considerable emphasis on off-JT because they need to acquire skills immediately to compensate for insufficient internal skill development.

4. Econometric analysis: Are product architecture and HR management complementary?

The discussion so far has considered product architecture and HR management separately. The key question to be examined here, however, is what kind of combinations of the two result in superior (or inferior) development performance. In other words, the question is whether some kind of complementarity between the two can be observed and, if so, what form it takes.

4.1 Definition of complementarity

Milgrom and Roberts (1992: 108) define activities as mutually complementary if doing more of any one activity increases (or at least does not decrease) the marginal productivity of other activities. Or, to quote Roberts (2004: 37, emphasis in original):

"Complementarity involves the interactions among changes in different variables in affecting performance. […T]wo choice variables are complements when *doing (more of) one of them increases the returns to doing (more of) the other.*"

In terms of the topic discussed in this paper, what we are asking is whether product architecture and HR management are variables that involve interactions which affect the performance of product development activities overall or, in other words, whether a relationship such as that shown in Figure 4 can be observed. What Figure 4 shows is that what we expect is that when firms combine an integral architecture with a long-term orientation in HR management or, conversely, when they combine a modular architecture with a short-term orientation in HR management, development performance should be high. On the other hand, when firms implement different combinations from these two cases, we would expect development performance to be low. The purpose of the next subsections is to examine whether we indeed observe such a pattern.

4. 2 Observations based on contour graphs

In a three-dimensional figure such as Figure 4, it is difficult to depict a clear pattern with a relatively small data sample such as the one used in this paper. Therefore, we instead try to examine the three relationships among product architecture, HR management, and development performance using two-dimensional contour graphs.

Before, however, let us explain the construction of our variables (see Table 3). The key variables in our analysis are development performance, an index representing the extent to which the architecture of a product is integral or modular, and an index representing the degree to which the HR management of a firm is long-term or short-term oriented. Starting with our variable for development performance, we use the answer to the following question: "*With regard to your main product or information system, how do you rate your firm's development performance relative to the top level in your industry. Setting the top level in the industry to 10, please rate your firm's performance on a scale from 1 to 10*." Firms were asked to rate the following three items: (1) manufacturing quality; (2) development lead times and productivity; and (3) general product appeal and customer satisfaction. The average values for the three countries ranged from 7.9 to 8.3. [6]

Next, the product architecture index is constructed from answers to the question presented in Section 3.1 by converting answers (which ranged from 1 to 100) into interval values ranging from -1 to +1.

Finally, we construct the HR management index by calculating the average number of years of employment at each firm (which we standardize by adjusting for the average age of employees at each firm) and then, like we did for the product development index, converting the values into a variable that ranges from a minimum of -1 to a maximum of +1.

The purpose of this conversion is that when we take the cross-term of the product architecture index and the HR management index, the two combinations that we expect to yield the highest development performance – namely the combination of an integral product architecture (+1) and HR management with a long-term employment orientation (+1) as well as the combination of a modular architecture (-1) and HR management with a short-term employment orientation (-1) – yield a product of 1. In practice, as can be seen in Table 3, the minimum value of the cross term is -0.966 and the maximum value +0.865, i.e., we obtain values quite close to -1 and +1.

Let us now examine what the contour graphs for the three variables look like. To

[6] It could be argued that these indicators only provide a subjective assessment of performance. However, since the focus of this paper is the product or information system making the greatest contribution to turnover, objective indicators along the lines of firms' overall turnover or operating profit unfortunately are not available.

illustrate how the figures should be read, Figure 5 shows the hypothetical case for perfect complementarity. Like in a geographical map, dark regions represent areas with high elevation. Thus, in the top right corner for the combination of an integral architecture (+1) and long-term employment orientation (+1) as well as in the bottom left corner for the combination of a modular architecture (-1) and short-term employment orientation (-1), development performance is high, while in the other regions it is low.

Using the actual data, we start with the case of Japan, which is shown in Figure 6.[7] The figure indicates that development performance tends to be high in the top right and bottom left regions, although there are also other regions in which performance is high. Next, looking at Figure 7 for Korea, we find that although the pattern that performance in the top right and bottom left quadrants tends to be high, there are actually no firms in the neighborhood of the combination of integral architecture (+1) and long-term employment orientation (+1), which is very different from the situation for Japan. Finally, Figure 8 for China shows that, again, there are no firms in the top right corner of the graph. In addition, unlike for Japan and Korea, there appears to be no pattern suggesting that performance in the top right and bottom left quadrants is higher than in the other quadrants. However, it appears that in the middle regions, there are white spots where performance is relatively low. Thus, as far as we can tell from the contour graphs, a pattern of complementarity can be most clearly observed for Japan, followed by Korea, while no clear pattern can be observed for China.

4.3 Estimation strategy and results

While the contour graphs just presented provide a visual illustration of the patterns regarding the relationships among the three variables, they do not consider (i.e., control for) anything other than the three variables. In the next step, we therefore employ econometric analysis to examine if the way product architecture and HR

[7] Development performance here and in the other contour graphs is measured in terms of manufacturing quality.

management are combined affects product performance, controlling for other factors.

Specifically, we estimate the following specification:

$$performance_i = \alpha + \beta_1 architecture_i + \beta_2 HRM_i + \beta_3 (architecture_i \times HRM_i) + \varepsilon_i$$

where the dependent variable, $performance_i$, is the development performance index of firm *i*. We conduct the estimation using each of the three different types of development indicators discussed in Section 4.2. Next, $architecture_i$ is the product architecture index of firm *i*, while HRM_i is the HR management index of firm *i*.

The variable of greatest interest for capturing complementarity is the cross-term of $architecture_i$ and HRM_i, $(architecture_i \times HRM_i)$. By definition, if product architecture and HR management are combined in the most appropriate manner (that is, the combination of a modular architecture with short-term employment orientation or integral architecture with long-term employment orientation), the cross-term takes a value close to +1, and when they are combined in the opposite manner, the value approaches –1. Given our hypothesis that if product architecture and HR management are complementary, development performance should increase, we expect the coefficient on the cross-term, β_3, be positive.

Before we start our estimation, however, further adjustments are necessary. That is, although fundamentally we follow the estimation strategy just described, it is necessary to further adjust the estimation equation in order to accurately measure the effect brought about by this complementarity. The reason is that HR management and product architecture may affect development performance through channels other than the channel assumed here. In other words, unless we control for those other channels, we cannot correctly test our hypothesis.

This is most easily explained by referring to Figure 9, where the solid lines represent the causal links assumed in our hypothesis. That is, we assume that product architecture is chosen based on product market conditions and organizational design. Further, there is assumed to be a complementary relationship between this product architecture and HR management, which in turn affects development performance.

Thus, what we are examining here is whether the channel shown by the solid line exists or not. However, market factors and organizational design obviously may affect development performance not only through product architecture as in the channel depicted by the solid line, but may each affect development performance directly. These channels are shown by the broken lines.

In order to isolate the channel depicted by the solid line, it is necessary to control for the channels shown by the broken lines. To do so, we add to the equation various variables on product characteristics, HR systems and practices, and market conditions, as well as on firm characteristics, and try to control for the effect of these in the estimation. Summary statistics of the variables used are provided in Table 3, while specific control variables used are shown under B, C, D, E, and F in Table 4.

Moreover, in addition to estimating complementarity effects for all countries together, we also tried estimating them for each country separately by employing cross-terms of dummies for Korean and Chinese firms with the complementarity index, using Japanese firms as the reference group.

The estimation results are shown in Table 4. The estimation was conducted for each of the three performance indicators (manufacturing quality; lead time and productivity; and general product appeal and customer satisfaction) and the results are shown in each of the columns. We start with the row for the "Cross-term of product architecture index and HR management index (Japan, base)," which shows the coefficient on the complementarity index for Japan. As can be seen, the coefficient is positive and significant for all three development performance indicators. This means that, in Japan, if product architecture and HR management are combined in the appropriate manner, development performance increases. The result thus can be said to be consistent with our hypothesis.

Next, turning to Korea, we look at what we call the "complementarity coefficient for product architecture and HR management," which we obtain by summing the baseline coefficient in the first row and the coefficient in the second row (× Korea dummy). This result is shown in the lower part of Table 4 under "Complementarity coefficient for product architecture and HR management" for Korea. For example, looking at the first column, the baseline coefficient in the first row is 8.368, while the coefficient in the second row for the cross-term with the Korea dummy is -6.576. Therefore, the coefficient for the complementarity effect in Korea is the sum of these two values, 1.791, which is shown in the lower part of Table 4. However, looking at the F-value for this estimation, we find that this is not significantly different from zero. Therefore, we did not find any statistically significant complementarity between product architecture and HR management in Korea. This is the case irrespective of which development performance indicator is used.

Turning to the results for China, we obtain positive estimates for the first two development performance indicators (in the first two columns), but neither is significantly different from zero, so that we did not obtain any significant results.

Summing up the above results, we find that in Japan, if product architecture and HR management are combined in the right way, this significantly raises development performance. Because in our estimation we controlled for factors other than the channel we are interested in, this result strongly supports our hypothesis. However, although our estimates of the coefficients on the complementarity index for Korea and China generally take positive values, they are not statistically significant. This provides at best weak support for our hypothesis. However, this result may reflect the fact that our model specification assumes that the relationship between the complementarity index and development performance is linear. In the next section, we consider this point in greater detail.

4.4 Interpretation of results and further analysis

How should we interpret the estimation results with regard to the three countries? The following two interpretations are possible.

First, we found that only for Japan the complementarity coefficient was positive and significant, while for Korea and China, although positive, it was not significant. This implies that while in Japanese firms the relationship between product architecture and HR management is relatively consistent, this is not the case in Korean and Chinese firms. A potential explanation is that Korea and China as "late developers" are still in the process of establishing complementarity.

Second, however, a different interpretation is also possible. In the preceding analysis, it was assumed that there is a linear relationship between the combination of product architecture and HR management on the one hand and development performance on the other.

Let us relax this assumption and examine whether there might be a non-linear relationship by dividing the range of values that the cross-term of the product architecture index and the HR management index can take, i.e., -1 to +1, into ten intervals. That is, we construct dummy variables for the different intervals, with the first one taking a value of 1 for the interval from -1.0 to -0.8 (which we refer to as Interval 0), the next one taking a value of 1 for the interval from -0.8 to -0.6 (Interval 1), and so on in intervals of 0.2 up to Interval 9. Adding these dummies to the specification, we then re-run the regressions shown in Table 4. In other words, we look at the effect of the size of the cross-term on development performance (relative to the worst case=Interval 0).

The results are shown in Table 5. As can be seen, for Japanese firms, the coefficients increase non-linearly from Interval 2 to Interval 9 (the baseline for Japan is Interval 1, since there are no firms in Interval 0). In other words, the appropriate combination of product architecture and HR management does not affect development performance in a linear fashion; instead, as firms move in the direction of the appropriate combination of product architecture and HR management, development performance gradually increases. Put differently, if firms adopt an integral product architecture and do not do so thoroughly, and, moreover, do not thoroughly adopt HR management oriented toward long-term employment alongside it, their development performance will also not be very high. Conversely, this means that if firms adopt a modular architecture and short-term oriented HR management, they have to do so thoroughly.

This relationship is even more pronounced for Korean firms. Development performance increases gradually towards Interval 9. That is, it appears that one reason why simply including the cross-term did not yield significant estimates in the case of Korea in Table 4 is that the relationship between the combination of product architecture and HR management on the one hand and development performance on the other is non-linear. Thus, in Korea, too, firms that properly combined product architecture and HR management achieved high development performance. However, even in intermediate intervals between the best and the worst combination, an increase in performance can be observed.

Finally, looking at the case of China, we find that while there are no firms that fall into Intervals 8 and 9, coefficients for the range from Interval 3 to Interval 7 are positive and significant, indicating that when the appropriate combination is chosen, development performance increases. Therefore, we find that, at least compared with the worst case, the appropriate combination gives rise to higher development performance. Yet, while – in contrast with Japan and Korea – there are no firms that fall into Intervals 8 and 9 (second best and best), knowledge transfers (for example through product development by Japanese and Korean firms in China and through business partnerships with Chinese firms) may lead Chinese firms to choose more appropriate combinations of product architecture and HR management. The impact of such activities by Japanese and Korean firms on Chinese firms is an issue that requires further research.

5. Conclusion

The key aim of this paper was to empirically examine the complementarity between product architecture and HR management and its impact on development performance. The findings of the paper can be summarized as follows.

First, in Japan and Korea, firms were more or less evenly divided between those employing a modular and those employing an integral architecture. On the other hand, in China, more firms employed a modular architecture.

Second, with regard to HR management practices and customs, there were differences in the emphasis of internal training of new graduates and the emphasis of mid-career recruitment. Japan and China are at the two extremes, with firms in the former tending to emphasize the recruitment of new graduates and firms in the latter emphasizing mid-career recruitment, while firms from Korea were in-between, but closer to Japan.

Third, we found that, in Japan, development performance was significantly higher when product architecture and HR management were appropriately combined. However, we did not find such significant effect for the case of Korea and China.

And fourth, we found that when we drop the assumption that the relationship between the combination of product architecture and HR management on the one hand and development performance on the other is linear and examine the non-linear effect of the former on the latter, both in Japan and Korea, the more firms approach the best combination, the more their development performance increases.

We would like to close this paper by pointing out some implications of the results obtained here. First, except for the case of Chinese firms, we were able to confirm the complementarity of product architecture and HR management in affecting development performance when taking into account that the relationship between the combination of product architecture and HR management on the one hand and development performance on the other is not necessarily linear. Specifically, we found that as complementarity between product architecture and HR management increases, development performance gradually increases with this. This suggests that if firms move even only a little in the direction of correctly aligning product architecture and HR management, this will raise their development performance. Particularly for China this means that while at present there are few firms that fully align product architecture and HR management, by learning how to do so they should be able to raise their development performance.

And second, the results for Japan suggest that the traditional combination of integral architectures and long-term oriented HR management is not automatically superior and that the right combination of the other extreme – modular architectures combined with short-term oriented HR management – also represents a quite viable strategy. It is often said that Japan's *forte* lies in the development of integral architectures (see, e.g., Fujimoto 2001). However, the results here suggest that if Japanese firms chose the appropriate HR management approach, they could be equally successful in the development of modular architectures. It is frequently argued that Japanese firms focus excessively on quality and design. The reason, although at present this is only speculation, may be that firms do not sufficiently consider product characteristics and market conditions, and excessively and, moreover, uniformly rely on the development of integral architectures. In the future, Japanese firms need to make careful strategic choices with regard to product architecture and HR management based on a close monitoring of the competition from Korea and China. Elucidating the conditions necessary to achieve this is a topic left for future research.

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Table 1. Population and sample

(a) Japan

		Population	No. of responses	Response rate
Total		3,504	104	3.0%
By no. of employees	Fewer than 300	1,345	50	3.7%
	300–499	882	24	2.7%
	500–999	666	18	2.7%
	1,000 or more	611	12	2.0%
By industry	Manufacturing	3,115	89	2.9%
	Software	389	15	3.9%

Notes: 1. Sample firms were drawn from the business information database of Tokyo Shoko Research, Ltd.
2. Firms with 185 or more employees only.

(b) Korea

		Population	No. of responses	Response rate
Total		738	140	19.0%
By no. of employees	Fewer than 300	69	38	55.1%
	300–499	354	34	9.6%
	500–999	194	40	20.6%
	1,000 or more	121	28	23.1%
By industry	Manufacturing	656	121	18.4%
	Software	82	19	23.2%

Notes: 1. Sample firms were drawn from the 2008 *Survey of Establishments* .
2. Firms with more than 300 employees (manufacturing sector) and 150 employees (software) only.

(c) China

Region	Industry	Population	Firms contacted	No. of responses	Response rate
Shanghai	Manufacturing	5,558	487	35	7.2%
	Software	188	57	5	8.8%
Beijing	Manufacturing	9,792	403	30	7.4%
	Software	206	132	10	7.6%
Guangzhou	Manufacturing	27,481	528	35	6.6%
	Software	117	52	5	9.6%
Shenzen	Manufacturing	17,215	341	30	8.8%
	Software	9	0	0	0.0%

Notes: 1. Sample firms were drawn from the *Yearbook of Chinese Companies* (Shanghai) and a list of companies provided by the State Administration for Industry and Commerce (Beijing, Guangzhou, Shenzen).
2. Firms with more than 300 employees (manufacturing sector) and 50 employees (software sector) only.

Table 2. Product architecture

(a) Japan

Unit: %

		No. of respondents	Modular	Integral
			1st & 2nd quartile	3rd & 4th quartile
Total		75 (100%)	50.7	49.4
By no. of employees	Fewer than 300	35 (100%)	45.7	54.2
	300–499	16 (100%)	62.6	37.6
	500–999	16 (100%)	43.8	56.3
	1,000 or more	8 (100%)	62.5	37.5
By industry	Manufacturing	64 (100%)	48.5	51.6
	Machinery	33 (100%)	51.5	48.5
	Other than machinery	31 (100%)	45.2	54.8
	Software	11 (100%)	63.7	36.4

(b) Korea

Unit: %

		No. of respondents	Modular	Integral
			1st & 2nd quartile	3rd & 4th quartile
Total		132 (100%)	50.0	50.0
By no. of employees	Fewer than 300	36 (100%)	52.8	47.2
	300–499	32 (100%)	43.8	56.3
	500–999	39 (100%)	53.8	46.1
	1,000 or more	25 (100%)	48.0	52.0
By industry	Manufacturing	114 (100%)	50.0	50.0
	Machinery	72 (100%)	50.0	50.0
	Other than machinery	42 (100%)	50.0	50.0
	Software	18 (100%)	50.0	50.0

(c) China

Unit: %

		No. of respondents	Modular	Integral
			1st & 2nd quartile	3rd & 4th quartile
Total		150 (100%)	57.4	42.7
By no. of employees	Fewer than 300	11 (100%)	100.0	0.0
	300–499	99 (100%)	49.5	50.5
	500–999	25 (100%)	72.0	28.0
	1,000 or more	15 (100%)	53.3	46.7
By industry	Manufacturing	130 (100%)	55.4	44.6
	Machinery	31 (100%)	58.1	41.9
	Other than machinery	99 (100%)	54.5	45.5
	Software	20 (100%)	70.0	30.0

Figure 1. Emphasis on new graduate recruitment or mid-career recruitment

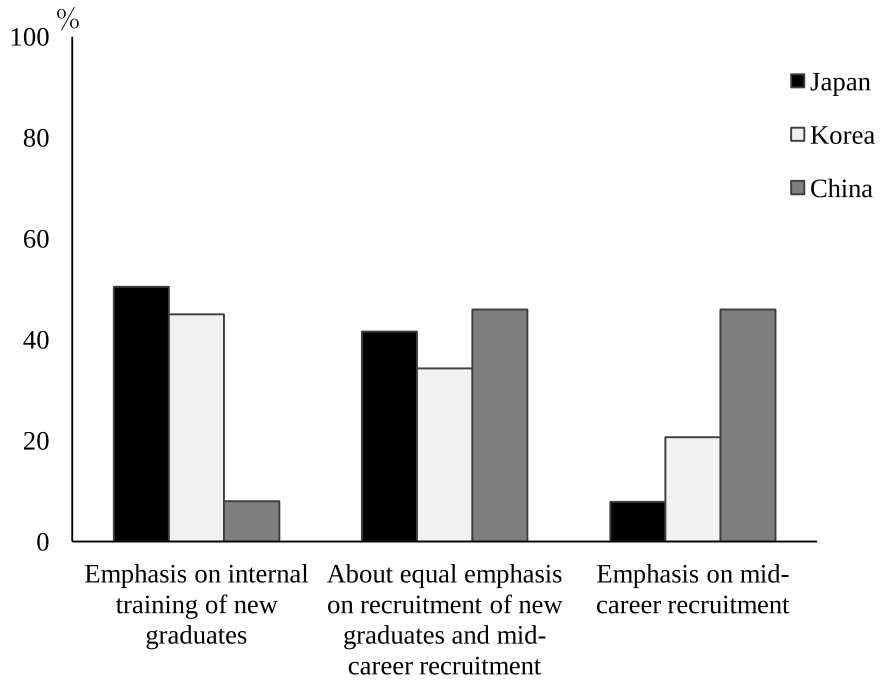


Figure 2. Attitudes to on-the-job training

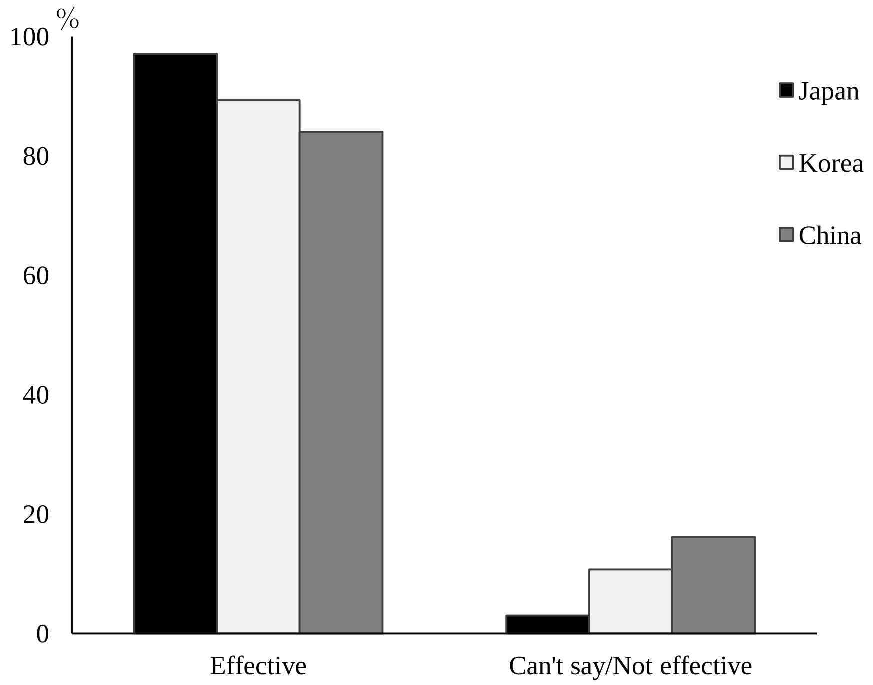


Figure 3. Attitudes to off-the-job training

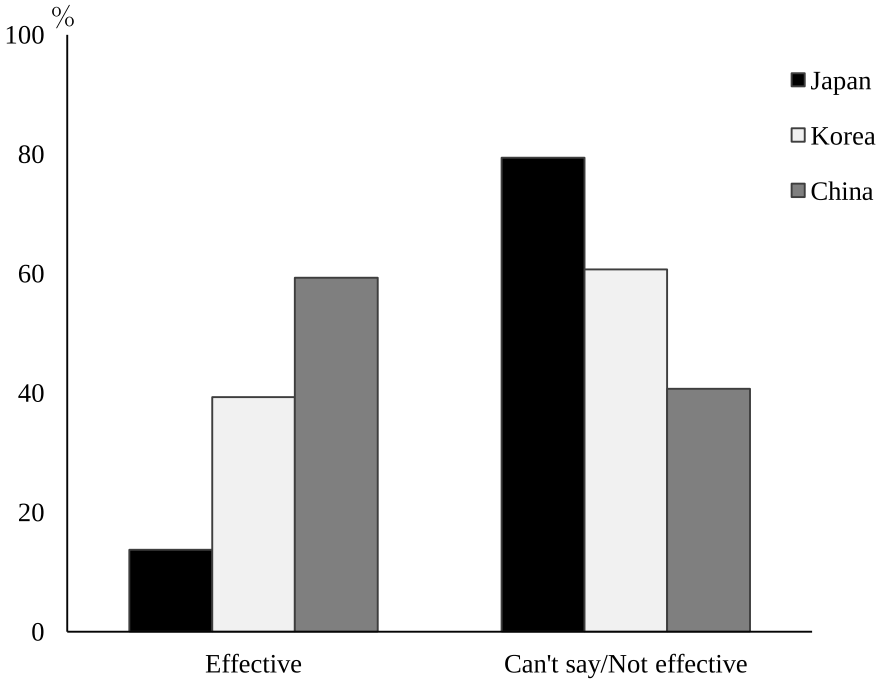


Figure 4. Relationship among product architecture, HR management, and development performance (3-dimensional representation)

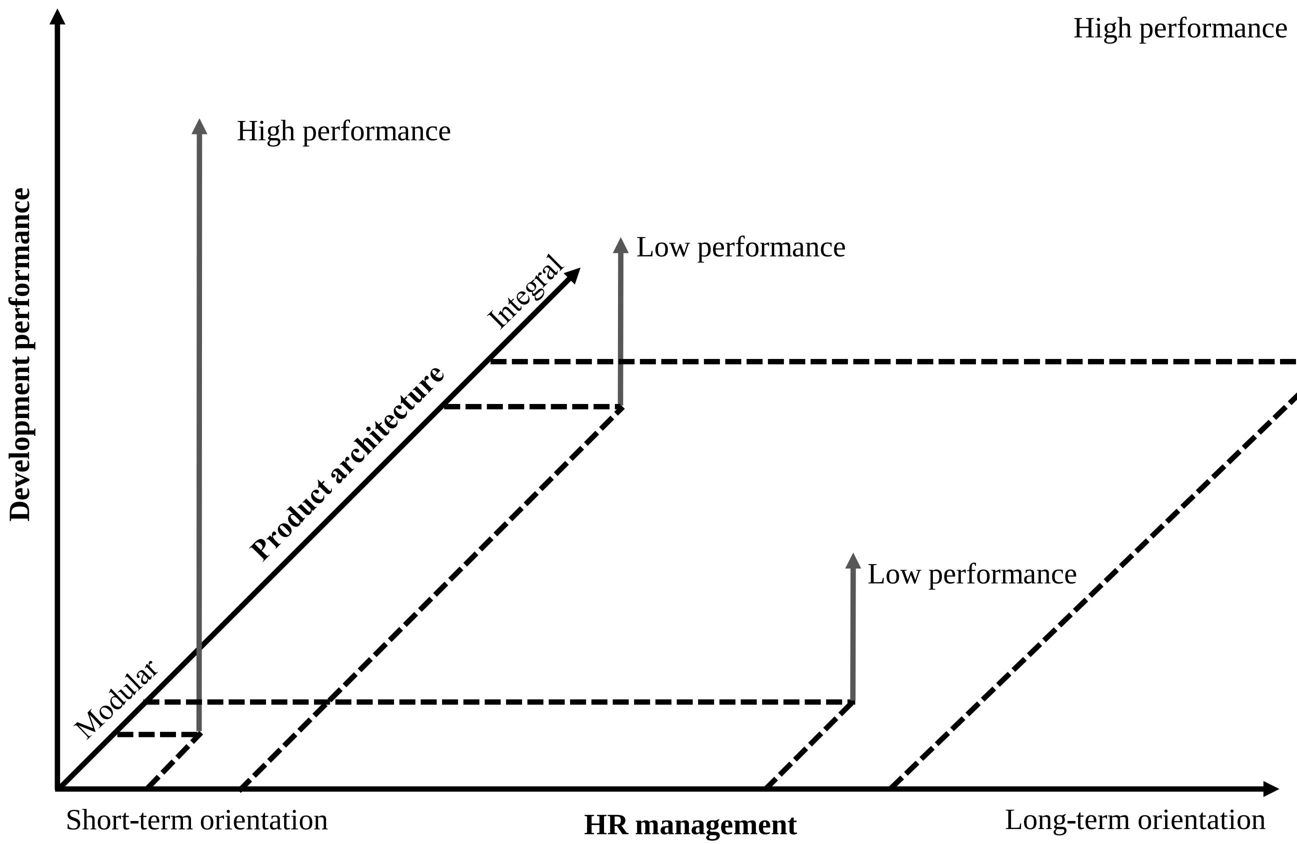
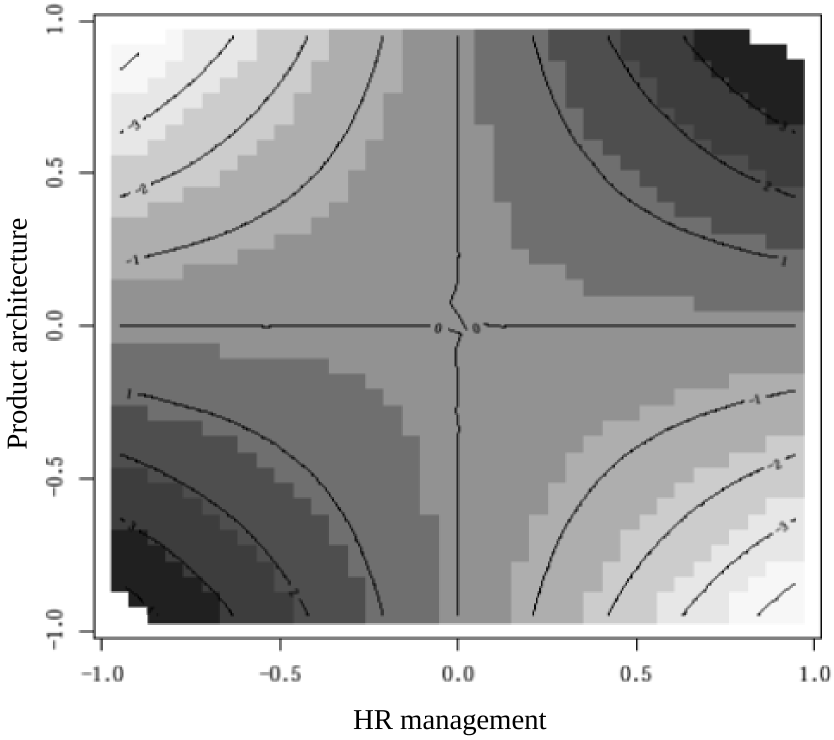
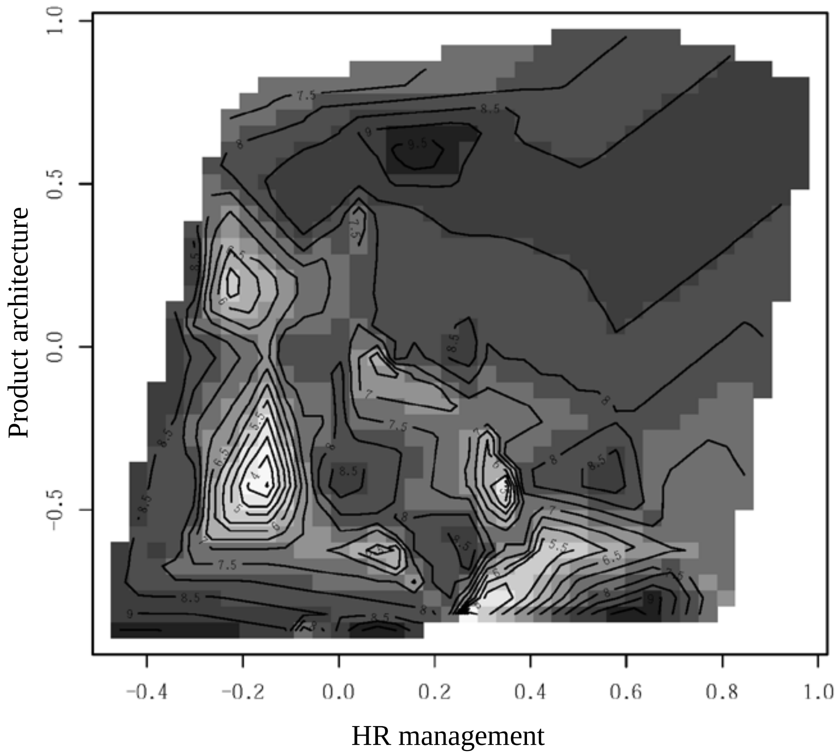


Figure 5. Relationship among product architecture, HR management, and development performance (Contour graph)



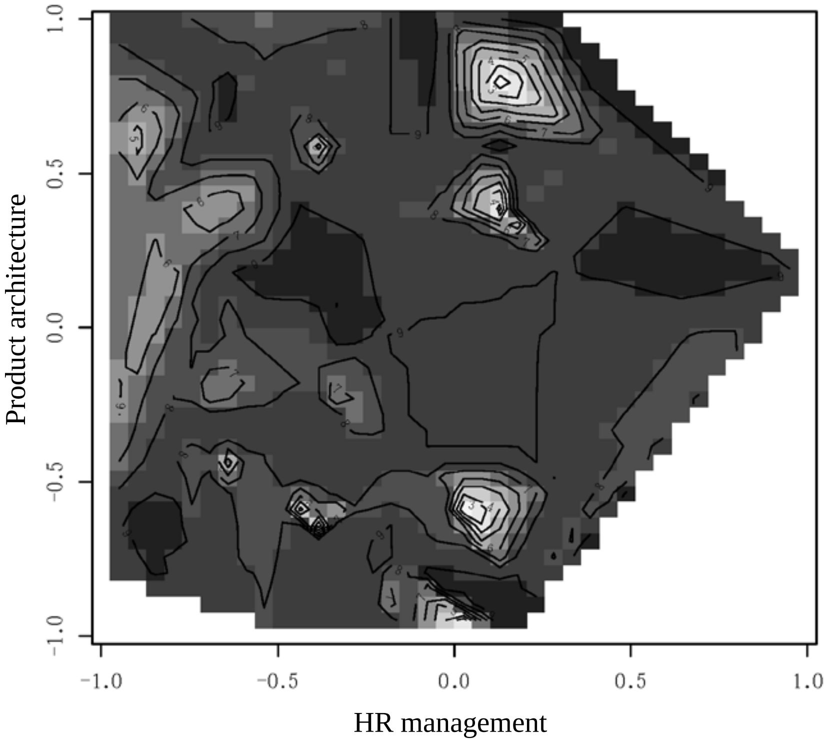
Note: A value of -1 for the product architecture index corresponds to a modular architecture, while a value of +1 corresponds to an integral architecture. Moreover, a value of -1 for the HR management index corresponds to short-term employment orientation, while a value of +1 corresponds to long-term employment orientation.

Figure 6. Contour graph (Japan)



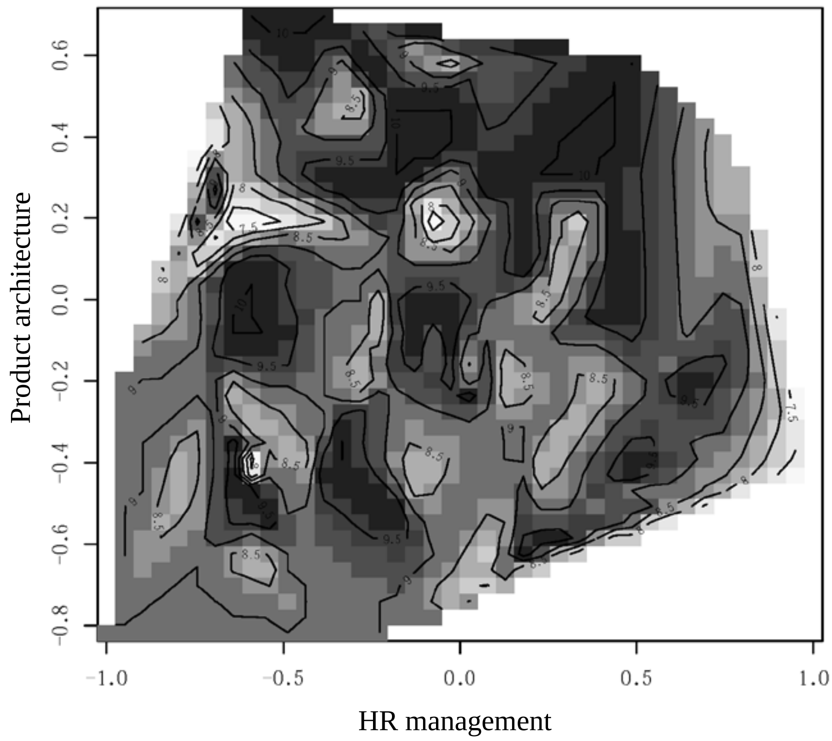
Note: A value of -1 for the product architecture index corresponds to a modular architecture, while a value of +1 corresponds to an integral architecture. Moreover, a value of -1 for the HR management index corresponds to short-term employment orientation, while a value of +1 corresponds to long-term employment orientation.

Figure 7. Contour graph (Korea)



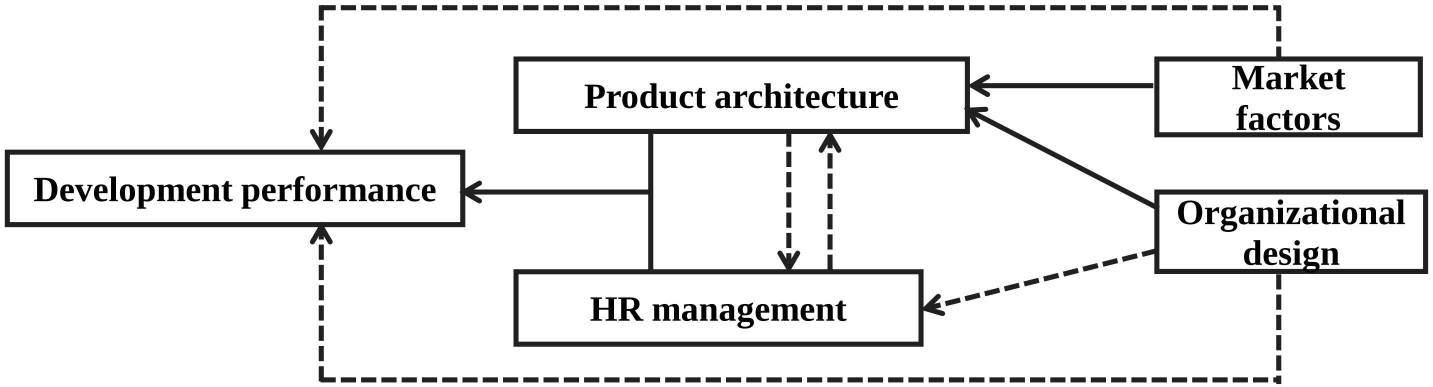
Note: A value of -1 for the product architecture index corresponds to a modular architecture, while a value of +1 corresponds to an integral architecture. Moreover, a value of -1 for the HR management index corresponds to short-term employment orientation, while a value of +1 corresponds to long-term employment orientation.

Figure 8. Contour graph (China)



Note: A value of -1 for the product architecture index corresponds to a modular architecture, while a value of +1 corresponds to an integral architecture. Moreover, a value of -1 for the HR management index corresponds to short-term employment orientation, while a value of +1 corresponds to long-term employment orientation.

Figure 9. Basic structure of the estimation model



Note: The solid lines in the graph show the causal chain we assume in our model. However, organizational design and market factors naturally are likely to affect development performance directly as well as indirectly through development performance. Therefore, it is necessary to explicitly control for the links indicated by the broken lines.

Table 3. Summary statistics

	No. of observations	Average	Std. err.	Min.	Max.
Development performance 1 (Manufacturing quality)	379	8.317	1.605	1	10
Development performance 2 (Lead time; productivity)	379	7.900	1.597	1	10
Development performance 3 (Product appeal; customer satisfaction)	379	8.092	1.458	1	10
Product architecture index (+1 = modular; -1 integral)	357	-0.122	0.469	-1	1
HR management index (-1=short-term; +1: long-term)	379	-0.475	0.498	-1	1
Cross-term of product architecture index and HR management index	353	0.051	0.355	-0.966	0.865
Dummy for machinery manufacturing industry (Reference: software industry)	394	0.376	0.485	0	1
Dummy for non-machinery manufacturing industry (Reference: software industry)	394	0.487	0.500	0	1
Index of use of product-specific parts	362	52.721	25.419	2	100
Index of openness/closedness of product interfaces	349	48.676	25.846	2	100
Dummy for emphasis on recruitment of new graduates (Emphasis on new graduates = 1)	394	0.320	0.467	0	1
Emphasis on monetary incentives (5-step variable)	392	1.679	0.685	1	5
Emphasis on off-JT (Sending employees to graduate school; 5-step variable)	392	2.737	0.887	1	5
Dummy for use of skill grade system (Use = 1)	394	0.335	0.473	0	1
Dummy for use of unified HR system throughout company (Unified = 1)	394	0.721	0.449	0	1
Dummy for organization by function (If yes = 1)	394	0.619	0.486	0	1
Dummy for make-to-order production (Make-to-order = 1)	394	0.640	0.481	0	1
Company turnover (log)	356	8.702	2.584	2.303	16.213
Years since establishment	394	3.059	0.845	0	4.575
No. of employees (log)	394	6.105	0.816	3.912	10.162

Table 4. Determinants of development performance

	Development performance 1 (Manufacturing quality)	Development performance 2 (Lead time; productivity)	Development performance 3 (Product appeal; customer satisfaction)
A. Product architecture and HR management variables			
Cross-term of product architecture index and HR management index (Japan, base)	8.368 **	9.363 *	8.724 *
	(4.013)	(5.571)	(4.554)
Cross-term of product architecture index and HR management index (×Korea dummy)	-6.576	-7.397	-6.593
	(7.008)	(7.502)	(6.626)
Cross-term of product architecture index and HR management index (×China dummy)	-7.628 *	-8.778	-9.382 **
	(4.083)	(5.627)	(4.593)
Product architecture index (Japan, base)	7.076 **	7.748 *	7.295 **
	(3.073)	(4.366)	(3.485)
Product architecture index (×Korea dummy)	-5.341	-5.888	-5.122
	(5.968)	(6.268)	(5.557)
Product architecture index (×China dummy)	-6.784 **	-7.796 *	-7.296 **
	(3.071)	(4.381)	(3.482)
HR management index (Japan, base)	0.903	1.776	1.050
	(2.618)	(3.218)	(2.551)
HR management index (×Korea dummy)	1.509	0.232	0.017
	(3.781)	(4.291)	(3.493)
HR management index (×China dummy)	-0.738	-1.489	-1.109
	(2.613)	(3.223)	(2.543)
B. Control variables for product characteristics			
Index of openness/closedness of product interfaces	0.009 **	0.005	0.007
	(0.005)	(0.005)	(0.005)
Index of use of product-specific parts	-0.001	-0.005	0.001
	(0.005)	(0.005)	(0.004)
C. Control variables for HR system and practices			
Dummy for organization by function (If yes = 1)	0.158	0.306 *	0.249
	(0.174)	(0.176)	(0.162)
Dummy for use of skill grade system (Use = 1)	-0.025	0.095	-0.003
	(0.196)	(0.202)	(0.185)
Dummy for use of unified HR system throughout company (Unified = 1)	0.032	-0.019	0.036
	(0.193)	(0.185)	(0.171)
Emphasis on monetary incentives (5-step variable)	-0.163	-0.019	0.015
	(0.137)	(0.119)	(0.105)
Emphasis on off-JT (Sending employees to graduate school; 5-step variable)	-0.021	-0.168 *	-0.104
	(0.099)	(0.100)	(0.088)
Dummy for emphasis on recruitment of new graduates (Emphasis on new graduates = 1)	-0.006	0.081	0.153
	(0.264)	(0.247)	(0.236)
D. Control variable for market conditions			
Dummy for make-to-order production (Make-to-order = 1)	-0.090	-0.062	0.022
	(0.164)	(0.165)	(0.153)
E. Control variables for firm characteristics			
Company turnover (log)	-0.077	-0.042	-0.069
	(0.068)	(0.051)	(0.060)
Years since establishment	0.082	0.158	0.144
	(0.144)	(0.138)	(0.114)
No. of employees (log)	0.152	0.304 **	0.238 *
	(0.134)	(0.133)	(0.122)
Dummy for machinery manufacturing industry (Reference: software industry)	0.398	0.027	0.277
	(0.336)	(0.294)	(0.271)
Dummy for non-machinery manufacturing industry (Reference: software industry)	0.146	-0.087	0.118
	(0.324)	(0.302)	(0.273)
F. Other variables			
Constant	7.571 ***	6.550 **	6.338 ***
	(2.128)	(2.729)	(2.047)
Korea dummy	1.632	1.255	0.613
	(3.214)	(3.548)	(2.947)
China dummy	0.562	0.343	0.551
	(2.051)	(2.561)	(1.975)
Complementarity coefficient for product architecture and HR management			
Japan	8.368 **	9.363 *	8.724 *
Korea	1.791	1.967	2.131
China	0.740	0.585	-0.658
No. of observations	324	324	324
F-value	3.90	4.19	3.42
Adj. R-squared	0.2113	0.2373	0.2003

Note: Figures in parentheses are standard errors. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Table 5. Estimation results for interval dummies for combination of product architecture and HR management

	Japan	Korea	China
Interval 1 (Second worst)	Baseline	1.775	N.A.
		(1.359)	
Interval 2	1.525	2.852 *	Baseline
	(1.395)	(1.617)	
Interval 3	1.198	3.671 *	2.218 ***
	(1.983)	(2.182)	(0.483)
Interval 4	1.560	6.054 **	2.193 ***
	(2.391)	(2.884)	(0.404)
Interval 5	1.948	7.383 **	2.233 ***
	(3.191)	(3.653)	(0.474)
Interval 6	1.242	9.409 **	2.315 ***
	(4.012)	(4.721)	(0.608)
Interval 7	2.506	9.993 *	2.566 ***
	(4.590)	(5.285)	(0.523)
Interval 8 (Second best)	3.583	12.540 **	N.A.
	(5.032)	(5.972)	
Interval 9 (Best)	5.560	14.910 **	N.A.
	(5.426)	(6.831)	
Control variables included	Yes	Yes	Yes

Notes: Figures in parentheses are standard errors. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively. N.A. means that there were no firms in this interval. The baseline for South Korea is Interval 0 (Worst).