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A RESOURCE-BASED VIEW OF MANUFACTURING STRATEGY AND THE RELATIONSHIP TO MANUFACTURING PERFORMANCE

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This paper examines manufacturing strategy from the perspective of the resource-based view of the firm. It explores the role of resources and capabilities in manufacturing plants that cannot be easily duplicated, and for which ready substitutes are not available. Such resources and capabilities are formed by employees' internal learning based on cross-training and suggestion systems, external learning from customers and suppliers, and proprietary processes and equipment developed by the firm. Based on data from 164 manufacturing plants, the paper empirically demonstrates that competitive advantage in manufacturing (as measured by superior plant performance) results from proprietary processes and equipment which, in turn, is driven by external and internal learning. The implication is that resources such as standard equipment and employees with generic skills obtainable in factor markets are not as effective in achieving high levels of plant performance, since they are freely available to competitors. The paper also demonstrates the important role of internal and external learning in developing resources that are imperfectly imitable and difficult to duplicate.

INTRODUCTION

This study places research on manufacturing strategy in the context of the resource-based view (RBV) of the firm (Barney, 1991; Rumelt, 1984; Teece, 1987) by studying how manufacturing plants develop capabilities and resources in pursuit of better performance and competitive advantage. Capabilities in functional areas of the firm, such as manufacturing, contribute to the development of deployable resources for the firm. Their positive contribution to performance may also confer advantages compared to competitors, alone or in combination with resources in other functional areas. We develop three constructs (internal learning, external learning and proprietary processes and equipment) for measuring manufacturing capabilities and we test hypotheses that lead to higher manufacturing performance in a cross-sectional sample of 164 manufacturing plants.

This is one of the first studies to define and test RBV-based theory in a manufacturing plant setting (Amundson, 1998; Flynn, Flynn, and Shrader, 1998; Swamidass, 1991). Previous research in this area has focused on the market-driven development of capabilities in manufacturing, and potential

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trade-offs between simultaneously pursuing goals such as improved cost and quality (Ferdows and De Meyer, 1990). Defining the criteria necessary for manufacturing process innovations to contribute to competitive advantage when competitors are also engaged in the adoption of similar process innovation is an important unaddressed issue. We extend this line of research by examining the ability of firms to build idiosyncratic capabilities in manufacturing processes that cannot be easily duplicated and have no ready substitutes.

The resource-based view

The resource-based view of the firm (Barney, 1986, 1991; Teece, 1987; Wernerfelt, 1984) argues that organizations incorporate privately held knowledge, which can be employed to create idiosyncratic modes of technology at any point in time (Conner and Prahalad, 1996). The RBV distinguishes between resources that can be acquired in factor markets and those developed inside the firm. To confer competitive advantage, resources must not be possessed by all competing firms, they must be difficult to imitate or duplicate through other means, and contribute positively to performance (Barney, 1991).

We address the development of idiosyncratic manufacturing processes within plants, where decision-makers are able to focus on the development of manufacturing processes for specific production lines, rather than across the potentially disparate processes of an entire business unit. If resources are produced through routine-changing routines (or meta-routines, see Adler, Goldoftas, and Levine, 1999) that transform knowledge into production processes, then resources are a function of the social construction of knowledge within the plant, its interactions with customers and suppliers, and the opportunities and limitations of its current technologies. This argument regarding capability building also suggests a measurement strategy for evaluating how firms build manufacturing capabilities with strategic impact. We propose that internal and external learning in a manufacturing plant leads to unique proprietary processes and equipment, which in turn leads to superior manufacturing performance. Such resources and capabilities are by definition not available to competitors in the factor markets and therefore can provide competitive advantage.

In summary, previous discussions within the RBV have focused on the characteristics of resources with respect to competitors rather than their development within the firm. Other discussions have centered on why resources may be difficult to acquire in the short term, if they can be acquired at all (Barney, 1986; Dierickx and Cool, 1989; Teece, 1976; Teece, 1980; Teece, Pisano, and Shuen, 1997). Our research contributes a perspective on how internal and external learning may create a valuable resource, proprietary processes, and equipment. Manufacturing resources such as proprietary processes and equipment may be difficult to imitate in the short term and are subject to causal ambiguity if they result from an iterative process within the plant (St John and Harrison, 1999; see also Abernathy and Utterback, 1975; Hayes and Wheelwright, 1984).

Empirical research in manufacturing strategy

Several approaches for developing manufacturing capabilities have been articulated. Hayes and his colleagues (Hayes, 1985; Hayes and Jaikumar, 1988; Hayes and Pisano, 1994; Hayes and Upton, 1998; Hayes and Wheelwright, 1984; Hayes, Wheelwright and Clark, 1988) have consistently argued that manufacturing capabilities should play an important role in how firms compete in product markets, and that firms must continually develop these capabilities. Ferdows and De Meyer (1990) focused on endowing manufacturing processes with an expanding set of capabilities by pursuing a specific sequence of improvement initiatives. Others have demonstrated a positive link between an influential role for manufacturing managers in strategic decision making and performance (Roth and Miller, 1990; Swamidass and Newell, 1987). These studies establish the role of manufacturing processes as a potential resource, and emphasize the role of human and organizational factors in creating competitive advantage, findings that are consistent with the focus of the RBV (Teece *et al.*, 1997).

Another line of manufacturing strategy research links capabilities or competencies based on specific manufacturing process innovations to the ability of the organization to achieve low costs, high flexibility, dependability, and quality (Cleveland, Schroeder, and Anderson, 1989; Hayes and Wheelwright, 1984; Hill, 1989; Vickery, Dröge, and Markland, 1993). Similarly, Flynn, Schroeder and their colleagues have demonstrated an empirical link between quality management practices, just-in-time management practices, manufacturing strategy processes, and manufacturing performance (Bates and Flynn, 1995; Flynn, Sakakibara, and Schroeder, 1995; Flynn, Schroeder, and Sakakibara, 1995). Other studies have demonstrated a relationship between manufacturing capabilities and competencies to market outcomes and financial performance measures (Cleveland *et al*., 1989; Fiegenbaum and Karnani, 1991; Gupta and Somers, 1996; Kim and Arnold, 1992; Swamidass and Newell, 1987; Vickery *et al*., 1993; White, 1996; Williams *et al*., 1995).

Past manufacturing strategy research differs from the RBV in several respects. It investigates the adoption of specific manufacturing practices and their relationship to current performance, but does not explicitly address the effects of competitors imitating a successful innovation. Further, it fails to recognize the importance of proprietary processes and equipment that cannot be obtained in the factor markets. Instead, past research explores the characteristics of successful innovations' impact on performance, and points to an important role for learning, and organizational factors. These results are consistent with the RBV emphasis on tacit knowledge and learning as criteria necessary for achieving sustainable competitive advantage.

Our research extends previous research in the manufacturing strategy literature by evaluating whether the capability to develop proprietary processes and equipment through internal and external learning within the firm is associated with competitive manufacturing performance. This study places the development of manufacturing processes in the context of the RBV by explicitly addressing the potential for a plant's processes to differ from competitors and to incorporate incremental, privately developed process innovations.

DEFINITIONS, CONCEPTS, AND HYPOTHESES

As we have noted above, the primary focus of this study will be on manufacturing strategy as defined by capabilities and resources, and their relationship to manufacturing performance. We consider three types of resources and capabilities that are built within the manufacturing function and are difficult to imitate and transfer (St John and Harrison, 1999): (1) proprietary process and equipment, (2) internal learning, and (3) external learning.

We would emphasize that we do not propose the resources and capabilities discussed in this paper prescriptively as 'best practices,' the paradigm that dominated manufacturing strategy research in the 1980s and early 1990s (see, for example, Wheelwright and Bowen, 1996). Our contention is the opposite: manufacturing practices adopted by imitating world-class manufacturers may contribute to competitive parity but not to competitive advantage. Rather, we evaluate whether some manufacturers may have built a potentially sustainable competitive advantage through building capabilities that generate idiosyncratic learning, and production processes that lead to a performance advantage. Such learning and processes would not, and indeed by their idiosyncratic nature could not, be prescribed for every manufacturer.

We emphasize that the role of learning and knowledge generation within the plant is to generate proprietary process and equipment (Conner, 1991; Kogut and Zander, 1996). Proprietary processes and equipment are thus created through a process of path-dependent problem solving and they mediate between learning and performance. Learning, by itself, will not provide superior performance, but must be embedded in a tangible process or equipment for superior performance to occur.

Internal learning

The concept of learning within the plant builds on the RBV focus on privately held knowledge, causal ambiguity, and socially complex factors that both confer advantage and inhibit transfer (Barney, 1991; Teece *et al*., 1997). Internal Learning includes the training of multifunctional employees (Gerwin and Kolodny, 1992) and incorporating employee suggestions (Hall, 1987) into process and product development. These practices lead to an adaptable work organization, the performance impact of which is often underestimated (Gerwin and Kolodny, 1992). Further, these practices are routine-changing routines suggestive of the path-dependent development of manufacturing processes (Nelson and Winter, 1982). Our focus on learning routines within the plant is consistent with Pisano's (1994) concept of learning-before-doing, and Adler and Clark (1991), who both make the case for a positive relationship between learning and performance in manufacturing. Indeed, Prusak (1997) argues that learning is the only source of sustainable competitive advantage. Learning may occur in an unpredictable and sometimes haphazard way that is difficult to codify, leading to deployable resources whose impact is causally ambiguous.

External learning

Organizations regularly engage in problem solving with other organizations in ways that function as routine-changing routines (Nelson and Winter, 1982; Teece *et al.*, 1997). In the context of manufacturing plants, we define external learning as interorganizational learning through problem solving with customers and suppliers. Recent certification of suppliers' production methods by customers, and establishment of ongoing customer–supplier relations, suggests that customers are an important source of routines (Dyer and Singh, 1998). Relationships with customers create tacit knowledge that is not easy to duplicate (Madhok and Tallman, 1998; Ward *et al.*, 1995). External learning also occurs through long-term relational contracting with suppliers (Gerwin, 1993). This can take many forms, including supplier input into new product or process design and supplier involvement in quality and in continuous improvement practices and routines.

Proprietary manufacturing processes and equipment

The capabilities inherent in situated learning should result in idiosyncratic manufacturing processes, including proprietary process technology that confers competitive advantage. (St John and Harrison, 1999). We therefore focus on competitive assessments of production processes of the plant as a whole, and the degree to which production processes are proprietary; we do not attempt to identify specific practices. Our definition of proprietary processes and equipment includes equipment protected by patents as well as unpatented processes and equipment held in secret. It also includes state-of-the-art equipment and processes that have been developed exclusively by the plant. We propose that production processes that incorporate idiosyncratic methods are those in which the learning capabilities discussed above have been incorporated, leading to our first hypotheses linking learning to proprietary processes and equipment.

Hypothesis 1a: Greater internal learning leads to more proprietary processes and equipment.

Hypothesis 1b: Greater external learning leads to more proprietary processes and equipment.

Manufacturing performance

We assess competitive advantage through manufacturing performance. Many factors external to the plant may distort the degree to which resources in manufacturing processes affect financial performance measures, such as sales and profits. Therefore, we build on previous measures of plant performance used in manufacturing strategy (Ferdows and De Meyer, 1990; Hayes and Wheelwright, 1984; Miller and Roth, 1994). We use an index of several manufacturing performance variables: cost as a percentage of sales, conformance quality, percentage of on-time deliveries, days from receipt of raw materials to customer receipt (cycle time), and the length of the fixed production schedule (flexibility).[1]

Hayes and Wheelwright (1984) have argued that the development of proprietary processes and equipment should lead to competitive advantage expressed here as a manufacturing performance advantage. They propose a four-stage model of manufacturing in which the most advanced stage 4 includes proprietary processes and equipment as one of its elements, leading to a manufacturing-based competitive advantage. Stages 1, 2, or 3 are competitively neutral or have a market-driven focus and do not provide a manufacturing-based competitive advantage. Thus, Hayes and Wheelwright (1984) provide a specific rationale for the linkage of proprietary process and equipment to competitive manufacturing performance, leading to the following hypothesis:

Hypothesis 2: Greater proprietary process and equipment leads to higher competitive manufacturing performance.

Thus far we have discussed propositions of the RBV in terms of manufacturing processes and prior research in manufacturing strategy. We propose that learning situated in manufacturing plants

[1] This measure of flexibility is based on the idea that most plants construct a fixed production schedule fence inside of which they will not make changes in the production plan. The shorter the time of this fixed production fence, the more flexible the plant.

will lead to proprietary processes and equipment that are predictive of performance advantages. We focus on the development of idiosyncratic production processes as a function of internal problem solving, and external learning as a function of the plant's embeddedness in networks of customers and suppliers, building on the notion of routine-changing routines (Nelson and Winter, 1982). However, situated learning may also be subject to disadvantages associated with a single trajectory of learning (Levinthal and March, 1993), if that specialization no longer confers competitive advantage. Similarly, causal ambiguity may also lead to plants pursuing a wrong learning trajectory that inadvertently destroys the complex or distributed source of competitive advantage (Lippman and Rumelt, 1982). These effects, if present, suggest an alternative line of reasoning to that advanced in the hypotheses above, and highlight the importance of empirical tests of our hypotheses.

Figure 1 expresses our hypotheses as a series of relationships of the constructs discussed above. After defining our data collection methods, we jointly test these hypotheses using a structural equation model.

DESCRIPTION OF THE DATA, MEASUREMENT OF VARIABLES AND METHODS OF ANALYSIS

The data were collected through written questionnaires from a total of 164 manufacturing plants in Germany, Italy, Japan, the United Kingdom, and the United States (Flynn, Schroeder, and Sakakibara, 1994; Schroeder and Flynn, 2001).[2] Plants in the sample represent three industries, defined at the 4-digit SIC level: electronics, machinery, and automobile component suppliers. Stratified sampling was used to select an approximately equal number of plants for each industry in each country, as shown in Table 1. The selection of a diverse set

[2] We acknowledge the generous support in the data collection effort by colleagues at Wake Forest University, Padova University, Udine University, Mannheim University, London Business School, Bath University, Gakushuin University, Kanagwa University, Tokyo Keizai University, and Yokohama University.

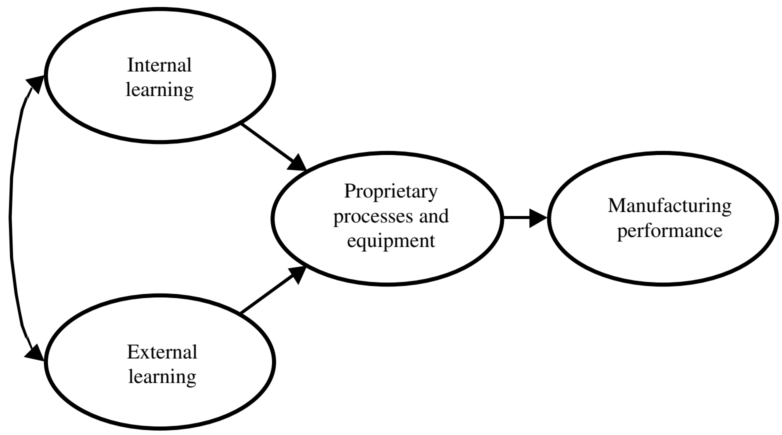

Figure 1. The theoretical model and hypotheses represented as a nomological network

Table 1. Stratification of the sample

		Industry			
		Electronics	Machinery	Auto supplier	Total
Country	Germany	9	11	13	33
	Italy	11	13	10	34
	Japan	17	14	15	46
	U.K.	7	7	7	21
	U.S.A.	10	10	10	30
	Total	54	55	55	164

of industries in five different countries improves the generalizability of the research findings to a broader population. Moreover, these five countries represent the three important trading blocks: Pacific Rim, Europe, and North America, and together they produce 60 percent of global output (World Bank, 1995).

Sixty-five percent of the plants contacted participated in the study. This high response rate was achieved by telephoning the plant managers to request their participation and offering each plant a profile report at the end of the study, indicating its performance relative to other plants in the same industry. Both objective data on performance and perceptual data on the constructs of interest (internal learning, external learning, and proprietary processes and equipment) were collected from 23 respondents in each plant using a survey instrument developed by Flynn *et al.* (1994). The reliability and the validity of the survey instrument is discussed in Flynn *et al.* (1994). Detailed information on the respondents is given in the Appendix.

Modeling of theoretical concepts

We model internal learning, external learning and proprietary process and equipment as unidimensional latent constructs with multiple indicator variables. See the Appendix for the specific items used in this study. Because we are introducing new measures, we examine content, convergent and discriminant validity, and internal consistency prior to testing our substantive hypotheses (Bagozzi, 1981).

We model manufacturing performance as an index of performance measures that capture the relevant dimensions of manufacturing performance (Cleveland *et al.*, 1989; Vickery *et al.*, 1993; Ward, *et al.*, 1990). Unlike many previous manufacturing strategy studies, the performance variables are not measured by Likert scales comparing plant performance to competition. In an attempt to avoid common method and respondent bias, we measure performance using accounting and operations measures, and standardize by industry (4-digit SIC) as a proxy for competition. Although this approach does not address competition directly, it avoids the common method bias and it does not rely on perceptual measures of performance.

We assess the reliability and validity of the constructs using a two-step structural equation model (Anderson and Gerbing, 1988). The measurement model, estimated through maximum likelihood confirmatory factor analysis, examines the constructs when the structural portion of the model is saturated (just identified) with bidirectional correlations. We estimated the measurement model separately from the theoretical model to perform a formal test of discriminant validity, and to test for interpretational confounding of factors.

Measurement model

Identification

Each latent construct has at least three indicators and is hence identified: the three-indicator rule is a sufficient condition for mathematical identification of the model (Bollen, 1989). Further, we have fixed the latent variable variances to 1 to achieve identification (Gerbing and Hunter, 1982).

Reliability

We assess reliability using composite reliabilities.[3] The composite reliabilities for the internal learning, external learning, and process and equipment are 0.82, 0.74, and 0.70 respectively. Construct reliabilities hence appear adequate.

Convergent validity

The factor loadings range from 0.48 to 0.83 with an average loading of 0.67 (see Table 2). This provides evidence of adequate convergent validity of the constructs: all loadings are statistically significant and positive; hence, convergent validity is achieved (Bagozzi and Yi, 1991).

Discriminant validity

We assess discriminant validity by constraining inter-construct correlations in the measurement model to unity one at a time, and measuring the change in the χ^2 statistic (Anderson and Gerbing, 1988). The $\Delta\chi^2$ (on 1 d.f.) statistics are given in

[3] In this case we prefer composite reliabilities over Cronbach's α because α measures the internal consistency of a *sum* of tau-equivalent or parallel measures. In the case of congeneric measures (such as ours), α underestimates the true construct reliability (Bollen, 1989: 217).

Table 2. Parameter estimates

Factor loadings	CFA	CFA with MIs	Theoretical model	Theoretical model with MIs
IL1	0.67	0.80	0.68	0.81
IL2	0.76	0.69	0.76	0.69
IL3	0.83	0.93	0.83	0.93
IL4	0.63	0.58	0.63	0.58
EL1	0.63	0.65	0.64	0.65
EL2	0.57	0.60	0.58	0.61
EL3	0.79	0.77	0.79	0.76
EL4	0.58	0.57	0.58	0.57
PE1	0.73	0.73	0.74	0.76
PE2	0.70	0.69	0.67	0.62
PE3	0.48	0.47	0.47	0.40
PE4	0.54	0.55	0.54	0.57

Correlations/path coefficients	CFA	CFA with MIs	$\Delta\chi^2$	Theoretical model	Theoretical model with MIs
IL and EL	0.40	0.42	92.8	0.41	0.42
EL and PE	0.29	0.24	87.4	0.19	0.24
IL and PE	0.44	0.33	79.2	0.38	0.33
PE and Performance	N/A	N/A	N/A	0.34	0.36

Table 2—all changes in χ^2 are highly significant, hence discriminant validity is achieved.

There are many rules of thumb for evaluating overall model fit. Most commonly, they suggest a certain cut-off for a goodness of fit index. Recent literature suggests, however, that many of these heuristics are outdated and should be replaced with a more detailed assessment of the stability of parameter estimates and changes in residuals (Hu and Bentler, 1999; MacCallum *et al*., 1999; Raykov and Widaman, 1995). In assessing overall fit, we report several indices: the comparative fit index (CFI), Tucker–Lewis index (TLI), and the root mean square error of approximation (RMSEA) (Bagozzi and Edwards, 1998; Bagozzi, Yi, and Nassen, 1999; Hu and Bentler, 1999). However, we augment our use of fit indices with an examination of residuals because fit indices collapse the multifaceted notion of fit into a single index and therefore should be only one consideration when assessing model fit. Based on fit indices, the fit of the CFA model may be problematic (see Table 3).

Table 3. Overall fit of models

Model	χ^2 statistic (d.f.) (p-value)	95% confidence interval for RMSEA	CFI	TLI	Number of residuals $\lvert r\rvert > 2$
CFA	106.31 (51) (0.000)	[0.060, 0.103]	0.90	0.88	3 out of 78
CFA with MIs	60.45 46 (0.075)	[0.000, 0.072]	0.95	0.93	0 out of 78
Theoretical Model	124.89 (62) (0.000)	[0.059, 0.099]	0.89	0.86	7 out of 78
Theoretical Model with MIs	72.61 (56) (0.067)	[0.000, 0.068]	0.97	0.96	4 out of 78

The significant χ^2 and the fit indexes RMSEA = 0.08 (with a 95% confidence interval [0.06, 0.10]), CFI = 0.90, and TLI = 0.88 suggest an adequate, but not good model fit. Yet, only 3 normalized residuals out of 78 exceed 2 in absolute value (and none of them exceed 3), suggesting the model fit may indeed be quite acceptable. However, we will explore model fit in more detail to assess potential problems.

Although our research design is intended to minimize the impact of method bias, due to our sample size we were not able to explicitly model method factors (using MTMM analysis, for instance). We therefore examine the *modification indexes* (MI) for error covariances where common method bias may be present. We avoid data-driven modifications to the model in the following ways. First, we do not use the indices with the goal of improving the overall fit of the modified model; rather we use MIs to examine the robustness of parameter estimates to small changes in the model. Second, we will free only error covariances for items that share an informant or the same method.

In order to estimate parameter estimate stability, we freed five error covariances one at a time, each of which had an MI of at least 5; all covariances freed were for items with a common method. As Table 3 suggests, the overall fit improved, although the fit of the modified model is not of theoretical interest, as discussed above. What is interesting is the stability of the parameter estimates (factor loadings and inter-construct correlations), shown in Table 2. The estimates are robust to minor changes in the model. We therefore proceed to evaluate substantive hypotheses, using the original model, based on the stability of the parameter estimates.

TEST OF HYPOTHESES

The theoretical model and the hypotheses are tested using full information maximum likelihood estimation. The model (Figure 2) is recursive and hence identified (Bollen, 1989). We have again fixed the variances of the endogenous latent variables at 1 to achieve identification. The overall fit of the model is shown in Table 3. The χ^2 of 124.89 (62 d.f.) is significant, hence the hypothesis of perfect fit is rejected. Seven normalized residuals exceed 2 in absolute value (but none of them exceed 2.5); CFI and TLI are 0.89 and 0.86, respectively. The 95 percent confidence interval for RMSEA is [0.059, 0.099]. There is some indication of lack of fit, which will be examined through modified models.

We explored alternative models using the modification indices, with the same motivation as

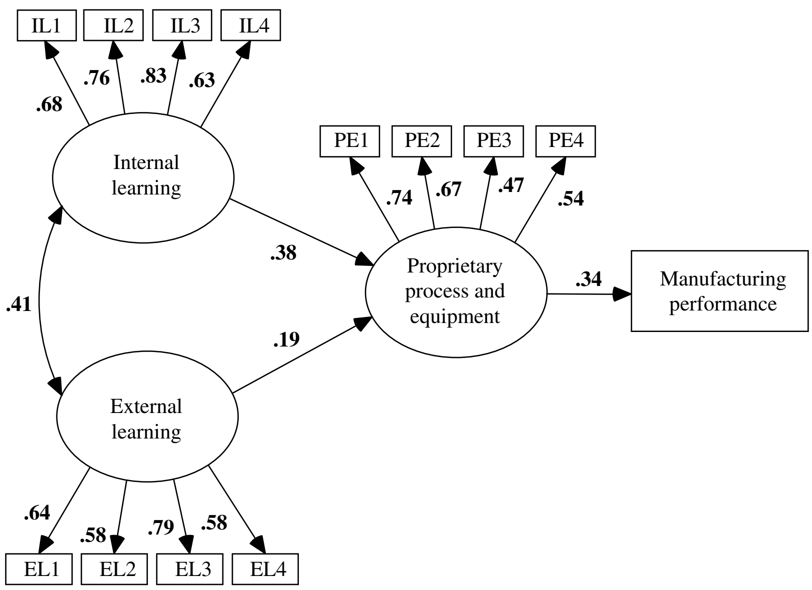

Figure 2. Parameter estimates for the theoretical model (all estimates are significant at the 0.05 level; all error terms omitted for clarity)

above, to examine the stability of the estimates to minor misspecifications in the model. Six error covariances with an MI > 5 were freed, one at a time. Only covariances that make substantive sense, as discussed above, were estimated. As expected, the overall fit of the model improved substantially. More importantly, the path coefficient and factor loading estimates were stable, indicating robustness of parameter estimation and low interpretational confounding. In sum, the path coefficient estimates are stable and the lack of fit does not seem to affect substantive conclusions.

Figure 2 suggests that the constructs are largely related in the theoretically predicted manner. There is a statistically significant link between internal learning and process and equipment ($r = 0.38$ with $p = 0.001$), providing support for Hypothesis 1a. The link from external learning to proprietary process and equipment is also significant, but not as strong ($r = 0.19$, $p = 0.044$), supporting Hypothesis 1b. There is a strong link from proprietary process and equipment to manufacturing performance ($r = 0.34$ with $p = 0.000$), lending support for Hypothesis 2.

The significant paths in the structural model also establish the nomologic validity of the constructs. The learning constructs have nomologic validity as they are directly linked to development of proprietary process technology and indirectly to manufacturing performance, as hypothesized. Proprietary process and equipment also exhibits nomologic validity via its strong link to performance.

The analysis suggests an important role for internal and external learning and idiosyncratic processes and equipment in achieving competitive advantage through superior manufacturing performance. We found that capabilities such as internal learning and external learning are linked to development of deployable resources, specifically proprietary processes and equipment. In other words, these capabilities lead to development of valuable resources that in turn lead to higher competitive performance. Consistent with the RBV, our proposition is that external and internal learning are privately held knowledge that is idiosyncratic and difficult for competitors to imitate.

This study has a number of limitations. Our database restricted the choice of indicators for the constructs and may have had an adverse effect on the content validity of the constructs. However, we contend that the indicators, while not an exhaustive representation of the domain, are relevant and appropriate. Further, the constructs demonstrate both convergent and discriminant validity which leads to the conclusion that we have measured what we intended. Second, inferences in this study are based on cross-sectional data, making causal claims difficult. We were also unable to assess performance effects over time, and believe that a longitudinal database with strong measures of relevant variables should be developed to assess the issues of path dependency in resource building through learning routines. Finally, although we explained 20 percent of the variation in performance, 80 percent remains unexplained. Some of this variation certainly arises from contextual factors that were not modeled, such as country of origin, industry, process choice, and plant size. In future models, we recommend these factors be included in the analysis.

CONCLUSIONS

We have modeled three distinct manufacturing resources and capabilities that have the potential for creating a performance advantage. There is evidence in the extant manufacturing strategy literature that manufacturing performance will, in turn, enable the plant to be competitive in product markets (Cleveland *et al*., 1989; Vickery *et al*., 1993, 1997). The capability of the plant to incorporate internal and external learning into proprietary processes and equipment emerges as an important contributor to manufacturing performance. Our results suggest that the RBV is an appropriate theoretical framework for addressing shortcomings in manufacturing strategy research, which has not addressed the issue of how manufacturing processes can contribute to competitive advantage when multiple competitors adopt the same innovation. The RBV implies that such innovations can only contribute to competitive advantage when they cannot be easily duplicated by competitors who have access to the factor markets. By empirically demonstrating that routinized learning and idiosyncratic, proprietary processes are associated with better performance, we have also demonstrated the promise of this approach for understanding the link between long-term investments in manufacturing processes and competitive advantage. We believe that framing the role of manufacturing processes in this manner is a contribution to the manufacturing strategy literature that will aid future theoretical developments in this line of research.

Our research also contributes to the RBV by demonstrating that it is possible to measure theoretical relevant constructs across plants. We have empirically shown the reliability and validity of internal learning, external learning, and proprietary process and equipment constructs in a manufacturing context. We have used multiple respondents and multiple methods to alleviate the common respondent and method biases. Further, multiple respondents per plant created continuous and normally distributed indicators that increase our confidence in the robustness of the parameter estimates. Finally, we have used latent variable modeling in operationalizing the constructs and testing hypotheses, thereby enabling a more realistic and accurate estimation of the pertinent relationships than would regression-based models. We feel confident asserting the importance of learning and proprietary processes and equipment to superior manufacturing performance.

We hope that future research will build on these beginnings. The manufacturing strategy literature critically needs to incorporate ideas from the RBV. At the same time, the RBV literature needs to measure constructs at the plant level where capability and resources are actually built.

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APPENDIX: OPERATIONALIZATION OF CONSTRUCTS

Items use 1–5 Likert scales, indicating degree of agreement or disagreement unless otherwise stated. The * symbol indicates a reversed item. All items are made consistent before analysing the data; that is, a high value indicates high capability.

Respondent codes:

ACCT	Plant Accountant	
HRM	Human Resource Manager	
IM	Inventory/Purchasing Manager	
PE	Process Engineer	
PM	Plant Manager	
PRC	Plant Research Coordinator	
PS	Plant Superintendent	
QM	Quality Manager	
SUP	Supervisor	(2 supervisors)
WRK-1	Worker, Group 1	(4 workers)
WRK-2	Worker, Group 2	(4 workers)

Process and Equipment

PE1 We have equipment which is protected by the firm's patents.
(Respondents: PM, PS, PRC)

PE2 Proprietary equipment helps us gain a competitive advantage.
(PM, PS, PRC)

PE3 How does the process technology at your plant compare to industry competition on a global basis?

= 1 if Poor or low end of the industry
= 2 if Below average
= 3 if Average or equal to the competition
= 4 if Better than average
= 5 if Superior
(PM, PS, PRC)

PE4* What term below describes your production equipment relative to your industry?

= 1 if Absolutely state-of-the-art
= 2 if Better than most of the companies in the industry
= 3 if About equal to the industry average
= 4 if Below the industry average
= 5 if Poor, near the bottom of the industry
(PE)

Internal learning

IL1 Employees are cross-trained at this plant so that they can fill in for others if necessary. (HRM, PE, QM, SUP, WRK-1, WRK-2)
IL2 Employees receive training to perform multiple tasks. (HRM, PE, QM, SUP, WRK-1, WRK-2)
IL3 Management takes all product and process improvement suggestions seriously. (SUP, WRK-2)
IL4 Many useful suggestions are implemented at this plant. (SUP, WRK-2)

External learning

EL1 We strive to establish long-term relationships with suppliers.
EL2 We maintain close communication with suppliers about quality considerations and design changes.
EL3 Our customers give us feedback on quality and delivery performance.
EL4 Our customers are actively involved in the product design process.
(PE, QM, WRK-1 on all items)

Manufacturing performance

1. Manufacturing cost as a percentage of sales (ACCT)
2. Scrap rate (conformance quality) (QM)
3. Percentage of deliveries customers receive on time (ACCT)
4. Number of days from receipt of raw materials to customer receipt (cycle time) (ACCT)
5. Length of fixed production schedule (flexibility) (IM)