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Protection and internal transfer of technological competencies

The role of causal ambiguity

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Abstract

Purpose – The purpose of this paper is to study how causal ambiguity around technological competencies can help firms to achieve superior performance.

Design/methodology/approach – Traditionally, it has been recognised that causal ambiguity of technology represents an effective protection against imitation. Recently, however, researchers have unearthed evidence that the effects of causal ambiguity also could be extending to the interior of the firm itself, hampering the diffusion of its own technological capabilities among its managers. In this case, the existence of causal ambiguity of technology will have a negative impact on firm performance. In this paper both effects are studied in a sample of 258 Spanish manufacturing firms using several statistical techniques.

Findings – The results indicate that causal ambiguity exerts a double-edged influence on firm performance. On the positive side, by protecting technological competencies from imitation and, on the negative, hampering the diffusion of these capabilities within the firm, with this second effect being stronger.

Research limitations/implications – The main limitation of this work is that there are clearly many other factors that can explain firm performance apart from causal ambiguity of technology. However, as the main objective of the present work is to study the relations between causal ambiguity around technological capabilities and firm performance, it did not seem wise, for operational reasons, to complicate the analysis by including other variables.

Practical implications – In order to achieve better results, firms must use causal ambiguity around technological competencies to protect these competencies against imitation and should make great efforts to diffuse them within the firm.

Originality/value – The results obtained allow one to make a contribution to the debate existing on the literature about the influence that causal ambiguity around technological competencies has on firm performance.

Keywords Organizational performance, Core competences, Communication technologies, Spain

Paper type Research paper

Technological innovation is crucial to a variety of important outcomes, including economic growth, firm performance and industrial change. Hence, the ability to effectively innovate is a central challenge for firms. Firms with superior technological competencies (i.e. the ability to apply scientific and technical knowledge to develop and improve products and process) tend to be more innovative and thus perform at high levels (McEvily *et al.*, 2004). Technological competencies consist of knowledge and skills embedded in people and knowledge embedded in technical systems (Leonard-Barton, 1995). Technical systems are the manifestations of years of accumulating, codifying and structuring the tacit knowledge embodied in people. These competencies can become institutionalized. That is, they are part of organizational assumptions that guide strategic decision making. Technology

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embedded in technical systems and people skills typically can be traced back to the firm's first products or services (De Carolis, 2003, p. 34).

The creation of technological competencies is theoretically linked to competitive advantage (Barney, 2001; Prahalad and Hamel, 1990; Leonard-Barton, 1995). According to resource-based view, firms with resources that are valuable, rare, non-substitutable and difficult to imitate can achieve and maintain over time a position of advantage with respect to their competitors (Barney, 1991). Of these four characteristics, inimitability is the most important (Hoopes *et al.*, 2003, p. 890), and it is the most significant contribution of the RBV (Barney, 2001, p. 45). In that sense, technological competencies will lead to a competitive advantage, when they are inimitable-costly or difficult for competitors to imitate. In general, the duration of a particular technological advantage will depend on the degree to which the firm can protect the competencies on which its advantage is based from imitation. In other words, technological competencies of a firm will lead to a competitive advantage when they are difficult to imitate. Thus, protecting competencies against imitation becomes a crucial aspect to take into account for achieving a sustainable competitive advantage (Dierickx and Cool, 1989; Spender and Grant, 1996).

Technological competencies tend to be protected by various isolating mechanisms. There is empirical evidence about the degree of use and the effectiveness of some of these mechanisms. Thus, scholars have verified that firms tend to protect their technological competencies with legal protection measures (such as patents), using secrecy, adopting leadership strategies (lead time), by moving quickly down the learning curve, or controlling certain complementary resources (complementary sales/service, complementary manufacturing) (Cohen *et al.*, 2000; Geroski, 1995; Levin *et al.*, 1987; Teece, 1987).

Another barrier preventing valuable technology resources from imitation is the causal ambiguity of technology, which refers to "a similar lack of understanding of the logical linkages between actions and outcomes, inputs and outputs, causes and effects that are related to technological or process know-how" (Simonin, 1999, p. 597).

It might in principle be thought that causal ambiguity, like the other isolating mechanisms, in protecting a firm's technological competencies from imitation by competitors will produce a positive effect on performance. However, some authors point out that causal ambiguity can also hamper managers' attempts to identify the technological capabilities on which their firm bases its competitive advantage (Reed and DeFillipi, 1990; King and Zeithaml, 2001). This ignorance will hinder the diffusion of routines inside the organisation (Szulanski, 1996) and in this case, causal ambiguity will have a negative effect on firm performance.

Which of these two effects will exert a bigger influence on firm performance? It has been noted that a technological capability, in order for it to be a source of competitive advantage, "must not be so simple that it can be easily imitated, or so complex that it is difficult to use and control internally" (Shoemaker and Amit, 1994, p. 9). Causal ambiguity which hinders the comprehension of technological competencies affects both competitors and the managers of the firm itself. While the first effect will positively impact firm performance, the second will have a negative impact.

The objective of this paper is to analyse how causal ambiguity around technological competencies influences firm performance. With this in mind, the rest of the paper is structured as follows: in the next section, we establish the theoretical framework of the

problem, based on a review of the main research on the phenomenon of causal ambiguity, and we advance the hypotheses to be tested; next, we describe the sample used and the empirical methodology followed; subsequently, in Part 4, we present our findings; after that, we ground the main conclusions drawn from this work within the previous literature in the Conclusions section, at the same time as we point out the main limitations of the study and we suggest some directions for future research. Finally, we advance several implications to managers.

Theoretical framework

The concept of causal ambiguity was introduced by Lippman and Rumelt (1982) to reflect the basic ambiguity concerning the nature of the connections between actions and outcomes. Citing Demsetz (1972, p. 2), these authors describe this ambiguity in large and consolidated firms as follows: "it is not easy to ascertain just why GM or IBM perform better than their competitors. The complexity of these firms defies easy analysis, so that the inputs responsible for their success may be often undervalued by the market for some time".

In this way, causal ambiguity reflects the inability of economic agents to understand fully the causes of efficiency differences between firms (Rumelt , 1984, p. 855). Causal ambiguity is a consequence of the uncertainty of markets, and is therefore present in every process of competition between firms. There is ambiguity about what factors of production actually are and how they interact. In contrast to the assumption of neoclassical economics – whereby there is a finite and known group of factors of production – with causal ambiguity it is impossible to produce an unambiguous list of factors of production, much less measure their marginal contribution (Rumelt, 1984, p. 562).

Subsequently, in a seminal work, Reed and DeFillipi (1990) analyse the relations between firm competencies, barriers to imitation and sustainable competitive advantage. They point out that certain characteristics of firm competencies, such as tacitness, complexity and specificity, generate – in isolation or in combination – causal ambiguity, and therefore create barriers to imitation. Thus, under conditions of causal ambiguity, firms that try to imitate others cannot identify precisely and use the resources which have led the first firm to obtain a competitive advantage (Reed and DeFillipi, 1990; Barney, 1991). Causal ambiguity has been seen to be the most efficient isolating mechanism that firms have to protect themselves from imitation by competitors (Rumelt, 1984; Mahoney and Pandian, 1992).

The effects of causal ambiguity are not only felt between competitive firms, but also affect organisations participating in cooperation agreements. Causal ambiguity will also hold up the transfer of knowledge between alliance partners (Simonin, 1999). Thus, it will be difficult for the partners to determine which technological competencies have led each of them, respectively to succeed. If they are unable to identify these resources, they will not be able to imitate and apply them in their own organisation either (Barney, 1991).

Traditionally, this reasoning has led scholars to assume that causal ambiguity is required for a sustainable competitive advantage, since it constitutes a barrier preventing valuable technology resources from imitation. Under this perspective, by impeding imitation, causal ambiguity enhances performance (Lippman and Rumelt, 1982; Rumelt, 1984; Dierickx and Cool, 1989; Reed and DeFillipi, 1990; Barney, 1991; Mahoney and Pandian, 1992).

Recently, however, some researchers have questioned the direction of the influence of causal ambiguity on firm performance (King and Zeithaml, 2001). They have pointed out that causal ambiguity, by hindering the identification of the technological competencies which lead firms to achieve superior performances, also restricts the transfer of the same competencies inside the organisation (Szulanski, 1996) and may block factor mobility (Lippman and Rumelt, 1982, p. 420; Reed and DeFillipi, 1990, pp. 90-1). In this way, causal ambiguity will impede the internal diffusion of knowledge and reduce its level of creation inside the organisation (Lin, 2003). Hence, in this case causal ambiguity exerts an adverse influence on performance.

Thus, at present there is a debate in the literature about the influence exerted by causal ambiguity on firm performance, since although on the one hand this variable slows the diffusion of superior practices and technologies across firms, on the other hand it impedes the creation of new knowledge within the firm (McEvily *et al.*, 2000).

In their contribution to this debate, King and Zeithaml (2001) consider that causal ambiguity has been addressed in the literature in two different ways: linkage ambiguity and characteristic ambiguity. The first refers to the ambiguity about the link between competencies and competitive advantage (Lippman and Rumelt, 1982). The second, to "the characteristics of the competencies … which can be simultaneous source of advantage and of ambiguity". This paper will focus on the first of these forms, since its aim is to study the ambiguity that affects the relation between technological competencies and superior competitiveness, with the ultimate aim of determining the effect of ambiguity on firm performance. With this in mind, we distinguish between two types of causal ambiguity, depending on the economic agent which it affects.

First, competitor ambiguity refers to the causal ambiguity that a firm's competitors face when they attempt to identify the technological competencies that have helped the firm to achieve its superior competitive status in the market. Resource-based theorists (Barney, 1991) suggest that causal ambiguity of technological knowledge is an important source of competitive advantages that keep firm's competencies from imitation. In practice, firms do sometimes bribe or hire away knowledgeable employees to learn about a competitor's superior capabilities (Besanko *et al.*, 2000). These intelligence-gathering strategies will be less productive when employees can explain little about how a firm achieves superior performance (McEvily *et al.*, 2000). On the basis of this reasoning, we advance the following hypothesis:

H1. Competitor ambiguity about firm technological competencies has a positive influence on firm performance

Second, manager ambiguity refers to the ambiguity perceived by the managers of a firm when attempting to determine the relation between their competencies and competitive advantage. McEvily *et al.* (2000, p. 294) argue that as a firm extensively acquires explicit knowledge it reduces the level of causal ambiguity that protects its distinctive competence from imitation. Causal ambiguity impedes not only technology transfer across firms but also the creation of new knowledge within the firm. It would frustrate efforts to diffuse technological knowledge with organizational boundaries to at least the same degree (Lin, 2003).

Szulanski (1996) found causal ambiguity to be one of the primary factors hindering best practice transfer within firm. Teece (1976) also reports that firms incur high costs to transfer poorly understood technologies, which is consistent with the resource-based arguments, causal ambiguity also prevents a firm from learning from its own experience

and form improving its performance over time (Huber, 1991). Causal ambiguity hinders the internal diffusion of technological knowledge and decelerates the rate of knowledge creation within company. As Reed and DeFillipi (1990, pp. 90-1), suggest, "where ambiguity is so great that managers do not understand intra firms causal relationships, or factor immobility exists, it may be impossible to utilize competencies for advantage". Thus, the less ambiguity faced by the firm's management – i.e. the more they understand the technological competencies required to achieve certain outcomes – the better the firm performance. This idea leads to our second hypothesis:

H2. Manager ambiguity about firm technological competencies has a negative influence on firm performance

Methodology

Data and sample

The sample of firms we have used to test our two hypotheses comes from a directory of the largest Spanish firms (*Duns 50.000*, edition 2001, see *Dun & Bradstreet España*, 2001). The process of data selection and collection was as follows: first, we limited the sample to manufacturing firms (with SIC codes between 20 and 39), and large and medium-sized companies (with a turnover of at least €20 m in 1999). These criteria were applied to guarantee that the firms had developed a certain number of complex technological competencies that might potentially cause problems of identification and comprehension on the part of both competitors and the firm's managers. Initially the sample contained 1967 firms meeting these criteria.

Second, as the information provided by the above-mentioned directory was insufficient for the needs of our research, we sent a questionnaire to each of the 1967 firms. The format and content of the questionnaire were initially developed from a thorough literature review and pretested using doctoral students, faculty and business executives. In particular, a group of five business executives participated in a pretest phase by completing an advanced version of the questionnaire and by offering criticisms and suggestions for improving it.

The questionnaire was directed at the chief executive (CEO), considered to be the person most qualified to respond to the questions and with easiest access to the information required. We received 258 usable responses, which represents a sampling error of ± 5.80 per cent with a confidence level of 95 per cent. Tables I-III show a description of the sample by activity sector, workforce and firm age. Most of the sample firms are in the range of 101-250 employees and approximately 38 per cent of the firms have more than 40 years of experience.

Variable measures

To make the variables included in this research operative, we used mainly subjective measures provided by the responses from the questionnaire on a series of indicators. A seven-point Likert-type scale was used, with 1 representing "totally disagree" and 7 "totally agree". In the Appendix (Table AI) we present the indicators used to measure each of the variables considered in the research. We might mention that the indicators used to measure the competitor ambiguity were adapted from those used in the work of Simonin (1999) and Szulanski (1996). Simonin's work was focused on knowledge transfer between strategic partners and Szulanski's paper studied the transfer of best practices within firm. Since a measure of causal ambiguity faced by rivals was not found in the literature we had to adapt these available measures to our case.

Sic code	Activity sector	Firms	Per cent
20	Food and kindred products	42	16.3
21	Tobacco products	0	0
22	Textile mill products	9	3.5
23	Apparel and other finished products made from fabrics and similar materials	2	0.8
24	Lumber and wood products, except furniture	2	0.8
25	Furniture and fixtures	0	0
26	Paper and allied products	5	1.9
27	Printing, publishing and allied industries	9	3.5
28	Chemicals and allied products	37	14.3
29	Petroleum refining and related industries	1	0.4
30	Rubber and miscellaneous plastics products	12	4.7
31	Leather and leather products	2	0.8
32	Stone, clay, glass and concrete products	22	8.5
33	Primary metals industries	10	3.9
34	Fabricated metal products except machinery and transportation equipment	16	6.2
35	Industrial and commercial machinery and computer equipment	27	10.5
36	Electronic and other electrical equipment and components, except computer equipment	21	8.1
37	Transportation equipment	30	11.6
38	Measuring, analysing and controlling instruments; photographic, medical, and optical goods; watches and clocks	6	2.3
39	Miscellaneous manufacturing industries	5	1.9
	Total	258	100

Table I.
Sample description by activity sector

Number of employees	Firms	Per cent
0-100	54	20.9
101-250	93	36.0
251-500	66	25.6
501-1,000	22	8.5
1,000-5,000	20	7.8
>5,000	3	1.2
Total	258	100

Table II.
Sample description by number of employees

Firm age (years)	Firms	Per cent
<10	19	7.4
10-20	42	16.3
21-40	101	39.1
41-60	50	19.4
>60	46	17.8
Total	258	100

Table III.
Sample description by firm age

In order to measure manager ambiguity, King and Zeithaml (2001) asked firm managers about, on a +3 to −3 scale, whether his or her organization was at an advantage or disadvantage with respect to its competition for a set of competencies. The average Euclidean squared distance among the scores provided by the members of a team was used as a measure of manager ambiguity (i.e. linkage ambiguity).

Since, it was impossible for us to employ a measure similar to the one used by King and Zeithaml (2001), the construct for manager ambiguity of technological competencies was especially built for this research.

Moreover, the Appendix (Table AI) includes also Cronbach's α coefficients in order to assess the reliability of the scales proposed. The recentness and the originality of the topic analysed impeded us in the achievement of high reliability coefficients. Anyway, Cronbach's α reliability greater than 0.6 is considered to have internal consistency of the scales (Malhotra, 1981) and yet even other authors consider lower values (0.53) as medium reliability (Hung *et al.*, 2005, p. 174). The validity of our scales was tested using a confirmatory factor analysis, following the suggestions provided from some researchers (Bagozzi *et al.*, 1991; Bagozzi and Foxall, 1996; Bollen, 1989; Steenkamp and Van Trijp, 1991). A model including our independent variables as latent variables was built using the items included in the questionnaire as observable variables. The confirmatory factor analysis model was estimated by use of AMOS 4.0. The overall fit of the model was satisfactory ($\chi^2 = 56.13$ $p = 0.01$; NFI = 0.882; CFI = 0.948)[1] and all factor loadings were significant and generally high. These results confirm the construct validity of our measures. Discriminant validity among constructs can be assessed by examining if they are correlated since the smaller is the correlation, the greater the discrimination (Bagozzi and Foxall, 1996, p. 206). In our case, the correlation among competitor ambiguity and manager ambiguity was not significant and this result contrasts the discriminant validity of our measures.

With regard to firm performance, this was made operative using two measures. First, we use return on assets (ROA) as an objective measure of success. A rich and long tradition operationalizes firm performance based on financial data from secondary sources, such as ROA, return on invested capital and return on sales (Bettis, 1981; Christensen and Montgomery, 1981). ROA presented several advantages as a measure of performance. Hill *et al.* (1992) argue that this measure provides superior relative year-to-year stability against other measures. ROA continues to be accepted in the current literature (Wiersema and Bantel, 1993; Balinga *et al.*, 1996).

Furthermore, financial measures resulted insufficient to assess firm performance since they do not reflect effectiveness in managing change and intangible factors (Saad, 2001). For that reason, we also use a multidimensional subjective measure to assess organizational performance. This measure included economic-financial as well as socio-organisational indicators, since only considering these in combination allows us to evaluate the success of an organisation (Robbins, 1990). Consequently, and following Naman and Slevin (1993), we built two scales of items. The objective of the first scale was for the managers to evaluate the importance of the indicators proposed. With the second scale, the aim was for the managers to express their level of satisfaction with respect to their expectations about these indicators during the past trading year. Subsequently, we calculated a weighted average of the satisfaction scores of the managers on the nine indicators, with the importance scores acting as weights.

Such hard measures of performance have obviously desirable properties, we also use perceptual measures since Delaney and Huselid (1996) observed that various

studies have shown strong relationships between both types of measures. In that sense, we use the financial data collected (ROA) to validate our perceptual measure following Bae and Lawler (2000). The correlation between ROA and our perceptual performance scale is 0.13 ($p < 0.05$). That the correlation is statistically significant supports the general validity of the organizational performance measure, although the magnitude of the correlation is low. On the basis of this result, we decide to choose the subjective measure of performance since the rest of variables are measured in the same way.

In order to get unbiased estimators of the impact of the two types of ambiguity on firm performance, we selected some control variables considered to be related to the dependent variable of the model as well as to at least one of the independent variables. The control variables were: the size of the firm, the age of the firm, the period of time the CEO had been in the company and the sector which the firm belonged to.

For firm size we used the natural logarithm of the number of employees. For firm age, a question in the questionnaire asked respondents for the year the firm was founded. The longevity of the CEO was also requested in the questionnaire.

The firm age was included as a control variable, since it has been considered in the literature as a measure of the ambiguity which competitors face (Mosakowski, 1997). Mosakowski believes that the longer the firm has been operating in the market, the better its competitors will know it, and hence the lower the degree of causal ambiguity these agents will face. Similarly, the same argument applies to CEO longevity and manager ambiguity, so that this variable was also included as a control variable.

Moreover, it could be said that the performance of the firm will differ in function of the sector in which it operates, and the level of ambiguity of the competitors and managers may also differ between firms from different industries. Thus, we included in the model 17 dummy variables representing 18 different sectors to which the sample firms belonged according to their two-digit SIC codes. The number of sectors to which the firms from the initial population belonged was 20, but this was reduced to 18 for the final sample, since it was not possible to obtain any response from firms belonging to the sectors with SIC codes 21 and 25.

Table IV shows the means, standard deviations and correlations for all the dependent and independent variables considered in this study.

Results

In order to analyse the data collected, initially we ran a factor analysis on the indicators used to measure competitor and manager ambiguity of technological competencies, with a view to summarising the original data with the least possible information loss. The analysis was carried out following the principal components method, and in order

Variable	n	Mean	SD	1	2	3	4	5
Firm performance	236	4.02	1.99					
Competitor ambiguity	256	0.00	1.00	0.14*				
Manager ambiguity	256	0.00	1.00	−0.37**	0.000			
Firm size[a]	253	5.68	1.31	0.06	−0.11	−0.17**		
Firm age[a]	258	3.50	0.72	−0.01	−0.06	−0.04	0.18**	
CEO longevity[a]	248	2.29	1.01	0.14**	−0.08	0.04	0.08	0.08

Notes: *$p < 0.05$; **$p < 0.01$; [a]these variables were transformed by natural logarithm function

Table IV.
Mean, standard deviations and correlations

to obtain more easily interpretable results, we applied a factor rotation using the varimax method with Kaiser normalisation. In Table V we present the matrix of rotated components, the communalities, the initial eigenvalues, and the percentage of variance accounted for each component. As can be seen, the analysis resulted in two factors, each of which grouped the indicators corresponding to one type of ambiguity. Once these factors corresponding to the two types of ambiguity of technological competencies were detected, the factor scores of all the firms were noted for each factor.

Subsequently, with the scores obtained in the factor analysis we applied a regression analysis, with the aim of explaining the performance of the sample firms in function of the variables competitor ambiguity and manager ambiguity, once the effects of size, age, CEO longevity and sector had been controlled for. Table VI shows the results of the hierarchical regression analysis carried out.

In the first model, only the control variables were included as independent variables. The second model added the ambiguity about technological competencies faced by the competitors. The third model added the ambiguity of technological resources faced by the firm's managers as explicative variable to the above-mentioned variables.

With regard to the control variables, some turned out to be marginally significant, indicating that they exert an influence on the dependent variable. Thus, the coefficient associated with CEO longevity was significant at the 95 per cent level of confidence in the first model, and at 90 per cent in the other two models. It was positive in the three models, indicating that the longer the CEO had been in the firm, the better the firm performance. On the other hand, the parameter for the age of the firm was negative and significant in the third model at the 90 per cent confidence level, indicating that the longer the firm had been operating in the market, the worse its performance. This may, according to Mosakowski (1997), be because the longer the firm had been operating, the more its competitors know it, and hence the less causal ambiguity they face. Its competitors can then appropriate its technological competencies, which will lead the firm to achieve worse results.

On the other hand, we cannot demonstrate the relationship between manager ambiguity and CEO longevity. Therefore, we cannot affirm, on the basis of the data (Table VI), that the longer a manager has been in a company, the less ambiguity he will face. However, Table VI shows a positive and significant coefficient between CEO longevity and firm performance. Since, there is no relationship between manager

ITEM	Components 1	2	Communalities
MA1	*0.63*	0.01	0.39
MA2	*0.55*	0.02	0.30
MA3	*0.80*	−0.03	0.64
MA4	*0.82*	−0.02	0.68
MA5	*0.63*	0.07	0.40
MA6	*0.74*	−0.06	0.56
CA1	−0.04	*0.66*	0.45
CA2	0.05	*0.76*	0.58
CA3	0.12	*0.67*	0.46
CA4	−0.12	*0.73*	0.55
Per cent of variance accounted for	30.07	50.28	
Eigenvalue	3.007	2.02	

Table V.
Factorial analysis: types of ambiguity around technological competencies

Variables	Model 1 B	SE	Model 2 b	SE	Model 3 b	SE
Constant	4.11***	1.24	3.78**	1.23	4.04***	1.14
Firm size	0.15	0.13	0.18	0.12	0.13	0.12
Firm age	−0.25	0.20	−0.26	0.20	−0.31****	0.19
CEO longevity	0.27*	0.13	0.26****	0.13	0.22****	0.12
Sector sic20	−0.52	0.92	−0.29	0.91	−0.01	0.85
Sector sic22	0.53	1.10	0.78	1.09	1.30	1.02
Sector sic23	0.67	1.64	1.22	1.64	0.87	1.52
Sector sic24	−2.74****	1.61	−2.36	1.60	−1.08	1.50
Sector sic26	0.67	1.29	0.89	1.28	1.29	1.19
Sector sic27	−0.67	1.11	−0.39	1.11	−0.68	1.03
Sector sic28	−1.02	0.92	−0.75	0.92	−0.54	0.85
Sector sic29	−0.15	2.12	0.37	2.10	0.61	1.95
Sector sic30	−1.32	1.06	−1.24	1.04	−0.99	0.97
Sector sic31	0.17	1.63	0.54	1.62	1.07	1.50
Sector sic32	−0.70	0.99	−0.49	0.98	−0.15	0.91
Sector sic33	−2.13****	1.08	−1.84****	1.08	−1.29	1.00
Sector sic34	−0.31	1.02	0.03	1.01	0.32	0.94
Sector sic35	−0.29	0.95	−0.12	0.94	−0.07	0.88
Sector sic36	−1.10	0.97	−1.02	0.96	−0.69	0.90
Sector sic37	−1.08	0.97	−0.95	0.96	−0.60	0.89
Sector sic38	−0.26	1.17	−0.16	1.16	−0.28	1.07
Competitor ambiguity			0.33*	0.14	0.35**	0.13
Manager ambiguity					−0.77***	0.13
R^2	0.19		0.14		0.27	
F	1.33		1.56****		3.28***	
n	258		258		258	

Notes: *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$; ****$p < 0.10$

Table VI.
Results of regression analysis for firm performance

ambiguity and the time they have been at the company, the positive correlation between CEO longevity and firm performance could not be explained using the causal ambiguity concept but rather, its explanation should be based on other concepts. Thus, for example, that relationship could be explained by the experience effect or the learning curve. In that sense, firm performance typically increases as organizations gain production experience. These "learning curves" have been found in many organizations in different industries. For example, the unit cost of producing aircraft (Alchain, 1963; Benkard, 2000; Wright, 1936), iron (Arrow, 1961; Leonard-Barton, 1995), ships (Rapping, 1965), trucks (Argote and Epple, 1990) and semiconductors (Hatch and Mowery, 1998) have been shown to follow a learning curve: the cost of producing a unit of each product decreased at a decreasing rate as production experience was acquired (Andress, 1954; Abernathy and Wayne, 1974; Hirschman, 1964).

H1 proposes that the ambiguity of technology perceived by the competitors of a firm will be positively related to the performance achieved by the firm. The significance and positive sign of the coefficient of this variable in both models 2 and 3 supports this hypothesis. Similarly, *H2* predicts that the ambiguity about technological competencies faced by the firm's own managers is negatively related to the firm's performance. The negative sign of the coefficient of this variable in model 3, along with its significance, supports this hypothesis too.

Moreover, in the third model, it can be seen that the parameter associated with the manager ambiguity is greater in absolute terms than that of the competitor ambiguity, which means that the effect exerted on firm performance by manager ambiguity is greater than that exerted by competitor ambiguity.

Conclusions

Our findings allow us to confirm that causal ambiguity around technological competencies exerts a double-edged influence on the performances of large and medium-sized Spanish manufacturing firms. Thus, we have shown, on the one hand, that causal ambiguity constitutes one of the mechanisms which firms can use to defend their technological resources from the actions of their rivals, since we have tested that there is a positive association between the causal ambiguity of technology faced by a firm's competitors and the performance of the firm. Thus, and as is suggested by a number of previous studies, causal ambiguity protects firms from imitation, which contributes to the sustainability of their competitive advantage (Lippman and Rumelt, 1982; Barney, 1986; Dierickx and Cool, 1989; Reed and DeFillipi, 1990; Barney, 1991; McEvily *et al.*, 2000; King and Zeithaml, 2001).

When the link between firm's technological competencies and its sustained competitive advantage is poorly understood, it is difficult for imitators to know which competencies it should imitate. Imitating firms may be able to describe some of the competencies controlled by a successful firm. However, under conditions of causal ambiguity, it is not clear that the competencies that can be described are the same that generate a sustained competitive advantage, whether that advantage reflects some other non-described firm competencies (Barney, 1991). In other words and following Lippman and Rumelt (1982) rivals can attempt to imitate successful firms but if causal ambiguity exists, the outcome will be uncertain.

On the other hand, we have demonstrated that the causal ambiguity of knowledge which is faced by the firm's own managers has an adverse effect on firm performance. This finding is consistent with the authors that have questioned the effect of causal ambiguity on firm performance, arguing that although it impedes the diffusion of a firm's competencies outside the firm, thereby protecting the firm from the risk of imitation, it also blocks the transfer of technological competencies inside the firm itself (Szulanski, 1996; McEvily *et al.*, 2000; King and Zeithaml, 2001; Lin, 2003). For example, Lin (2003) tested empirically that causal ambiguity of technology hinders the internal diffusion of technological knowledge. In the same way, Szulanski (1996) found that causal ambiguity can hamper the transfer of best practices and Simonin (1999) verified how causal ambiguity can hinder knowledge transfer between partners. Moreover, Arias-Aranda and Molina-Fernández (2002) found that improved techniques that help firms to integrate, inside the company, different and highly specialized knowledge has a positive impact to the innovation levels and then will lead to achieve better results.

Moreover, we have found that the effect on firm performance of manager ambiguity of technology is greater than the effect of competitor ambiguity. This last finding contributes to resolving the debate in the literature, and is consistent with those studies that stress the need for knowledge to flow within organisations (Szulanski, 1996; O'Dell and Grayson, 1998; Hansen, 1999; Argote and Ingram, 2000; Lin, 2003), since manager ambiguity about technology will only be reduced by the transfer of technological competencies within organisations. So, internal communication is essential to achieve a superior performance since it promotes the adoption and diffusion of ideas within an organization (Wagner *et al.*,

2001) and in this way reduces manager ambiguity. The organization has to mobilize knowledge created and accumulated at the individual level (Zang *et al.*, 2004, p. 259). Only in this case will the firm be able to achieve superior performance.

Thus, both competitor ambiguity and manager ambiguity around technological competencies determine firm performance, with the second effect being greater. Hence, the two types of causal ambiguity of technology we have considered should be added to the list of factors that help firms achieve and sustain a competitive advantage.

We should point out that this work has some limitations. First, we have to recognise that there are clearly many other factors that can explain firm performance apart from causal ambiguity of technology. However, as the main objective of the present work was to study the relations between causal ambiguity around technological capabilities and firm performance, it did not seem wise, for operational reasons, to complicate the analysis by including other variables. Moreover, the measures of some of the variables used may be less precise than would be desirable, which may blunt some of the power of our tests on the two hypotheses proposed. In this context, it would have been desirable for the competitors themselves to evaluate the causal ambiguity that they face when attempting to imitate a firm. This was not possible as it proved impossible to determine which firms were rivals of which other firms.

In addition, several questions arise out of our study: what kinds of factor contribute to both types of ambiguity? Can firms effectively control these factors, and hence the effects of causal ambiguity around technological competencies, such that the causal ambiguity affects competitors more than the firm's managers? How can a firm protect its technological capabilities from a competitor's actions at the same time as spreading knowledge about them throughout the organisation? Research on various aspects of human resource management, focusing on the creation of a climate favouring the transfer of knowledge within organisations and impeding imitation, may shed some light on these issues. All these are promising directions for future research.

Managerial implications for logistics managers

The most important contribution of this study to business is that it provides practical suggestions concerning imitation and internal transfer of technological competencies. Unlike other transactions among firms, there are many critical interrelated factors that affect the imitation and internal transfer processes. In that sense, this study goes into one of these crucial factors, causal ambiguity.

Specifically, from our findings we might advance two suggestions to help managers sustain a position of competitive advantage and obtain superior performances to their competitors. On one hand, they must protect their technological capabilities from imitation by their rivals. One the way of doing this is to attempt to project to the outside the greatest level of ambiguity possible. If managers hide the sources of competitive advantage of their firms from their competitors, these will not easily be able to imitate.

Additionally, logistics managers should make great efforts to identify the technological capabilities that contribute most to their companies' success, and at the same time diffuse knowledge to all the employees, thereby reducing the level of causal ambiguity of technology inside the organisation. In order to achieve and sustain a competitive advantage, managers must examine the internal processes of their companies (Beheshti, 2004, p. 377). In that sense, firms should facilitate organizational learning as the highest priority in management practice (Lee and Tsai, 2005, p. 326).

Note

1. By convention, an acceptable model is one where the p value is greater than or equal to 0.05. Reliance on the chi-square test as the sole measure of fit is not recommended because of its dependence on sample size. For example, in large sample even trivial deviations of a hypothesized model from a true model can lead to rejection of the hypothesized model or, for very small samples, large deviations of a hypothesized model may go undetected. Therefore, it is desirable to examine other measures of fit not as sensitive to sample size as the CFI index (Bagozzi and Foxall, 1996).

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Further reading

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Appendix

Variable	Measures
Manager ambiguity $\alpha = 0.79$	Top and middle managers in our firm know what technological resources lead to the firm achieving a superior performance to our competitors (MA1) Top and middle managers in our firm can determine the causes of failures of our firm (MA2) Top and middle managers in our firm know the technological strategy adopted by the firm (MA3) Top and middle managers in our firm are generally informed about any change in the technological strategy (MA4) The majority of the top and middle managers in our firm know when a new product is going to be developed and launched (MA5) Our firm has the policy of explaining to top and middle managers the causes of rises or falls in profits (MA7)
Competitor ambiguity $\alpha = 0.66$	Our competitors are unable to imitate immediately the knowledge and technology used by our firm (CA1) Our competitors do not know the keys of our success (CA2) Our competitors do not know the causes of rises or falls in the profits of our firm (CA3) Our competitors find it difficult to establish the specific technological actions carried out by our firm to achieve a superior performance (CA4)
Firm performance	*Financial measure* ROA *Subjective measure* Operating profit Sales growth Growth in profits Market share Return on investment New product development Market development Absence of conflict in firm Productivity

Table AI.
Items included in questionnaire