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Training and proprietary equipment: the bow and the arrow to shoot the target

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Abstract

Purpose – This study aims to investigate the relationship between proprietary equipment and anticipation of new technologies in enhancing product innovativeness and competitive performance.

Design/methodology/approach – It used survey data collected in the fourth round of the High-Performance Manufacturing project (HPM), which comprised 270 plants in 15 countries across three industries. The relationships proposed in this study were analyzed through structural equation modeling, confirmatory factor analysis and endogeneity tests.

Findings – Results show that proprietary equipment alone does not directly impact performance but can still serve as as a source of advantage since the proper mechanisms are implemented.

Research limitations/implications – The theoretical underpinnings of the relationship among proprietary equipment, anticipation of new technologies and training provide a strong foundation for a better understanding of the integration of the structural and infrastructural elements of operations strategy and their benefits for competitive performance.

Practical implications – Results show how operations managers can capitalize on proprietary equipment to anticipate new technologies by developing training routines to absorb and apply new knowledge in the plant.

Social implications – This research contributes to the competitiveness of manufacturing firms by showing how knowledge can be created and disseminated in their operations to develop better-prepared employees.

Originality/value – This study advances the literature on world-class manufacturing by demonstrating that proprietary equipment per se has no direct impact on product performance and innovativeness, contrary to what previous literature has demonstrated.

Keywords Operations strategy, Absorptive capacity, Proprietary equipment, New technologies, Training

Paper type Research paper

1. Introduction

The enduring success of some Japanese companies like Toyota has several reasons. One of them, according to Benders & Morita (2001), is the role of the company's division Toyota Machinery in developing their own manufacturing equipment. Other examples can be found in the so-called "hidden champions," companies in countries like Germany, China and even Brazil, which are leaders in very specific market niches. These companies are concerned

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about keeping the "proprietary nature" of internal knowledge resources, including manufacturing equipment (Simon, 2009). Thus, why do companies develop proprietary equipment rather than buy it from suppliers? In their seminal work about world-class manufacturing, Hayes and Wheelwright (1984) argued that by developing proprietary equipment, companies can more effectively and efficiently respond to their customer needs, bringing to their plants valuable knowledge about operations that otherwise would be in suppliers' hands. Accordingly, this capability is firm specific and has a strong tacit dimension, potentially leading to competitive advantages (Amit & Schoemaker, 1993; Peteraf, 1993).

In fact, can proprietary equipment be a source of competitive advantage that positively impacts superior operational performance? So far, no unequivocal answer to this question can be found in the literature. While some researchers have found a direct and positive relationship (e.g. Schroeder, Bates, & Junttila, 2002), others indicated that superior operational performance was not significantly and directly associated with proprietary equipment (e.g. Cua, McKone, & Schroeder, 2001; Zander & Kogut, 1995). However, recent studies have stressed the role of proprietary equipment in competitiveness. Jin, Vonderembse, and Ragu-Nathan, (2013) claimed the importance of proprietary equipment for flexibility. Ketokivi & Mahoney (2020) argued that scholarly conversations on Transaction Costs Economics (TCE) have advanced from a narrow approach related to costs to an enhanced view, including revenues. Within the new view, asset specificity can also have implications for revenues. According to them, "[…] the discussion on whether an industrial firm should use general- or special-purpose technology has always been relevant in operations management." (Ketokivi & Mahoney, 2020, p. 1020) Other past studies related to proprietary equipment like Juntilla, Schroeder and Bates' (2002) considered external learning as a continuous process of learning based on the clients and suppliers. Nevertheless, all these references do not explore issues related to building new knowledge and capabilities from a future perspective like the search for new technologies.

Thus, although the development of proprietary equipment has a critical role in operations by bringing to the plant valuable knowledge, it *per se* may have little impact on operational performance (Hayes, Wheelwright, & Clark, 1988), only supporting the obtention or maintenance of competitive parity. As a result, manufacturing companies need to advance a more robust operations strategy to leverage the competitiveness of proprietary equipment. Moreover, the notion of ambidexterity is absent in prior studies, that is, how manufacturing companies can explore new knowledge while exploit established capabilities (March, 1991).

Considering that current and future perspectives are viewed as complementary (Gupta, Smith, & Shalley, 2006; Kristal et al., 2010), we claim that proprietary equipment effectiveness will be higher when companies have actions oriented toward both. A current perspective allows the enhancement of the use of current resources (through training), while a future perspective orients the development of resources to fulfill customers' future expectations (through the anticipation of new technologies). In this scenario, training will allow new technologies like proprietary equipment to be absorbed by developing job-related skills (Ahmad & Schroeder, 2003). Therefore, more research is needed on how the combination of current and future perspectives is related to proprietary equipment.

Manufacturing companies need to develop proper mechanisms to capitalize on their proprietary equipment to anticipate and successfully implement new technologies. These mechanisms can be paramount to the advancements of technologies of the Industry 4.0. For instance, training has been a successful mechanism for manufacturing companies to develop technologies of the Industry 4.0 (Pozzi, Rossi, & Secchi, 2023; Saniuk, Dagmar, & Saniuk, 2023).

We analyze the advancement of proprietary equipment through the lens of absorptive capacity to discuss how current knowledge (i.e. proprietary equipment) can be a source to acquire and use new knowledge. Our research question is: What is the relationship between proprietary equipment, absorptive capacity, and performance? To answer this research question, we used survey data collected in the fourth round of the High-Performance Manufacturing project (HPM), which comprised 270 plants in 15 countries across three industries.

We begin by discussing the literature on proprietary equipment, focusing on its sources of competitive advantage and using the resource-based view as the backdrop. Next, we present the study's theoretical foundations, reviewing the absorptive capacity perspective and discussing the frontiers of proprietary equipment and its effect on product innovativeness and competitive performance. Then, we present the research methodology based on mediation analysis and the importance of endogeneity in the implications of causal relations. Next, we present the results, comparing them with previous literature. Finally, we discuss the contributions and limitations of this study, offering recommendations for future research.

2. Theoretical foundation

2.1 Absorptive capacity

When companies develop proprietary equipment, there is a twofold process: searching and applying knowledge. Absorptive capacity has been used to explain how companies can use current knowledge to develop the capability to recognize and use new valuable knowledge (Cohen & Levinthal, 1990). Specifically, absorptive capacity stipulates that a company's ability to recognize, absorb, and apply valuable external information depends on the company's current knowledge (Cohen & Levinthal, 1990; Lane, Koka, & Pathak, 2006; Todorova & Durisin, 2007; Zahra & George, 2002).

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

We use the absorptive capacity perspective to explain how manufacturing companies can leverage current knowledge developed through proprietary equipment so that these companies can identify, assimilate and absorb new technologies that lead to competitive advantage.

The capability to develop proprietary equipment is the firm's current knowledge base used to anticipate new technologies. Once new technologies are identified, manufacturing companies have to provide the mechanisms through which operations can assimilate and apply the new knowledge to commercial purposes (Cohen & Levinthal, 1990). Assimilation and application are developed through training routines. Training routines are crucial because they diffuse knowledge, build the necessary capabilities (Boudreau, Hopp, Mcclain, & Thomas, 2003) and enable new routines to achieve desired goals (Tharenou, Saks, & Moore, 2007).

2.2 Proprietary equipment

Proprietary equipment is characterized by the development of equipment by the plant, which can be patented or not to increase performance (Schroeder et al., 2002). Proprietary equipment is developed to meet the plant's specific needs (Hayes & Wheelwright, 1984). For example, Hayes and Wheelwright (1984) found that Japanese companies have modified their machines by making them smaller and more flexible to meet market demands.

The development of proprietary equipment has long been believed to be a source of superior operational performance (Hayes & Wheelwright, 1984; Schroeder et al., 2002; Wheelwright & Hayes, 1985). Schroeder et al. (2002) argued that casual ambiguity and path dependency are elements present in the development of proprietary equipment, making it imperfectly imitable. By the same token, Jin et al. (2013) showed that proprietary equipment and technology were significantly related to competitive advantage but negatively related to flexibility.

However, other studies have found different results. For instance, Cua et al. (2001) showed that proprietary equipment was not directly related to any dimension of operational performance. Similarly, Zander and Kogut (1995) found weak support for the argument that developing proprietary equipment hinders imitation. These inconclusive findings pose some doubts about the competitiveness of proprietary equipment that need to be clarified.

These confounding results may lie in the concept of best practices. Since the recognition of the importance of some practices to operations strategy, operations management scholars and managers alike have directed attention to best practices (Laugen, Acur, Boer, & Frick, 2005), that is, generic operational processes established by high-performance manufacturers to achieve superior performance (Flynn, Schroeder, & Flynn, 1999; Voss, 1995). Nevertheless, this widespread adoption of recognized practices may imply a weakness in the competitiveness of proprietary equipment to operations because it might become substitutable across companies (Arora & Fosfuri, 2003; Barney, 1991), not leading to superior operational performance (Peng, Schroeder, & Shah, 2011).

Thus, although developing proprietary equipment can lead to imperfectly imitable resources (Schroeder et al., 2002), recognizing its importance for operations strategy suggests that world-class manufacturers have derived options to substitute competitors' capabilities to advance proprietary equipment. Therefore, proprietary equipment alone would not support superior operational performance.

2.3 Anticipation of new technologies

Anticipation of new technologies refers to the ability of manufacturing companies to identify future customers' demands, products that satisfy them, the new technologies that support these product developments, and the capabilities necessary to implement these new technologies (Finger, Flynn, & Paiva, 2014).

Companies developing their own equipment should be ahead of their competitors in anticipating new valuable technologies. In doing so, these companies would have available mechanisms to meet market needs that competitors still have to meet (Coeurderoy & Durand, 2004; Finger et al., 2014). For instance, Jin et al. (2013) argued that companies can derive a stronger operations strategy to support a company's competitive advantage by integrating proprietary technology and suppliers' dedicated technologies. Recently, some scholars have focused on the advancements of the Industry 4.0 technologies, arguing that these technologies need critical antecedent factors for a successful implementation, such as training routines (Pozzi et al., 2023; Raj, Dwivedi, Sharma, Jabbour, & de, 2020; Saniuk et al., 2023; Sigov, Ratkin, Ivanov, & Da, 2022).

To anticipate new technologies, companies can rely on the routines that have already been performed to develop proprietary equipment. In this sense, the absorptive capacity perspective provides the theoretical foundations to understand how companies can leverage previous knowledge (i.e. the development of proprietary equipment) to identify external knowledge (i.e. new technologies) and absorb and apply it.

2.4 Hypotheses development

Manufacturing companies can use their capability to develop proprietary equipment to advance in the frontiers of new technologies. The capability to develop proprietary equipment comprises a group of routines aimed at building or adjusting equipment that supports 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). Therefore, we define proprietary equipment capability as the skills to develop internally new technologies based on internal routines.

This capability is developed through internal and external knowledge (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 to meet specific customer requirements (Hayes & Wheelwright, 1984).

This knowledge turns out to be a critical element for companies to identify and absorb new technologies (Finger et al., 2014). As follows, the employees' comprehension of internal operations is necessary so that resources are focused on anticipating technologies compatible with the plant's structure and significant to operations advancements (Schroeder et al., 2002).

Additionally, a crucial element in successfully anticipating new technologies is the ability to grasp customers' future expectations (Finger et al., 2014). Since customers' needs define proprietary equipment (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 future demands will be.

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 enables it to identify new external and valuable technologies more effectively. We thus posit our first hypothesis:

H1. Proprietary equipment capability is positively related to anticipating new technologies (ANT).

After identifying new valuable technologies, manufacturing companies must create mechanisms to absorb and apply them commercially (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 the new knowledge has to be applied (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 et al., 1988). As pointed out by Colarelli and Mantei (1996, p. 318), "A new technology represents a new way of doing things, and it usually requires new skills (to operate the technology), particularly when the technology is complex. Old routines and skills are unlikely to be useful."

To develop the necessary skills new technologies demand, companies should focus on training their employees to diffuse and apply new knowledge (Boudreau et al., 2003). Training may play a major role in the absorptive capacity of an operation (Cohen & Levinthal, 1990) because it provides the necessary learning that employees need to combine previous and new knowledge to absorb the new external information effectively

(Lane et al., 2006). By training their workers, companies create core capabilities (Huselid, 1995) and build the necessary technical competence to perform new routines (Hayes et al., 1988). For instance, training is considered a core element for implementing the Industry 4.0 technologies, such as advanced manufacturing technologies (AMT) (Pozzi et al., 2023; Saniuk et al., 2023).

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 on 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). Thus, training provides the mechanisms through which new technologies can be absorbed.

Moreover, the integration between technical and human capabilities can powerfully support and enhance operations strategy (Hayes & Wheelwright, 1984) because it is neither easily copied nor transferable to other companies (Hayes & Upton, 1998), leading to competitive advantages (Hayes & Wheelwright, 1984; Swink & Hegarty, 1998). For example, product performance and innovativeness can open new windows for manufacturing companies due to better profitability (Kleinschmidt & Cooper, 1991).

We consider "product capability" as "the consumer's beliefs about the product's ability to perform desired functions" (Thompson, Hamilton, & Rust, 2005, p. 432). Thus, product performance encompasses the reliability and quality of current products to meet desired functions (Hayes et al., 1988; Tracey, Vonderembse, & Lim, 1999), and superior performance in this dimension is an important measure of success because it allows companies to increase their market share (Wheelwright & Clark, 1992). On the other hand, product innovativeness comprises the level of novelty and newness of a new product (Zhang, Liang, & Wang, 2016) that strongly impacts the success of new product development and offers product advantage and differentiation (Kleinschmidt & Cooper, 1991).

Therefore, superior product performance and innovativeness are not achieved only by identifying and evaluating new technologies; it is necessary to diffuse the new knowledge through training to create the capabilities required to properly absorb and apply these technologies according to the operations strategy. This discussion leads us to the following hypotheses:

H2a. Training mediates the relationship between new technologies and product innovativeness.

H2b. Training mediates the relationship between new technologies and product performance.

Figure 1 presents the research model, depicting the relationship among the research constructs, the elements of absorptive capacity and the direct and indirect hypothesis.

3. Methodology

Next, we present the research methodology used to answer the research question. We structured our methods following the research onion designed by Saunders, Lewis, and Thornhill (2009).

3.1 Research philosophy

This study follows a positivist view considering the nature of reality, external and objective, and focusing on the causal relationships depicted in the hypothesis developed. Furthermore, the researchers were independent of the data and maintained an unbiased perspective. We used highly structured data collection methods, measurements and quantitative data to answer the research question (Saunders et al., 2009).

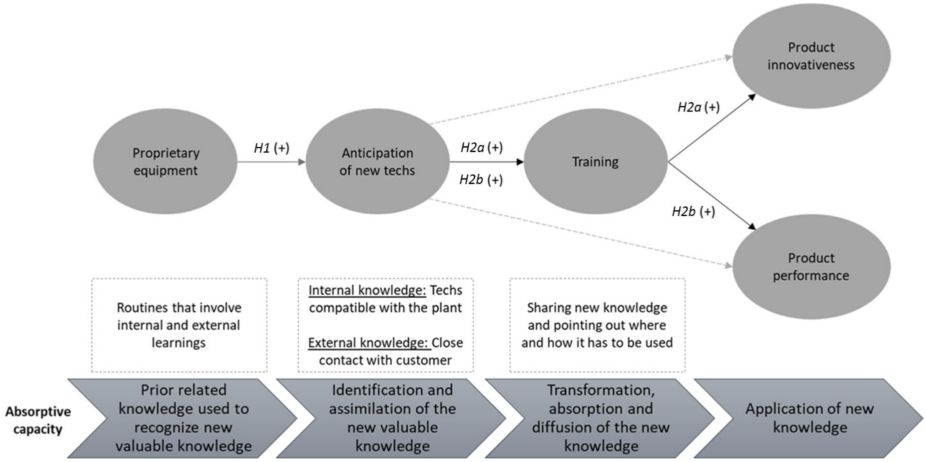

Figure 1. Research model
Source: Authors' own work

3.2 Research approach

We used a deductive approach for this research. The main objective of this study is to derive and test specific hypotheses (Stank, Pellathy, In, Mollenkopf, & Bell, 2017) about the relationship between proprietary equipment, new technologies, and training and their impact on some dimensions of operational performance. Additionally, this study is primarily descripto-explanatory (Saunders et al., 2009) as we describe and explain the relationship between proprietary equipment, new technologies, training and some operational outcomes.

3.3 Research strategy

This research is based on a survey design. We chose this design for three reasons: First, our research question focuses on "what" the relationship between the variables of interest is (Saunders et al., 2009). Secondly, we focus on a very mature theme that is composed of well-studied variables and constructs. Thirdly, we focus on the descriptive nature of the relationship between operations strategy variables.

3.4 Method choice

This study is characterized as a mono method since we use only a single data collection technique and statistical analysis procedures (Saunders et al., 2009) to understand the relationship between the variables of interest.

3.5 Time horizon

This study focuses on a cross-sectional time horizon because the data was collected at a single point in time. We further discuss the benefits and the limitations of cross-sectional data.

3.6 Techniques and procedures

The data is from the fourth round of the High-Performance Manufacturing project (HPM) and was collected from 2013 to 2018 through survey methodology (Schroeder & Flynn, 2001).

Plants were selected based on size (more than 500 employees) and segment (electronics, machinery and transport). The original sample contained 330 plants. The Little MCAR's test showed that missing data was predominant within some groups ($p < 0.000$). Then, we performed the listwise procedure to guarantee the original distribution of the data (Hair, Black, Babin, Anderson, & Tatham, 2009; Kline, 2011). The remaining sample contained 270 firms in 15 countries across three industries. Table 1 presents the sample details.

This survey is composed of 12 different questionnaires. In each one, items of the same construct were mixed so that a construct could not be 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. Afterward, questionnaires were carefully translated back to English by different researchers and compared to the original instrument to guarantee reliability.

SPSS 20 was used to conduct descriptive statistics and missing data analysis. Confirmatory factor analysis (CFA) assessed validity, reliability and overall model fit, and the research hypotheses were tested through AMOS 24. Finally, RStudio was employed to conduct a weakness test for endogeneity.

3.6.1 Measurement items. Items were measured using self-assessed and perceptual data. Previous scales were used to form the constructs of this study. Appendix Table A1 shows the items of each construct and the studies from which they were adapted. Some research items were assessed through a five-point Likert scale (1 – strongly disagree, to 5 – strongly agree). As for training, we used a 4-item scale measuring how much a plant applies routines to improve employees' skills continually. This questionnaire was administered to human resource managers. The anticipation of new technologies was measured through a 4-item scale, which determined how much a plant performed routines that enabled it to foresee and produce cutting-edge technology. The development of proprietary equipment was

Table 1. Sample details

Country	Electronics	Machinery	Transport	Total
Brazil	3	3	8	14
Germany	5	11	7	23
Spain	6	5	5	16
Israel	10	1	0	11
Sweden	2	3	0	5
Italy	6	17	5	28
Japan	6	6	9	21
China	10	15	4	29
Korea	8	5	12	25
Finland	6	6	4	16
Taiwan	18	10	1	29
Vietnam	8	5	8	21
United Kingdom	4	5	4	13
USA	1	6	3	10
Switzerland	3	4	2	9
Total	96	102	72	270

Source(s): Table by authors

determined by a 4-item scale measuring the extent to which operations advanced proprietary equipment to meet plant needs. Both instruments were administered to process engineers.

Product Innovativeness and product performance are items from the competitive performance questionnaire measured by a 5-point Likert scale (1 – Poor, much worse than global competitors, to 5 – Superior, much better than global competitors) and administered to the plant manager. These items assess the extent to which the plant has achieved product innovation and/or performance compared to its competitors on a global basis.

Researchers have measured product innovativeness either as a multiple-dimension construct (e.g. Zhang et al., 2016) or as a single-item measure (e.g. Calantone, Chan, & Cui, 2006; Kleinschmidt & Cooper, 1991). For this research, product innovativeness and performance were measured by single items because they can be considered simple concepts (Petrescu, 2013), well understood and explored by operations management practitioners and scholars (Calantone et al., 2006; Kleinschmidt & Cooper, 1991; Zhang et al., 2016). To address possible reliability and validity issues through single-item measures, we followed the recommendations by Bergkvist & Rossiter, 2007, and Petrescu, 2013. We used previous studies that tested the reliability and validity as inputs for product innovativeness and performance. For product innovativeness, Zhang et al. (2016) found a reliability of 0.92, while for current product performance, Schroeder, Shah, and Peng (2011) found a value of 0.68. Following these studies and the recommendation for single-item measures, we imputed 0.85 and 0.65 for product innovativeness and product performance, respectively.

3.6.2 Validity and reliability analysis. Validity and reliability were measured through construct validity (Floyd & Widaman, 1995; Hair et al., 2009) and are assessed by convergent and discriminant validities.

3.6.3 Convergent validity. Convergent validity was assessed by the factor loadings and the composite reliability. To guarantee convergent validity, the standardized factor loadings for each item should be above 0.60, and the composite reliability for each construct should be above 0.70 (Hair et al., 2009). Items with a factor loading below 0.60 or low validity expression were deleted from the first analysis (Hair et al., 2009). Appendix Table A1 illustrates that all the standardized factor loadings and the composite reliabilities have values equal to or above the cutoff criteria.

3.6.4 Discriminant validity. Discriminant validity was assessed by a one-degree-of-freedom chi-square difference test. The test indicated that all the constructs were significantly different, as illustrated in Table 2.

Additionally, discriminant validity was analyzed by comparing the average extracted variance for each construct with the squared correlation (average shared variance) among the constructs (Fornell & Larcker, 1981). Table 3 shows that each average extracted variance

Table 2. Discriminant validity

	Unconstrained		Constrained		
Construct scale pair	x^2	d.f	x^2	d.f	x^2 difference
ANT					
Prop. equip.	45.6	13	100.9	14	55.3*
Training	33.3	19	256.2	20	222.9*
Prop. equip.					
Training	14.1	13	179.8	14	165.7*

Note(s): $*p < 0.01$
Source(s): Table by authors

Table 3. Average extracted variance and squared correlation

Constructs	1	2	3	4	5
1. Prop. equip.	*0.652*	–	–	–	–
2. ANT	0.646**	*0.627*	–	–	–
3. Training	0.085**	0.236**	*0.709*	–	–
4. Prod. innovativeness	0.024*	0.035**	0.061**	NA	–
5. Prod. performance	0.001	0.015*	0.046**	0.347**	NA

Note(s): **p* < 0.05 (two-tailed); ***p* < 0.01 (two-tailed)
Source(s): Table by authors

presents values higher than the squared correlation for the pair of constructs, thus indicating that the constructs differ.

3.6.5 Common method variance. Potential problems of common method variance (CMV) were addressed through the design of the research instrument (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003). First, data was collected from different sources within each plant, and at least two respondents answered each item to mitigate the effects of consistency motives, social desirability tendencies, mood states, and the tendency of the participants to respond inaccurately. Second, the research instruments were conducted anonymously to increase the veracity of responses. Finally, the questionnaires were carefully designed to eliminate ambiguous terms, make terms as clear and straightforward as possible, and keep the questions simple, specific, and concise.

3.6.6 Endogeneity. Endogeneity refers to the problem of incorrectly estimating the relationship between two variables due to omitted causes (Antonakis, Bendahan, Jacquart, & Lalive, 2010; Ketokivi & McIntosh, 2017). To illustrate the endogeneity problem, consider that training is depicted as the sole predictor of product innovativeness and performance. Nevertheless, other than training, many factors would relate to the dependent variables (e.g. Ahmad & Schroeder, 2003; Peng, Schroeder, & Shah, 2008; Wu, Melnyk, & Swink, 2012).

We performed the Hausman test to guarantee the consistency of estimates (Antonakis et al., 2010). To this test, instrumental or exogenous variables must be used to account for the endogenous predictor (Ketokivi & McIntosh, 2017). ANT and proprietary equipment capabilities are measures presenting good reliability; they can be considered plausible exogenous constructs from a measurement error point of view and are used as instrumental variables (Antonakis et al., 2010; Ketokivi & McIntosh, 2017). In this case, the untestable assumption 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). Figure 2 shows the steps performed in AMOS to assess the Hausman test.

The Hausman test resulted in a non-significant difference in the chi-squares between the constrained and the unconstrained models, as Table 4 shows. Then, the disturbance terms of

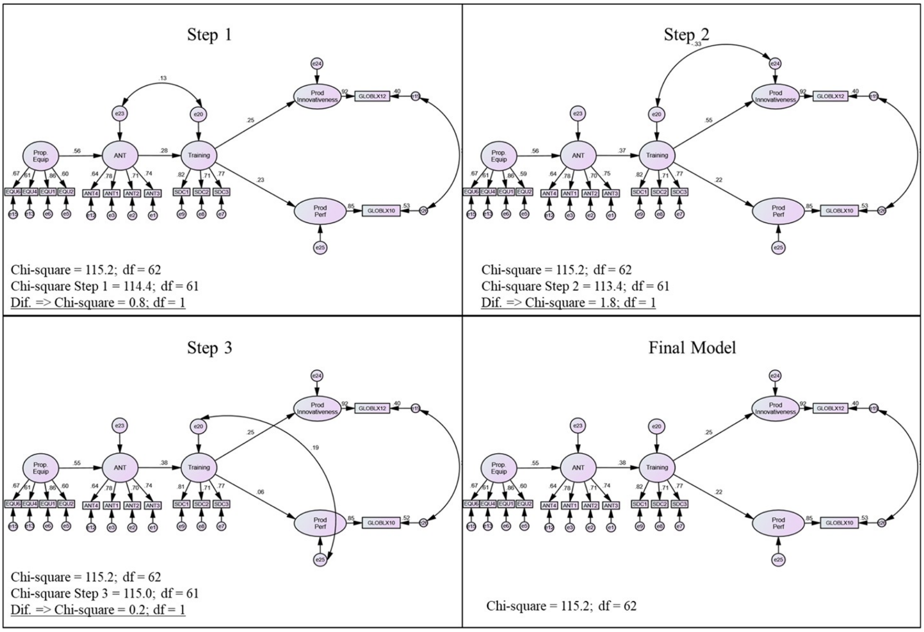

Figure 2. Procedure steps for the Hausman test
Source(s): Authors' own work

Table 4. Hausman test results

Model	x^2	DF	Difference from uncorrelated
Uncorrelated	115.2	62	–
Disturbance terms correlated (ANT – Training) — *Step 1 of* Figure 2 —	114.4	61	0.8
Disturbance terms correlated (Training – Prod. Innovativeness) — *Step 2 of* Figure 2 —	113.4	61	1.8
Disturbance terms correlated (Training – Prod. Perf.) — *Step 3 of* Figure 2 —	115.0	61	0.2

Note(s): All the results were not statistically significant at the $p < 0.05$
Source(s): Table by authors

ANT and training, as well as of training and product innovativeness and performance, were not co-variated in the research model (Antonakis et al., 2010).

Additionally, according to some suggestions to triangulate results (Lu, Ding, Peng, & Hao-Chun Chuang, 2018), we tested for the strength of the instruments used in the Hausman test. This procedure focuses on the first stage in a two-stage least square (2SLS) and shows whether proprietary equipment is a suitable instrument for the relationship between ANT and training, as well as if ANT is a good instrument for the relationship between training and the product variables. The F-statistic results (149.43 for the former and 51.438 for the latter relationships) are well above the threshold of 10 (Staiger & Stock, 1997), rejecting the null hypothesis that the instruments are weak.

3.7 Analysis

Descriptive statistics of the variables and constructs are presented in Table 5. All the correlations were statistically significant except for the relationship between proprietary equipment and the dependent variables and between ANT and product performance.

Structural Equation Modeling (SEM) was used to test the research hypotheses because of its advantages in analyzing mediation models (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 (Malhotra, Singhal, Shang, & Ployhart, 2014; Rungtusanatham, Miller, & Boyer, 2014).

3.8 Model fit

Table 6 presents the incremental fit indexes and the absolute fit measures. 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. The incremental fit index values (e.g. TLI and CFI) were close to the cutoff criteria, suggesting an overall satisfactory model fit (Hu & Bentler, 1999; Vandenberg & Lance, 2000).

Table 5. Mean, standard deviation and Pearson correlation among constructs ($n = 217$)

Constructs	Mean	SD	1	2	3	4	5
1. Prop. equip.	3.44	0.76	1	–	–	–	–
2. ANT	3.53	0.61	0.804**	1	–	–	–
3. Training	3.70	0.55	0.291**	0.486**	1	–	–
4. Prod. innovativeness	3.73	0.87	0.155*	0.188**	0.247**	1	–
5. Prod. performance	3.93	0.77	0.035	0.121*	0.214**	0.589**	1

Note(s): *$p < 0.05$ (two-tailed); **$p < 0.01$ (two-tailed)
Source(s): Table by authors

Table 6. SEM fit indexes

Overall model fit		Cutoff criteria (Hair et al., 2009; Schreiber *et al.*, 2006)
x^2	108.9	
DF	58	
CMIN/DF	1.88	≤ 2
GFI	0.94	≥ 0.95
IFI	0.96	≥ 0.95
CFI	0.95	≥ 0.95
TLI	0.94	≥ 0.95
SRMR	0.06	≤ 0.08
RMSEA	0.05	≤ 0.08

Source(s): Table by authors

4. Results

The results indicated that the development of proprietary equipment is positively and strongly related to the anticipation of new technologies ($\beta = 0.56$, p-value < 0.001) but not to performance, supporting the first hypothesis. Figure 3 shows the results of the proposed structural model.

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. Similarly, new technologies have no direct and significant effect on performance, confirming the need for mechanisms, such as training, through which these technologies can be diffused and applied to achieve the desired goal. Therefore, we confirm the mediation hypothesis between anticipation of new technologies, training, and product performance (*H2a* and *H2b*). Table 7 provides the results of the direct and indirect coefficients.

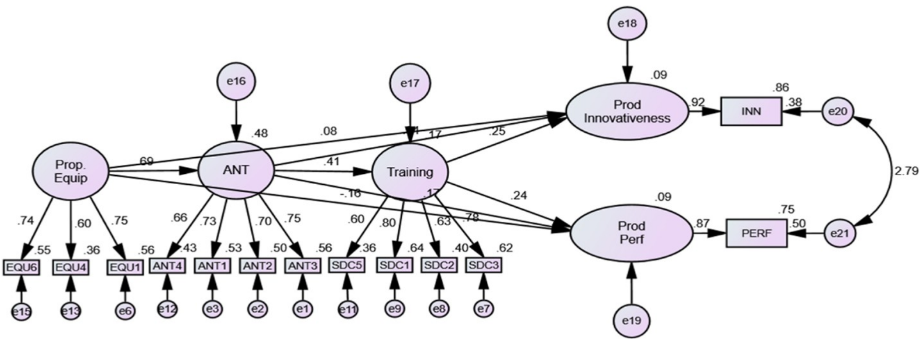

Figure 3. Figure 3. SEM results
Source(s): Authors' own work

Table 7. Standardized direct and indirect effects and confidence interval

Relationships	Coefficients	Lower limit	Upper limit
Direct effects			
Prop. Equip. => ANT (H1)	*0.695***	*0.546*	*0.813*
Prop. Equip. => Prod. Innov.	0.083	−0.167	0.345
Prop. Equip. => Prod. Perf.	−0.165	−0.464	0.125
ANT => Training	0.41**	0.263	0.545
ANT => Prod. Innov.	0.036	−0.239	0.319
ANT => Prod. Perf.	0.166	−0.119	0.486
Training => Prod. Innov.	0.252**	0.085	0.405
Training => Prod. Perf.	0.244**	0.06	0.424
Indirect effects			
ANT => Training => Prod. Innov. (H2a)	*0.103***	*0.041*	*0.19*
ANT => Training => Prod. Perf. (H2b)	*0.100***	*0.032*	*0.208*

Note(s): 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)
Source(s): Table by authors

Studies in operations strategy have shown differences among industries (Ahmad & Schroeder, 2003; Flynn & Flynn, 2004); thus, industry type's impact on the endogenous constructs and variables needed to be controlled. Following some recommendations of good practices of control tests (Becker, 2005; Malhotra & Grover, 1998), statistical results are reported in Table 8, which compares the industries' level of development to create proprietary equipment, anticipate new technologies and train and develop reliable and innovative products.

To this end, the industry segments were included in 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 for training levels. Electronic manufacturing plants present lower levels of training than transport manufacturing ones, as shown in Table 8. The control variables are not included in the research hypotheses because the focus of this study is not on the theoretical reasons for the differences among segments.

5. Discussion

This research provides important contributions to the recent literature on new technologies. For instance, by arguing that manufacturing companies can use the knowledge acquired from developing proprietary equipment to better identify new technologies and showing that training routines are critical to link previous to new knowledge, we contribute to a research stream that focuses on investigating the critical success factors for the advancement of new technologies in the operations management field of research (Pozzi et al., 2023; Saniuk et al., 2023; Zheng, Ardolino, Bacchetti, & Perona, 2020).

Additionally, this research resolves a previous confusion on the relationship between proprietary equipment and performance by demonstrating that proprietary equipment *per se* has no direct impact on product performance and innovativeness, contrary to the expectations of Hayes and Wheelwright (1984). As demonstrated by the absorptive capacity approach, proprietary equipment can be a source of competitiveness if leveraged through new technologies. Furthermore, training routines appeared crucial in integrating previous and new relevant external knowledge, providing the mechanisms through which new information is assimilated. As the notion of ambidexterity poses, manufacturing plants anticipating new technologies and diffusing them through training routines can better deal with the relationship between current and future proprietary equipment. Using the analogy of the bow and arrow, proprietary equipment is only effective for performance improvement when training is a part of the dissemination process. Our research findings suggest that programs to create the capabilities to implement these technologies may go unheeded without training.

This investigation highlights important practical implications. First, our results indicate a promising way for operations managers to capitalize on proprietary equipment capability to

Table 8. Control test

Segments	Machinery				Transport			
	ANT	Training	Prod. Innov.	Prod. Perf.	ANT	Training	Prod. Innov.	Prod. Perf.
Electronics	0.091	−0.112	0.088	0.04	0.118	−0.171*	0.01	−0.042
Machinery	–	–	–	–	0.027	−0.060	−0.080	−0.084

Note(s): *$p < 0.05$ (two-tailed)
Source(s): Table by authors

anticipate new technologies to leverage operations competitiveness. For instance, our research findings provide a framework for managers to implement the technologies of the Industry 4.0. For these technologies to be successfully implemented in a manufacturing plant, they must be integrated well with current technologies and diffused through training routines. Second, by integrating training into our theoretical model, we show that a strong operation strategy combines infrastructure and structure elements. Our results provide evidence of the critical role training has in an operations strategy, offering a possible road that operations managers can follow to absorb and apply new knowledge in the plant using the current knowledge base.

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 forecast technological trends more precisely and benefit from emerging opportunities before its competitors can identify them.

In sum, this tightly integrated system of technologies and skills development is crucial in leveraging 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 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 are part of a wider project, so the constructs had to be adapted according to this research's objectives. Furthermore, the three industry sectors and the sample size can limit the generalizability of the research findings to other segments. Future research, therefore, may test the relationship between proprietary equipment, new technologies and training in other industries. Finally, the data collection relied on two respondents per questionnaire, which can pose some data bias, whereas three respondents would mitigate potential bias problems.

6. Conclusion

Our study focuses on the relationship between proprietary equipment, anticipation of new technologies and operational performance. We found that proprietary equipment *per se* is not a source of competitive advantage. Manufacturing companies must combine current and future technologies to leverage competitiveness through proprietary equipment. For this combination to work out, training routines provide the connection between current and future technologies as employees understand how to integrate complementary yet different technologies.

As manufacturing companies advance in the frontier of new technologies in the context of the Industry 4.0, understanding their operations through the development of proprietary equipment and using this to anticipate new technologies can put these companies ahead of the competition. For example, a manufacturing company that develops proprietary equipment and uses this ability to anticipate technologies of the Industry 4.0 is more likely to integrate and develop meaningful technologies than a manufacturing company that simply follows the best practices approach, implementing new technologies that proved to be important to others but are not well integrated to its operations.

*The data supporting this study's findings are available from the corresponding author upon reasonable request.

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Appendix

Table A1. 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 and Schroeder (2003) Snell and Dean (1992)	0.81*	0.79
SDC2	Management at this plant believes that continual training and upgrading of employee skills is important.		0.63*	
SDC3	Our employees regularly receive training to improve their skills.		0.78*	
SDC4	Employees at this plant have skills that are above average, in this industry.		Dropped	
SDC5	Our employees are highly skilled in this plant.		Dropped	
Anticipation of new technology (ANT)				
ANT1	We pursue long-range programs, to acquire manufacturing capabilities in advance of our needs.	Cua et al. (2001)Finger et al. (2014)	0.73*	0.80
ANT2	Our plant stays on the leading edge of new technology in our industry.		0.70*	
ANT3	We are constantly thinking of the next-generation of manufacturing technology.		0.75*	
ANT4	We make an effort to anticipate the potential of new manufacturing practices and technologies.		0.65*	
Proprietary equipment				
EQU1	We actively develop proprietary equipment.	Cua et al. (2001) Schroeder et al. (2002)Peng et al. (2008)	0.75*	0.74
EQU2	We produce a substantial amount of our equipment in-house.		Dropped	
EQU3	We develop some of our own equipment in-house, so that we are close to state-of-the-art for that equipment.		Dropped	
EQU4	We frequently modify equipment to meet our specific needs.		0.60*	
EQU5	Developing our own equipment helps us to know more than our suppliers about everything that is critical to our business.		Dropped	
EQU6	Proprietary equipment helps us gain a competitive advantage.		0.74*	
EQU7	We have equipment that is protected by our firm's patents.		Dropped	
Performance				
PCP	Product capability and performance	Single item measures	0.65	–
PIP	Product innovativeness		0.85	–

Note(s): * $p < 0.01$
Source(s): Table by authors

Author contributions – Fernando Picasso – Conceptualization (Equal), Data curation (Equal), Methodology (Equal), Writing – original draft (Equal); Ely Paiva – Formal analysis (Equal),Writing – review and editing (Equal).

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