INFLUENCE OF KNOWLEDGE-BASED RESOURCE VARIETY AND PROCESS FLEXIBILITY ON PRODUCT INNOVATION: EMPIRICAL EVIDENCE FROM NORTH AMERICAN AND EUROPEAN MANUFACTURERS

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Abstract

This research asserts that the operations-based capabilities of process flexibility and product innovation result from the leveraging of competitive strengths on multiple and diverse knowledge-based resources, the set of which we call "K-B resource variety." K-B resource variety is operationalized as manufacturers' intellectual capital. Intellectual capital is comprised of 1) *structural capital* (e.g., codified knowledge in state-of-the-art manufacturing processes and superior information systems) and *human capital* (e.g., tacit and explicit knowledge manifest through the technical skill levels of the workforce and relative organizational learning capabilities). A recursive latent variable model is presented and tested relating K-B resource variety directly to process innovation and indirectly through process flexibility capabilities. In addition to assessing an operationalization of the K-B resource variety construct using confirmatory factor analysis, a multigroup analysis using the structural equation methodology was conducted to test the invariance of the research model and parameter estimates across two geographic operating regions: North America and Europe. Results from this research confirm the hypothesized positive impact of K-B resource variety on process flexibility and product innovation across both regions. Of theoretical interest are empirical findings that the parameter estimates indicating the influence of K-B resource variety on process innovation is invariant across firms within these regions. In contrast, the impact of process flexibility on product innovation was also positive as hypothesized, but was not invariant for firms between these regions. Our findings have important managerial implications for the development and management of a portfolio of knowledge-based resources for improving the effectiveness of product innovation processes. We believe that our results are especially meaningful for firms competing in clockspeed industries, where process flexibility and product innovation are frequently order-winning capabilities. For these firms in clockspeed sectors, we posit for future research that leveraging the promise of K-B resource variety becomes especially critical.

1. Introduction

The last decade has witnessed dramatic changes in the business environment, including technological advancements and globalization that have transformed the fundamental nature of competition in manufacturing (Clark, 1996; Flaherty, 1996; Roth, 1996; Hayes and Pisano, 1994). As a result, manufacturing firms face the inevitability of constant change. One strategy for confronting this inevitability has been through an emphasis on manufacturing process flexibility. A complimentary strategy for confronting this inevitability of constant change has been through an emphasis on product innovation (Deszca, Munro and Noori, 1999; Utterback, 1995; Brown and Eisenhardt, 1995).

The primary premise underlying this research is that the operations-based capabilities of process flexibility and product innovation result directly from the leveraging of a portfolio of knowledge-based resources, what we coin "K-B resource variety." K-B resource variety is a proxy for a manufacturer's relative intellectual capital. Intellectual capital, in turn, is comprised of 1) *structural capital* (e.g., codified knowledge in state-of-the-art manufacturing processes and superior information systems) and *human capital* (e.g., tacit and explicit knowledge manifest through the technical skill levels of the workforce and relative organizational learning capabilities) (Stewart, 1999). Emanating from the cybernetic work of Ashby (1956, 1958) on requisite variety and complex systems, theory suggests that those manufacturers with high degrees of K-B resource variety are more apt to be competitively successful. They can better leverage their intellectual capital to address varying and unpredictable marketplace demands. Thus, we posit that K-B resource variety is critical to the development of order-winning capabilities (Hayes and Pisano, 1994; Hill, 1989; Miller and Roth, 1994; Roth and Giffi, 1991). Therefore, the first research question we empirically examine asks: What is the influence of K-B resource variety on process flexibility and product innovation in manufacturing?

Research in global manufacturing (Vastag and Whybark, 1994; Roth, De Meyer and Amano, 1989; Miller and Roth 1994; Roth and Miller, 1990; Roth 1996; De Meyer, Nakane, Miller and Ferdows, 1989) is premised on the belief that manufacturing strategies and tactics differ between global operating regions and environments. Additionally, research in global manufacturing has traditionally focused on similarities and differences in specific practices or priorities / capabilities (see Roth, Gray, Singhal and Singhal, 1997; Whybark, 1997). Studied to a lesser extent are the similarities and differences in relationships linking manufacturing strategies (i.e., patterns of resource choices, see Giffi, Roth and Seal, 1990) with priorities / capabilities (Miller and Roth, 1994). Building upon this nascent research stream, the second research question we empirically examine asks: Is the pattern of relationships between K-B resource variety, process flexibility and product innovation invariant across geographic operating regions? Much empirical evidence exists indicating the business performance effects of product innovation. However, little empirical evidence exists that directly examines the influence of intellectual capital and process flexibility on product innovation capabilities.

After a brief review of the research literature and presentation of the research model and hypotheses, the remainder of this paper is organized into five sections. First, an overview of the research database and sample used in this analysis is provided. Additionally, the operationalizations of the latent constructs are detailed. Second, the measurement and latent variable models are specified. Third, the measurement and latent variable model fit is evaluated. Fourth, a discussion of the research results and their managerial and research implications is presented. Lastly, we offer our research conclusions.

2. Literature Review, Research Model and Hypotheses

Operations-based capabilities refer to a firm's realized or actual competitive strength on its manufacturing tasks relative to primary competitors in its target market (Miller and Roth 1994; Roth and van der Velde, 1991; Wheelwright 1978). Companies gain an enduring competitive advantage through building these unique capabilities (Hayes, Wheelwright, and Clark 1989; Hayes and Upton, 1998; Prahalad and Hamel, 1990; Roth 1996). In this research we investigate the impact of leveraging this competitive strength on multiple and diverse knowledge-based resources , or *K-B resource variety*, on the operations-based capabilities of *process flexibility* and *product innovation*. The relationships between K-B resource variety and these operations-based capabilities are diagrammed in figure 1. The hypotheses are formally stated in sub-section 2.2.

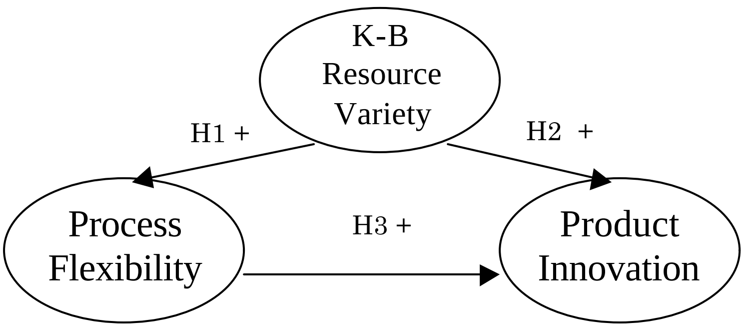

Figure 1: Model Linking K-B Resource Variety with Process Flexibility and Product Innovation

2.1 Operations-based Capabilities

Operations-based capabilities result from a coherent pattern of choices (Miller and Roth, 1994; Wheelwright 1978) that constitute a set of differentiated skills, complementary assets, and routines that provide the firm with a sustainable advantage in a particular industry (Teece, Pisano and Shuen, 1997). Manufacturing process flexibility has widely been recognized as one of the fundamental operations-based capabilities for time-based competition. Along with quality, delivery, and cost, a firm can differentiate itself by its ability to adjust or modify the operational processes to speedily accommodate changes required by the marketplace, for example, in production volumes or product mix (Koste and Malhotra, 1999; Anderson, Cleveland and Schroeder, 1989).

Besides interest in process flexibility, product innovation has increasingly been acknowledged as a critical "operation-based" (versus R&D or marketing) capability for competing on time (Swink and Hegarty, 1998; Leong, Snyder and Ward, 1990; Giffi, Roth and Seal, 1990). Much of the general literature on innovation makes the implicit assumption that innovation is important and beneficial for an organization, be it process-related (Gopalakrishnan and Damanpour, 1997; Subramanian and Nilakanta, 1996) or product-related (Wind and Mahajan, 1997). A number of academicians have noted conceptually the criticality of managing dissimilar resources synergistically (e.g., technology, teams, design tools, organizational structures) in order to achieve product innovation success (Cooper, 1999; Schilling and Hill, 1998; Kessler and Chakrabarti, 1996; Brown and Eisenhardt, 1995; Van de Ven, 1986). Little empirical support demonstrating this criticality currently exists.

2.2 K-B Resource Variety and Research Hypotheses

Conventional wisdom posits the importance of process flexibility and product innovation on business performance. However, less understood is the importance of the intellectual capital in manufacturing, especially regarding how competitive strengths acquired due to accumulating a variety of knowledge-based resources influences process flexibility and product innovation. Ashby's (1956, 1958) "law of requisite variety" succinctly posits that only variety can destroy variety. As defined in cybernetics, variety represents a multiplicity of distinctions; its existence is necessary for change and choice to occur. Extending this "law of requisite variety" from cybernetics to the management of knowledge-based resources is straightforward. In more static and supportive environments, it may be optimal for a firm to invest in, and utilize, a few similar K-B resources, such as codified structural capital in production processes to capitalize on economies of scale. Under these conditions, however, there may be an inefficiency in resource utilization if the collective set of resource investments are multiple and diverse in nature. As the operating environment becomes more dynamic and competitive, having slack multiple and diverse sources of intellectual capital may actually be more advantageous. Here this K-B resource variety provides the firm with a greater array of operational options. More than ever, it is within this type of operating environment that the resource-based view of the firm indicates that the operations-based capabilities of process flexibility and product innovation are becoming order winners (Roth 1996). Therefore, we hypothesize:

Hypothesis 1: K-B resource variety will be positively related to process flexibility.
Hypothesis 2: K-B resource variety will be positively related to product innovation.

The level of K-B resource variety a manufacturer possesses is posited to be a function of its intellectual capital that is captured by its relative competitive strengths on its structural and human operating resources. Operating resources include all assets, organizational / operational processes, information, knowledge etc. controlled by a firm that enable it to conceive of and implement strategies that improve its efficiency and effectiveness (Daft, 1998). Taken together two diverse resources constitute the manufacturer's intellectual capital (Stewart, 1999): (1) *structural capital* in the form of state-of-the-art manufacturing technologies and organizational information systems (Tracey, Vonderembse and Lim, 1999) and (2) *human capital* manifest by a skilled workforce (Jayaram, Droge and Vickery, 1999) and organizational knowledge and learning capabilities (Carillo and Gaimon, 2000; Lynn, Mazzuca, Morone, Paulson, 1998). Therefore,

Corollary 1: K-B resource variety is a multidimensional construct reflected by superior competitive strengths (i.e., significant and positive factor loadings) for proxy variables for relative structural and human capital.

We posit that there is an indirect effect of K-B resource variety on product innovation resulting from the mediating role of process flexibility. Similarly, Koste and Malhotra (1999) argue that individual resource flexibility, shop floor process flexibility, and plant level new product flexibility are hierarchically related. Much like the impact of improved process quality on lower production costs, higher levels of process flexibility may lead to greater product innovation. Therefore we hypotheses,

Hypothesis 3A: Process flexibility will be positively related to product innovation.
Hypothesis 3B: K-B resource variety will indirectly influence product innovation through the mediating effects of process flexibility.

Finally, published assessments of the importance of operations-based capabilities from a global perspective are relatively sparse despite the increasing number of empirical studies in operations strategy (Pannirselvam, Ferguson, Ash, and Siferd, 1999; Scudder and Hill, 1998). This paucity represents a window of opportunity considering the increasing importance of international issues for operations management research (Roth, Gray, Singhal, and Singhal, 1997). Like, Narasimhan, and Jayaram (1998), we investigate the patterns of relationships in our research model across geographic operating regions. While emphases on individual resources and priorities/capabilities may vary across geographic operating regions, we argue that the relationships between resources and capabilities should largely remain the same. Given the increasing importance of efficient and effective resource allocation, process flexibility and product innovation for global competitiveness, we posit that the relationships noted in figure 1 will be invariant across geographic operating regions. Therefore, we hypothesize:

Hypothesis 4: The pattern of relationships hypothesized between K-B resource variety, process flexibility and product innovation will be the same for all geographic operating regions.

These research hypotheses (H1-H4) are confirmatory in nature and will be studied using structural equations (SEM) modeling.

3. Methods

The manufacturing data analyzed in this research emanates from the *1997 Global Manufacturing Survey* jointly administered by Professor Aleda V. Roth at the University of North Carolina at Chapel Hill, and Deloitte and Touche and Deloitte Consulting (see Roth et al. 1997 for details of the study). The primary purposes of the survey were to identify manufacturers' needs, assess levels of operating capability and competitive strengths, and to benchmark factors deemed critical to competing effectively in the 21st century. Both perceptual and objective manufacturing practice and performance measures, refined since the Vision in World Class Manufacturing Project was initiated in 1987, were addressed on the survey.

The unit of analysis is the manufacturing business unit (MBU) which represents the highest level in the organization or strategic business unit in which the operations strategy is integrated with marketing and product development strategy (1998 Vision in Manufacturing Global Report). The sampling frame was constructed using databases that identified manufacturing companies representing the top 25 percent in sales in each of the 35 countries. A probability sample of more than 1300 MBUs was taken from this sampling frame. Overall, 867 top executives and their management teams responded to the survey.

3.1 Study Sample

The sample of manufacturing firms utilized in this research represents two distinct geographic operating regions: North America (US and Canada, n = 354) and Europe (Belgium, Czechoslovakia, Denmark, France, Germany, Hungary, Italy, Netherlands, Poland, South Africa, Spain, Sweden, Switzerland and UK, n = 260). Missing data on the research items were assumed to occur completely at random (Bollen, 1989) and listwise deletion of observations with incomplete data on the variables of interest was employed in calculating the input covariance matrices. Therefore, the resulting sample sizes for the North American and European region samples were, respectively, 231 firms and 164 firms.

3.2 Operationalization of Constructs

K-B resource variety, process flexibility, and product innovation are considered in this research as latent multidimensional constructs that are operationalized through multiple-item scales. The items used to operationalize each of the latent constructs are Likert-scaled (1-5) and detailed in the appendix (also see Roth 1996 and Giffi, Roth and Seal 1990). The covariance matrix (unreported here) for each region was used in studying the measurement and latent variable models and in the multigroup analysis reported later.

4. Model Specification

The path diagram of the measurement and latent variable models related to the general research model (figure 1) is shown in figure 2. There is a single exogenous latent variable, K-B resource variety (ξ_1), and two endogenous latent variables, process flexibility (η_1) and product innovation (η_2). The latent variable relationships hypothesized earlier are indicative of a recursive model. Each of the latent variables are reflected by three or more indicators and the indicators used to scale the latent variables, x_1 for K-B resource variety, y_2 for process flexibility and y_{10} for product innovation were chosen as being most representative of their respective latent variable.

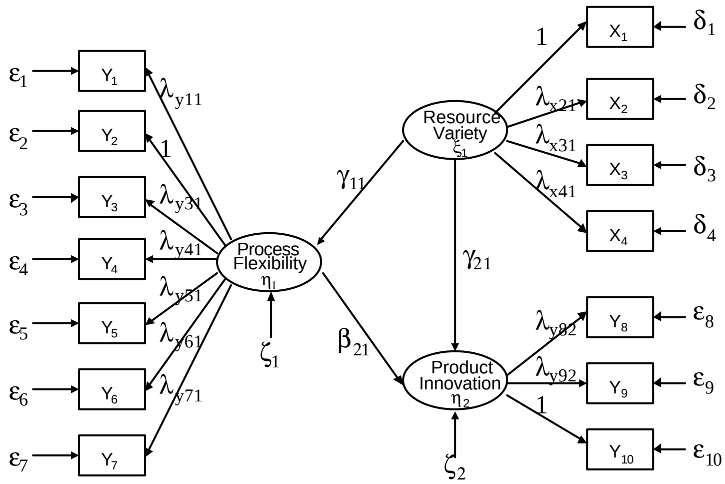

Figure 2: Path Diagram Representation of Research Model

In building and testing covariance models, it is important to formally assess the identification of the hypothesized models. Model identification guarantees that the proposed model has a unique solution since a separate and unique equation exists for the estimation of each path coefficient (Bollen, 1989). The identification of the proposed SEM model was established using the two-step identification. The three-indicator rule establishes the identification for x, h and L_x. Additionally, one observes that B is a lower triangular matrix and that Y is diagonal. Under these conditions, the recursive rule establishes the identification of the latent variable model. Successful application of the two-step identification rule is a sufficient condition for establishing the identification of a model. Therefore, the identification of the overall model specified in this research is established. Further, the maximum likelihood estimator (Bollen, 1989), widely employed in structural equation modeling, was chosen for this analysis.

5. Model Fit and Evaluation

The results from analyzing the measurement and latent variable models are reported in this section. Covariance matrices for each region were analyzed based on the raw data input to the Amos version 3.61 program.

5.1 Measurement Model

Following the procedure suggested by Anderson and Gerbing (1988), the first step in the analysis focuses on the estimation and refining of the measurement models prior to the estimation of the latent variable model path coefficients. Since each of the latent variables is hypothesized as reflected by three or more indicators, confirmatory factor analysis was performed on each latent construct separately (see table 1).

For the North American region, the maximum likelihood estimates for the K-B resource variety latent variable indicate a good fit for the item covariances observed in the sample. The same holds true for the K-B resource variety latent construct in the European region. Additionally, examination of the residual moments matrices contains no values significantly different from zero, lending further support for the specified K-B resource variety model. An examination of the unstandardized parameter reveals that the K-B resource variety latent variable is reflected by positive, statistically significant loadings on the four diverse operating resources. Thus, the K-B resource variety construct is multidimensional and reflected by positive competitive strengths on operating resources. Thus, we find support for corollary 1.

The process flexibility construct in the North American region appears to have excellent fit with the sample data. However, the statistically significant χ^2 for the process flexibility construct in the European region ($p = .002$), along with an AGFI = .89 and RMSEA = .095 is indicative of a moderately good fit with the item covariances in this sample. The fit for the European data is further supported by that the observed GFI = .945, IFI = .948 and TLI

= .920. Given these results, the specified structure of the process flexibility measurement model was deemed appropriate for the multigroup analysis. Finally, the models for the product innovation latent variables are “just identified” so no meaningful fit statistics are reported.

Table 1: Results of Measurement Modeling by Region

	North American		European	
Item	**ML Estimate Unstandardized l**	**Critical Ratio**	**ML Estimate Unstandardized l**	**Critical Ratio**
K-B resource variety				
x_1	1.000		1.000	
x_2	.933	6.448	.998	6.299
x_3	1.194	7.639	.952	6.344
x_4	1.093	7.617	.611	4.994
	χ^2_{2df} = .817 (p=.664) GFI = .998 AGFI = .991 IFI = 1.005 TLI = 1.016 1 – RMSEA = 1.00		χ^2_{2df} = .927 (p=.629) GFI = .997 AGFI = .986 IFI = 1.008 TLI = 1.026 1 – RMSEA = 1.00	
Process Flexibility				
y_1	1.128	8.880	1.178	6.745
y_2	1.000		1.000	
y_3	1.057	8.876	1.132	7.145
y_4	1.141	8.535	1.224	6.971
y_5	.892	8.583	1.188	7.118
y_6	.892	7.581	1.036	6.269
y_7	.939	8.560	1.253	7.159
	χ^2_{14df} = 15.439 (p=.349) GFI = .982 AGFI = .964 IFI = .997 TLI = .996 1 – RMSEA = .979		χ^2_{14df} = 34.735 (p=.002) GFI = .945 AGFI = .890 IFI = .948 TLI = .920 1 – RMSEA = .905	
Product Innovation				
y_8	.923	8.100	.974	7.932
y_9	1.014	8.339	1.234	8.152
Y_{10}	1.000		1.000	
	Just Identified		Just Identified	

In order to test the discriminant validity for the two endogenous variables, a χ^2 difference test was conducted between unrestricted and restricted models where the covariance between process flexibility and product innovation was, respectively, allowed to be freely estimated versus fixed to one (Segars, 1997) (see table 2).

Table 2: Results of Discriminant Validity Test For Endogenous Variables by Region

	ML Estimate of Correlation	**Critical Ratio**	**Constrained Model c^2 (df)**	**Unconstrained Model c^2 (df)**	**c^2 Difference**
North American Region					
Process Flexibility with Product Innovation	.577	5.334	121.44 (35)	50.37 (34)	71.075***
European Region					
Process Flexibility with Product Innovation	.742	5.015	104.14 (35)	63.27 (34)	40.866***

* p < .10, ** p < .01, ***p < .001

As noted in table 2, given the statistically significant χ^2 difference in both geographic regions, and given the lower χ^2 values for the unconstrained models, we find support for the distinctness of the two constructs process flexibility and product innovation. Therefore, estimating the hypothesized impact of process flexibility on product innovation, β_{21}, is statistically valid.

5.2 Multigroup Analysis Results: Overall Fit

Since multigroup equivalence is of part of the research focus, a baseline model was established for each group separately before testing their invariance across groups (Byrne, 1995). The path diagram representation in figure 2 was estimated separately for each geographic region. The ML estimation for the North American region resulted in a $\chi^2_{74\ df}$ of 142.63 ($p < .01$), GFI = .92, AGFI = .89, IFI = .94, TLI = .93 and 1 – RMSEA = .94 while that for the European region resulted in a $\chi^2_{74\ df}$ of 157.08 ($p < .01$), GFI = .88, AGFI = .83, IFI = .91, TLI = .89 and 1 – RMSEA = .92. Given the initial conceptual and theoretical basis for our hypothesized relationships, component fits were deemed appropriate. Therefore, these separate estimations lend support for the specified measurement and latent variable models. Table 3 reports the adequacy for the multigroup baseline model (labeled "form invariant") and subsequent tests of invariance across the geographic regions.

Table 3: Summary of Amos Tests for Invariance across Regions

Model	c^2	*df*	Overall Fit Statistics	Model Comparison	Dc^2	D*df*
(1) Baseline – Form invariant	299.81***	148	GFI = .90 AGFI = .86 IFI = .93 TLI = .91 1 – RMSEA = .95	---	---	---
(2) Lambda invariant	314.61***	159	GFI = .90 AGFI = .87 IFI = .93 TLI = .91 1 – RMSEA = .95	(1) vs. (2)	14.8	11
(3) Gamma invariant	317.12***	161	GFI = .90 AGFI = .87 IFI = .93 TLI = .91 1 – RMSEA = .95	(2) vs. (3)	2.51	2
(4) Beta invariant	321.03***	162	GFI = .90 AGFI = .87 IFI = .92 TLI = .91 1 – RMSEA = .95	(3) vs. (4)	3.91**	1

* p < .10, ** p < .05, ***p < .01

The model hierarchy used to test the invariance of the measurement and latent variable models across geographic regions proceeded as follows:

(1) H_{form}: Form invariant
(2) H_L: Lambda invariant where $L_{i's}$ are equivalent
(3) H_{LG}: Gamma invariant where $L_{i's}$ and $G_{i's}$ are equivalent
(4) H_{LGB}: Beta invariant where $L_{i's}$, $G_{i's}$ and $B_{i's}$ are equivalent
where i = {North American region, European region}

Based on the unstandardized parameter estimates and fit statistics reported for the measurement models in table 1, we felt confident in not conducting a separate test that restricts G and B to be equivalent among regions while allowing L to be freely estimated.

As indicated in table 3, testing the baseline model for form invariance results in a χ^2_{148df} of 299.81 ($p < .01$), GFI = .90, AGFI = .86, IFI = .93, TLI = .91 and 1 – RMSEA = .95. The model fit indices indicate a reasonably good fit for the item covariances observed in the sample. Subsequent model estimations stopped with the test for beta invariance. Specifically, a statistically significant $\Delta\chi^2_{1\,df} = 3.91$ ($p < .05$) indicates that at most, the specified model is gamma invariant across the geographic regions (see Figure 4 for unstandardized λs). Thus we find partial support for hypothesis 4.

5.3 Multigroup Analysis Results: Component Fit

The unstandardized parameter estimates for the complete measurement and latent variable model are displayed in figure 4. Specifically reported in Figure 4 are the unstandardized regression weights and their respective standard errors.

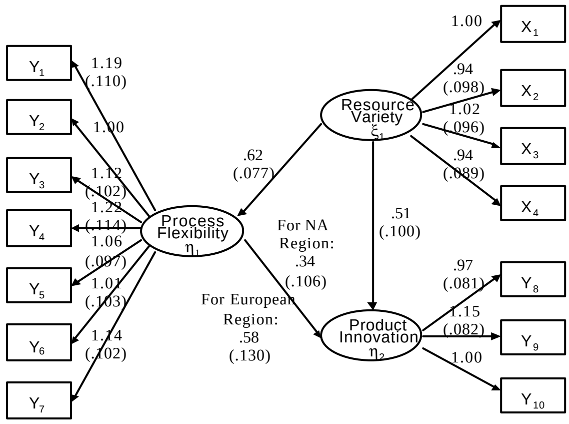

Figure 4: Unstandardized Parameter Estimates for the Gamma Invariant Model

Bollen (1989) generally recommends the use of unstandardized coefficients for making comparisons of a variable's influence in different groups. The positive and statistically significant parameter estimates for γ_{11} and γ_{21} lend support for hypotheses 1 and 2. A unit increase in K-B resource variety, ceteris paribus, increases process flexibility and product innovation by .62 and .51, respectively, across the geographic regions.

As noted in the previous section, the multigroup analysis ceased after testing for beta invariance. What differs between these groups is the parameter estimate for the impact of process flexibility on product innovation (β_{21}). This unstandardized parameter estimate equals .34 and .58 for the North American and European geographic regions, respectively. Thus it appears that a unit increase in process flexibility, ceteris paribus, results in positive, statistically significant, increases in product innovation within both geographic regions. Thus we find support for hypotheses 3A and 3B. What differs between the regions is the level of product innovation improvement. For European manufacturers, there is a greater direct effect of process flexibility on product innovation than for North American manufacturers. Additionally, there is a greater indirect effect of K-B resource variety on product innovation for European manufacturers over and above the equivalent direct effects between these two latent variables across the geographic regions.

6. Discussion

A primary focus of this research was on examining the relationships between a firm's portfolio of K-B resources and the operations-based capabilities of process flexibility and product innovation. The research findings reported here indicate the direct and indirect influence that possessing K-B resource variety has on these capabilities. These findings are noteworthy to the study of manufacturing strategy as they highlight the need to view operational resources as multiple and diverse sources of intellectual capital that act synergistically, rather than in isolation, to influence product innovation. Therefore, structural capital in the form of state-of-the-art manufacturing processes and information systems and human capital as manifest by a skilled workforce are two facets of our K-B resource variety construct. Assessing only one form of intellectual capital in isolation (e.g., Kathuria and Partovi, 1999) may capture only a singular aspect in capabilities development. For the practicing manager concerned with competing on flexibility and/or innovation, these findings indicate the need to develop a diverse K-B resource portfolio that allows for a greater degree of strategic response to environmental uncertainties. Additionally, the invariance of the K-B resource variety relationships to process flexibility and product innovation across geographic operating regions offers some evidence for a general theory of relating intellectual capital to product introduction capabilities in a global context. Consistent with the resource-based view of the firm, the accumulation of diverse and multiple sources of intellectual capital plays a key role in process flexibility and product innovation across global regions.

The difference in β_{21} between the two geographic operating regions is interesting as it suggests a context specific contingency related to possessing process flexibility. Specifically, the impact of process flexibility on product innovation appears to be greater for European manufacturers than their North American counterparts. The European sample largely differs from the North American sample in terms of (a) the percentage of firms reporting less than $100 million U.S. in company sales volume and (b) percentage of firms with less than 500 employees. In general, the European sample was biased to smaller firms that reported lower company sales volume (unreported here). For many of these smaller-scaled manufacturers, firm size may explain the greater positive impact of process flexibility on product innovation. Further, this finding is intuitively appealing. It suggests that the ability to rapidly introduce new, or offer innovative, products is more important for smaller firms given that they must rely on leveraging a more limited resource base, such as manufacturing a broad product mix within the same facility (Swamidass and Kotha, 1998).

Thus, the gap between the proverbial "haves" and "have-nots", where process flexibility and product innovation are concerned, can be reduced through the utilization and better management of a portfolio of diverse K-B resources. This finding fits nicely with Hayes and Upton (1998: 12-13, 14-15) who note three ways that organizations can achieve competitive advantages operationally:

> "First, they adopted an operations strategy that gave them a competitive advantage along dimensions or in locations that, although valued by certain subsets of their customers, were not being emphasized by competitors; this is what is sometimes referred to as a 'differentiating' competitive position. …Second, they reinforced this alternative way of appealing to customers with the development of a tightly integrated system of supporting values, skills, technologies, supplier / customer relationships, human resources, and approaches to motivation that were neither easily copied nor transferable to other organizations. …[Third, another] way that a company can use operations to create a competitive advantage is simply by executing that strategy more effectively than its competitors."

An effective operating strategy, in short, is concerned not only with "doing things differently," but also with "doing the right things better." This study provides provocative empirical evidence, and suggests the need for future research on how operations strategies can best develop structural and human capital resources.

7. Conclusions

This research adds to understanding in two emergent areas of operations management study: new product development and, to a lesser extent, technology (or resource) management (Pannirselvam et al., 1999). Specifically, we empirically examine the relationship between K-B resource variety and the operations-based capabilities of process flexibility and product innovation. Our results confirm the promise of leveraging the competitive strengths of multiple diverse K-B resources. As hypothesized, the impact of K-B resource variety was found to be a positive direct influence on process flexibility and product innovation. It also had an indirect effect on product innovation through the mediating effects of process flexibility. Notably, the results are invariant across North American and European manufacturing firms. However, the direct impact of process flexibility on product innovation, while positive, was not found to be invariant across both geographic regions. These findings provide unique insight into the management of K-B resources in dynamic and global contexts and shed some light on the theoretical underpinnings the importance of intellectual capital in manufacturing, where K-B resource variety influences manufacturing process flexibility and product innovation.

References

The complete set of references will be furnished upon request from Professor Aleda V. Roth, Kenan-Flagler Business School, University of North Carolina at Chapel Hill, Chapel Hill NC 27599 (aleda_roth@unc.edu).

Appendix

The operationalizations of the constructs identified in figure 1 are summarized in this appendix (see Roth 1996 for complete details of items). Each of the items listed below was originally conceptualized as a component of a critical success factor / capability for competing within an industry. Respondents were asked to "indicate how strong you feel your business unit is for each capability relative to your primary competitors in the same market?" (Scaled 1-5 where: (1) Lower, (3) Average and (5) Market Leader)

<u>K-B resource variety</u> (ξ_1) (Item scales: 1-5)

- x_1: Use state-of-the-art manufacturing processes
- x_2: Superior organizational information systems and databases
- x_3: Workforce with superior technical skills
- x_4: Organization's learning capabilities / knowledge base

<u>Process Flexibility</u> (η_1) (Item scales: 1-5)

- y_1: Ability to rapidly change product mix
- y_2: Manufacture broad product mix within same facilities
- y_3: Ability to rapidly change production volumes
- y_4: Rapidly handle custom orders or engineer-to-order
- y_5: Ability to rapidly modify methods for material or component
- y_6: Ability to customize / change products to meet mass market demands
- y_7: Overall workforce flexibility

<u>Product Innovation</u> (η_2) (Item scales: 1-5)

- y_8: Offer products with high R & D / new technology content
- y_9: Ability to rapidly introduce new products
- y_{10}: Offer innovative products