Proprietary equipment, training, and performance: An absorptive capacity approach

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Abstract

This study investigates the relationship between proprietary equipment and anticipation of new technologies, in the enhancement of product innovativeness and competitive performance. The absorptive capacity perspective suggests that companies that develop and modify their own equipment develop critical knowledge that will permit them to identify and assimilate new valuable technologies, that in turn, will put these companies on the frontier of equipment. Once these new technologies have been absorbed, operations training provides a key to the diffusion and application of the new knowledge. Contrary to previous literature, our results show that proprietary equipment has no direct effect on performance.

Keywords: Proprietary equipment, Absorptive capacity, Training

Introduction

Why do some companies develop proprietary equipment rather than buy it from suppliers? Different authors argued that by developing proprietary equipment, companies can more effectively and efficiently respond to their customer needs, bringing inside their plants valuable knowledge about operations that otherwise would be in suppliers' hands (Hayes & Wheelwright, 1984; Simon, 2009). Accordingly, this capability is firm specific and have a strong tacit dimension potentially leading to competitive advantages (Amit & Schoemaker, 1993; Peteraf, 1993).

In fact, can proprietary equipment be a source of competitive advantages positively impacting operational performance? Thus far, no unequivocal answer to this question can be found in the literature. Whereas some researchers have found a direct and positive relationship (e.g., Schroeder, Bates, & Junttila, 2002), others have indicated that a superior operational performance was not significantly and directly associated with proprietary equipment (e.g., Cua, McKone, & Schroeder, 2001; Zander & Kogut, 1995).

A plausible explanation to the mixed results may lie in the concept of best practices. Since the recognition of the importance of capabilities to operations strategy, OM scholars and managers have directed attention to what have turned out to be recognized as best practices (Laugen, Acur, Boer, & Frick, 2005); that is, generic operational processes established by high performance manufacturers to achieve superior performance and capability (Flynn, Schroeder, & Flynn, 1999; Voss, 1995). However, this widespread adoption of recognized practices may imply a weakness in the competitiveness of proprietary equipment to operations because this capability might become substitutable across companies (Barney, 1991), and as a consequence it would not lead to superior operational performances (Peng, Schroeder, & Shah, 2011).

Thus, although the development of proprietary equipment has a critical role for operations by bringing inside the plant valuable knowledge, it *per se* may have little impact on operational performance (Hayes, Wheelwright, & Clark, 1988), only supporting the obtainment or maintenance of a competitive parity. As a result, to leverage the competitiveness of proprietary equipment, companies need to advance a more robust operations strategy.

This research aims at answering the following research questions: a) can the capability to develop proprietary equipment lead to the anticipation of new technologies? and b) what is the relationship between new technologies, training, and performance?

We begin by presenting the study's theoretical foundations, reviewing the absorptive capacity perspective and developing the research hypotheses. The following sections discuss the research methodology and the results, focusing on the importance of data treatment for implications of causal relations. Finally, we discuss contributions and limitations of this study, offering recommendations for future research.

Theoretical foundation

Absorptive capacity

Absorptive capacity has been used to explain how companies can use previous and related knowledge to develop the capability to evaluate and use new valuable knowledge (Cohen & Levinthal, 1990). More specifically, absorptive capacity stipulates that a company's ability to recognize, assimilate or transform, and apply valuable external information depends on the company's previous knowledge (Cohen & Levinthal, 1990; Lane, Koka, & Pathak, 2006; Todorova & Durisin, 2007; Zahra & George, 2002).

The ability to recognize the potential value of external information is influenced by the complementary and diversity of knowledge sources of the company and its external environment (Cohen & Levinthal, 1990; Zahra & George, 2002). Once the valuable external knowledge is identified, the company integrates current and new knowledge by assimilating or transforming it (Todorova & Durisin, 2007). Assimilation takes place when there is a high degree of complementarity between a company's knowledge base and external information. On the other hand, when companies face different knowledge bases from their external environment, they need to transform their knowledge structures to assimilate new information (Todorova & Durisin, 2007). The company's capability to exploit this combined information is then used to create products, processes and technologies (Zahra & George, 2002) that are firm-specific and therefore not easily transferable to competitors (Cohen & Levinthal, 1990), leading to competitive advantages (Lane et al., 2006)

Hypotheses development

From the absorptive capacity perspective, companies can use their established expertise in developing proprietary equipment to advance in the frontiers of new technologies. Accordingly, the capability to advance proprietary equipment comprises a group of routines aimed at building or adjusting equipment that support the plant specific needs

(Hayes & Wheelwright, 1984). These routines are embodied in the plant's manufacturing technology (Zander & Kogut, 1995), and allow the plant to effectively respond to market needs (Hayes & Wheelwright, 1984).

This capability is developed through both internal and external learning (Schroeder et al., 2002). On the one hand, internal knowledge, built through a deep understanding of operations, is necessary so that plant workers know how to adapt or advance equipment according to the plant's needs and design. External knowledge, on the other hand, drives the development of proprietary equipment, signaling the most critical plant's machinery required to be developed or adjusted to attend specific customer requirements (Hayes & Wheelwright, 1984).

This knowledge turns out to be a critical element for companies to identify and evaluate new technologies. As it follows, the employees' comprehension of internal operations is necessary so that resources will be focused on anticipating technologies compatible with the plant's structure and significant to operations advancements. Rather than focusing on a varied of potential technologies, companies possessing a deep understanding of their operations would be more capable of targeting new technologies that make the most sense to the long-term operations strategy.

Additionally, a crucial element to successfully anticipate new technologies is related to the ability to grasp customers' future expectations (Finger, Flynn, & Paiva, 2014). Since proprietary equipment is directed by customers' needs (Hayes & Wheelwright, 1984), companies possessing this capability have a more developed flow of information going back and forth between operations and customers. As a result, these companies are more likely to foresee what demands in the future will look like. As posed by Hayes & Wheelwright (1984), companies advancing their own equipment are "close related to their customers so that they can understand and anticipate their needs, and to communicate those needs effectively back to the organization" (Hayes & Wheelwright, 1984, p. 344).

Consequently, to effectively move the frontiers of proprietary equipment, organizations should use their previously acquired knowledge to anticipate customers' future expectations, deploying the required resources and developing the necessary capabilities to implement new technologies (Finger et al., 2014; Peng, Schroeder, & Shah, 2008).

Therefore, according to the absorptive capacity perspective (Cohen & Levinthal, 1990; Todorova & Durisin, 2007; Zahra & George, 2002), the knowledge acquired through the development of proprietary equipment provides the plant with a cognitive structure that will enable it to more effectively identify and evaluate new technologies. We thus posit our first hypothesis H1: Proprietary equipment capability is positively and significantly related to the anticipation of new technologies (ANT)

Hayes & Wheelwright (1984) pointed out that investments toward new technologies not only have a positive impact on product innovativeness, but also enhance current product performance. However, after identifying new technologies, companies need first to create mechanisms through which they will absorb this new knowledge to apply it for commercial purposes (Cohen & Levinthal, 1990; Todorova & Durisin, 2007). The absorption of these technologies depends on the company's ability to share and communicate the new knowledge internally, pointing out where and how it has to be used (Lane et al., 2006). Furthermore, new technologies constantly change operations processes and procedures, demanding investments to advance the necessary skills to run these procedures effectively (Hayes, Wheelwright, & Clark, 1988).

To this end, training may play a crucial role for it serves to diffuse and apply new knowledge (Boudreau, Hopp, Mcclain, & Thomas, 2003), creating core capabilities among employees (Huselid, 1995) and building the necessary technical competence for the performance of routines (Hayes et al., 1988).

More specifically, training comprises the development of job-related skills (Ahmad & Schroeder, 2003) to improve employees' problem-solving and analytical abilities (Youndt, Snell, Dean, & Lepak, 1996), increasing the comprehension employees have of the impact of their activities to the organizations' strategy (Ahmad & Schroeder, 2003) and enabling the workforce to better link operations strategy to operational performance (Flynn et al., 1999; Wheelwright & Hayes, 1985). In this scenario, training provides the mechanisms through which new technologies can be absorbed and applied to achieve a desired operational performance.

Therefore, a superior product performance and innovativeness will not be achieved only by moving the frontiers of equipment through identifying new technologies, it is necessary, to diffuse the new knowledge through training to create the capabilities required to properly assimilate and apply these technologies according to the operations strategy. This discussion leads us to the following hypotheses H2a: New technologies have a positive and significant effect on product innovativeness through training and H2b: New technologies have a positive and significant effect on product performance through training.

Methodology

SPPS 20 was used to conduct descriptive statistics and missing data analysis. Confirmatory factor analysis (CFA), which assessed, validity, reliability and overall model fit, and the test of the research hypotheses were performed through AMOS 24.

Sample

The data is from the fourth round of the High Performance Manufacturing project (HPM) and was collected from 2013 to 2015 through survey methodology (Schroeder & Flynn, 2001). The original sample contained 266 plants, but due to missing values, the Little MCAR's test was performed to verify whether missing data was completely at random (Hair et al. 2009). The results showed that missing values were predominant within some subgroups ($p < 0.000$). Then, to guarantee the original distribution of the data, the listwise procedure was performed, removing all observations that have at least one missing value (Hair et al., 2009; Kline, 2011). The remaining sample contained 217 firms, located in 11 countries across 3 industries.

Instrument

This survey is composed of 12 different questionnaires. In each one of them, items of the same construct were mixed so that a construct was not easily identified. The questionnaires were administered to multiple respondents, such as plant managers, process engineers, and human resource managers.

The survey questionnaires and instructions to conduct the research instruments were equally distributed to the global research team. Questionnaires were translated from English to the native languages of each country. Afterwards, questionnaires were carefully translated back to English by different researchers and compared to the original instrument to guarantee reliability.

Validity and reliability analysis

Convergent validity was assessed by the factor loadings and the composite reliability. The appendix illustrates that all the standardized factor loadings and the composite reliabilities have values equal or above the cutoff criteria. Discriminant validity was assessed by a one-degree-of-freedom chi-square difference test. The test indicated that all the constructs were significantly different from each other.

The problem of common-method variance (CMV) was tackled with the aid of the Hausman test (Antonakis, Bendahan, Jacquart, & Lalive, 2010). This procedure permitted to verify that training was an exogenous construct (as it is further explained in the next section) so that it varies independently of other factors, demonstrating that CMV poses no threat to the reliability of the research results.

Endogeneity

When estimating the coefficients of the relationship between the anticipation of new technologies (ANT) and training and between this construct and product innovativeness and performance, the maximum likelihood performed in AMOS assumes that the predictor constructs (ANT and training) do not correlate with the disturbance term of the dependent constructs (Antonakis et al., 2010; Ketokivi & McIntosh, 2017). However, since many other factors may be related to training and product outcomes, it can be the case that ANT be correlated with the disturbance term of training as well as training be correlated with the disturbance terms of the dependent variables. As a result, the coefficient of the relationship between the predictor and dependent constructs will be adjusted to the extent that the predictor correlates with the unobserved causes of the dependent constructs (Antonakis et al., 2010). In this context, a statistical significant relation between both constructs is uninterpretable (Antonakis et al., 2010).

To guarantee the consistency of estimates, a method commonly applied is the Hausman test (Antonakis et al., 2010), which was performed in this research. To conduct this test, it is necessary to have instrumental or exogenous variables to account for the endogenous predictor (Ketokivi & McIntosh, 2017).

ANT and proprietary equipment capabilities are measures presenting a good reliability, then, they can be considered plausible exogenous constructs from a measurement error point of view (Antonakis et al., 2010; Ketokivi & McIntosh, 2017). The untestable assumption, in this case, is that the instrumental constructs do not correlate with the disturbance terms of the dependent constructs (Ketokivi & McIntosh, 2017).

The Hausman test assesses whether anticipation of new technologies and training are endogenous, and if affirmative, the unobserved causes (disturbance terms) of ANT and training, as well as, of training and product innovativeness and performance must be correlated. This test compares the chi-square of a model with a constrained correlation between the disturbance terms of the constructs with the chi-square of a model with an unconstrained correlation (Antonakis et al., 2010; Ketokivi & McIntosh, 2017). Since the research model presents one endogenous regressor, if a one-degree-of-freedom chi-square difference is not statistically significant, there is no need to correlate the disturbance terms to assess consistent estimates (Antonakis et al., 2010).

The Hausman test resulted in a non-significant difference of the chi-squares between the constrained and the unconstrained models. Then, the disturbance terms of ANT and training, and of training and product innovativeness and performance were not co-variated in the research model (Antonakis et al., 2010).

Analysis

Descriptive statistics of the variables and constructs are presented in table 1. All the correlations were statistically significant except for the relationship between proprietary equipment and the dependent variables and between ANT and product performance.

Table 1 - Mean, standard deviation and Pearson correlation among constructs (n = 217)

**p < 0.05 (two-tailed); **p < 0.01 (two-tailed)*

Constructs	Mean	SD	1	2	3	4	5
1. Prop. equip.	2.51	0.62	1	-	-	-	-
2. ANT	3.49	0.62	.641**	1	-	-	-
3. Training	3.67	0.55	.210**	.463**	1	-	-
4. Prod. innovativeness	3.62	0.83	.102	.185**	.218**	1	-
5. Prod. performance	3.87	0.73	-.048	.083	.184**	.567**	1

Structural Equation Modeling (SEM) was used to test the research hypotheses because of its advantages to analyze mediation hypotheses (Preacher & Hayes, 2008). To assess the mediation effects the bias-corrected bootstrapping method at a 95% confidence interval with 5,000 samples (Preacher & Hayes, 2008) was performed in accordance to the recommendations of Malhotra, Singhal, Shang, & Ployhart (2014) and Rungtusanatham, Miller, & Boyer (2014).

Bootstrapping is a nonparametric resampling procedure that does not impose the assumption of normality of the sampling distribution (Preacher & Hayes, 2008). This method provides a high statistical power even with relatively small sample sizes (Malhotra et al., 2014), demonstrating to be one of the most important statistical procedure to detect significant mediation effects (Rungtusanatham et al., 2014) while maintaining reasonable control over type I error rate (Preacher & Hayes, 2008).

Model fit

The values for the rate of x^2 to degrees of freedom and the absolute fit measures were below the cutoff values, indicating a good model fit (CMIN/DF = 2,00). The incremental fit index values (IFI = 0.932; CFI = 0.930; TLI = 0.910; RMSEA = 0.068) were close to the cutoff criteria, suggesting an overall satisfactory model fit (Hu & Bentler, 1999; Vandenberg & Lance, 2000).

Results

The results indicated that the development of proprietary equipment is positively and strongly related to the anticipation of new technologies (β = 0.56, p-value < 0.001), supporting the first hypothesis. The findings also confirmed the mediation hypotheses (2a and 2b) that anticipation of new technologies is positively related to product performance and innovativeness through training.

Since previous literature has presented mixed results for the relationship between proprietary equipment and operational performance, we tested the direct relationship between this capability and product innovativeness and performance. The results showed no significant direct relationship, supporting the importance of new technologies to move forward the frontiers of proprietary equipment. By the same token, new technologies have no direct and significant effect on performance, confirming the need of mechanisms, such as training, through which these technologies can be diffused and applied to achieve a desired goal. Table 2 provides the results of the direct and indirect coefficients.

Table 2 - Standardized direct and indirect effects and confidence interval
*Indirect effect significance levels were obtained from bootstrapping using the bias-corrected percentile method at 95% confidence interval; *p < 0.05 (two-tailed); **p < 0.01 (two-tailed)*

Relationships	Coefficients	Lower limit	Upper limit

Direct relationships	**Prop. Equip. => ANT (H1)**	**0.558****	**0.358**	**0.724**
	Prop. Equip. => Prod. Innov.	-0.004	-0.229	0.234
	Prop. Equip. => Prod. Perf.	-0.195	-0.441	0.045
	ANT => Prod. Innov.	0.130	-0.102	0.399
	ANT => Prod. Perf.	0.132	-0.119	0.411
	Training => Prod. Innov.	0.203*	0.001	0.382
	Training => Prod. Perf.	0.221*	0.011	0.420
Indirect relationships	Prop. Equip. => ANT => Training => Prod. Innov.	0.117	-0.004	0.295
	Prop. Equip. => ANT => Training => Prod. Perf.	0.122	-0.007	0.319
	ANT => Training => Prod. Innov. (H2a)	**0.080***	**0.013**	**0.177**
	ANT => Training => Prod. Perf. (H2b)	**0.087***	**0.016**	**0.201**

Studies in operations strategy have shown differences among industries (Ahmad & Schroeder, 2003; Flynn & Flynn, 2004), thus, the impact that industry type may have on the endogenous constructs and variables was controlled. Following some recommendations of good practices of control tests (Becker, 2005; Malhotra & Grover, 1998), statistical results are reported in table 3. The industry segment was included into the structural equation model and co-variated with all the other exogenous constructs and variables. A significant difference was found between the electronics and transport segments, indicating that the former presents lower levels of training than that of the latter. The control variables are not included in the research hypotheses because the focus of this study is not on the theoretical reasons of the differences among industry segments.

Table 3 – Control Test
**p < 0.05 (two-tailed)*

	Machinery				Transport			
	ANT	Training	Prod. Innov.	Prod. Perf.	ANT	Training	Prod. Innov.	Prod. Perf.
Eletronics	0.057	-0.123	0.058	0.059	0.157	-0.207*	-0.017	-0.041
Machinery	-	-	-	-	0.102	-0.086	-0.076	- 0.102

Discussion

The results of this study indicate that proprietary equipment is a crucial antecedent to anticipate new technologies and that training mediates the relationship between these technologies and performance. By demonstrating that new technologies have no direct relation with performance, the research findings suggest that without training programs to create the capabilities to implement these technologies, they may go unheeded.

This study advances the literature on world class manufacturing by demonstrating that proprietary equipment *per se* has no direct impact on operational performance, contrary to the expectations of Hayes and Wheelwright (1984). However, according to the absorptive capacity perspective, proprietary equipment can provide a foundation for the development of know-how that is important in finding new and valuable technologies that, once diffused through training, are positively associated with operational performance. Such relationship can be crucial to a company operations' competitiveness because by using knowledge developed through proprietary equipment to absorb external information a company can reinforce, complement, or refocus its operation's knowledge base (Lane et al., 2006).

Indeed, the theoretical underpinnings of the relationship among proprietary equipment, anticipation of new technologies and training provide a strong foundation for better understanding the integration of the structural and infrastructural elements of operations strategy (Hayes & Wheelwright, 1984; Swink & Hegarty, 1998) and their benefits for competitive performance.

This investigation highlights important practical implications. First, our results indicate a promising way for operations managers to capitalize on proprietary equipment by discussing its underlying elements and how these elements can be used to leverage the competitiveness of companies that develop their own equipment. Second, by integrating training in our theoretical model, we show that a strong operations strategy combines infrastructure and structure elements. Our results provide evidences of the critical role training has in an operations strategy, offering a possible road that operations managers can follow to diffuse and apply new knowledge in the plant. Therefore, by using the absorptive capacity perspective to underscore the relations among operations strategy's elements, we show how a company can use its proprietary equipment to more precisely forecast technological trends and take benefits of emerging opportunities before its competitors can identify them (Finger et al., 2014; Lane et al., 2006).

In sum, this tightly integrated system of technologies and skills development is a crucial element to leverage a company's competitive position because it is difficult to be copied or substituted by competitors (Hayes & Upton, 1998).

One limitation of this study is the use of cross-sectional data. Since the theoretical model depicts a causal relationship supported by the absorptive capacity perspective, it implies a sequential process that is not directly captured by the research data. Thus, future research investigating causal relations of operations strategies' factors should rely on longitudinal data that can depict more clearly the happenings in a sequential fashion.

Moreover, the scales used in this study is part of a wider project developed for reasons other than the ones explored in this investigation, so the constructs had to be adapted according to this research's objectives. Finally, the three industry sectors can limit the generalizability of the research findings to other segments. Future researches, therefore, may test how the relationship among proprietary equipment, new technologies, and training is in other industries relying on different data sources and using data suited more to the investigation's purposes.

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Appendix – Measurement items and composite reliability

Code	Item	Adapted from	CFA	Comp. Reliability
Training				
SDC1	our plant employees receive training and development in workplace skills, on a regular basis.	(Ahmad & Schroeder, 2003) (Snell & Dean, 1992)	0.79*	0.81
SDC2	management at this plant believes that continual training and upgrading of employee skills is important.		0.69*	
SDC3	our employees regularly receive training to improve their skills.		0.8*	
SDC4	employees at this plant have skills that are above average, in this industry.		Dropped	
SDC5	our employees are highly skilled in this plant.		0.6*	
Anticipation of New Technologies (ANT)				
ANT1	we pursue long-range programs, in order to acquire manufacturing capabilities in advance of our needs.	(Cua et al., 2001) (Finger et al., 2014)	0.78*	0.81
ANT2	our plant stays on the leading edge of new technology in our industry.		0.71*	
ANT3	we are constantly thinking of the next generation of manufacturing technology.		0.74*	
ANT4	we make an effort to anticipate the potential of new manufacturing practices and technologies.		0.64*	
Proprietary Equipment				
EQU1	we actively develop proprietary equipment.	(Cua et al., 2001) (Schroeder et al., 2002)	0.86*	0.78
EQU2	we produce a substantial amount of our equipment in-house.		0.6*	
EQU4	we frequently modify equipment to meet our specific needs.		*0.61**	
EQU6	proprietary equipment helps us gain a competitive advantage.		*0.67**	
Performance				
PCP	Product capability and performance	(Schroeder et al., 2011)	*0.65*	-
PIP	Product innovativeness	(Zhang et al., 2016)	*0.85*	-

*p < 0.01