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The intervening effect of business innovation capability on the relationship between Total Quality Management and technological innovation

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The growing diffusion and acceptance in the business world of Total Quality Management (TQM) has attracted greater interest on the part of academia. Although fundamental questions focus on how the different dimensions of TQM can bring about better business performance, a more recent recurring issue pertains to the relationship between TQM and technological innovation and whether technological innovation might provide a source of competitive advantage. Unfortunately, from both theoretical and empirical perspectives, the relationship between TQM and technological innovation appears contradictory and complex. This paper argues that the relationship might be better understood from the contingent perspective of strategic management and thus proposes a multidimensional intervening variable in the relationship, called Business Innovation Capability (BIC). An empirical study of 105 Spanish industrial firms reveals that the effect of some business practices suggested by TQM on technological innovation can be better understood when BIC dimensions are taken into account.

Keywords: total quality management; business innovation capability; technological innovation

1. Introduction

The concepts of quality and innovation have become guiding elements for what, in the business world, is known as management excellence. That is, they constitute the centre of ongoing discussion and a strategic management orientation for formulating and implementing objectives, policies and performance. Quality and innovation, as guides for managerial activity, have been nourished by, and spread from, pragmatic positions of business consulting to become true management models, and thus the concepts have moved from being simple attributes of goods and services to become conceptual nuclei of what currently is known as Total Quality Management (TQM) and innovation management. Both elements fall within the operations management area, and can increase a firm's competitive advantage (Garrido *et al.* 2007).

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However, although modern business management models of excellence consider quality and innovation objectives simultaneous and complementary, in general business practice first incorporates the concept of quality management and then gradually integrates innovation. This path has received attention from different theoretical perspectives, including the resource-based and dynamic capabilities (RBDC) view of the firm, which explains the shift from product attributes to management models by considering how firms generate organisational resources that offer sources of competitive advantage (Rumelt 1984, Barney 1986, Peteraf 1993). In addition, the RBDC view uses an evolutionary perspective to explain this change in management priorities as a path dependence and accumulation process, in that the quest for innovation performance requires greater organisational complexity than that for quality (Foss 1993, Teece *et al.* 1997, Hodgson 1998).

The intense dissemination of TQM as a business management model, especially for medium and large firms, prompts a recurring academic question concerning the effects of TQM on business performance. Although a unanimous and consistent answer to this question remains inexistent, most scholars have arrived at the conclusion that TQM positively affects business performance (Sousa and Voss 2002, Kaynak 2003). Paradoxically, despite the incorporation of innovation into management excellence models based on TQM and although the consensus states that innovation offers a principal source of sustained competitive advantage, research into the relationship between TQM and innovation performance remains scarce (Flynn 1994, Prajogo and Sohal 2003, 2004, Singh and Smith 2003).

This absence of empirical verification appears even more surprising if we reflect on the following comments by a quality 'guru', W. Edwards Deming: "Ultimately, management's job is to hone the entire system so that it is capable of making the leap from continual improvement to continual innovation in whole new product categories the customer has never even contemplated" (quoted by Gabor 1990). Evidently, even from the initial conception of quality-focused management, practitioners foresaw that fostering innovative practices and better performance would permit the construction of a path from continuous improvement to continuous innovation. In other words, TQM should foster technological innovation.

The empirical literature offers contradictory conclusions. Whereas work by Flynn (1994) and Prajogo and Sohal (2003, 2004) indicates a positive relationship between TQM implementation and technological innovation, research by Singh and Smith (2003) and Terziovski and Samson (1998) finds no empirical evidence that TQM promotes better performance in business innovation. The debate has been settled from a theoretical perspective by distinguishing two types of TQM practices: those associated with traceability, follow-up and quality assurance, called Total Quality Control (TQC) practices, and those emphasising people's work, internal and external relationships and human resource management, called Total Quality Learning (TQL) practices (Sitkin *et al.* 1994). That is, TQM comprises two distinct emphases: a *hard* focus on efficiency and a *soft* concentration on learning. In turn, the solution to the divergence of the empirical results pertaining to the relationship between TQM and technological innovation entails a weak and even negative relationship when considering hard TQM practices, but a positive, strong relationship for soft TQM practices (Prajogo and Sohal 2001, 2003). These empirical results also emerge from the relationship between TQM and other employee and manufacturing performance metrics (Challis *et al.* 2005).

However, the problem with this explanation is that TQM is generally promulgated as an integral philosophy, a 'package' of management principles that does not differentiate at the time of implementation between hard and soft aspects (Ahire *et al.* 1996, Dow *et al.* 1999, Samson and Terziovski 1999). Hence, those studies that find a significant relationship between TQM and business innovation cannot have been based solely on firms implementing soft practices, and those that find no significant evidence do not coincide only with firms implementing hard practices. Furthermore, studies that employ a broad scope and specifically work to determine the success factors of innovative firms indicate that many of the so-called hard TQM practices support better innovation performance (e.g. Utterback (1971), Freeman (1982), Maidique and Zirger (1984) and Delbecq and Mills (1985)).

Within this conceptual and theoretical dilemma, this article poses an alternative explanation for the relationship between TQM and technological innovation. According to the contingent perspective of strategic management (e.g. Fry and Smith (1987)), although TQM implementation constitutes a necessary precondition for greater technological innovation (universalist perspective), it is not sufficient; therefore, contingent variables alter, intensify or mediate the relationship. In particular, Business Innovation Capability (BIC) represents an important contingent variable. The BIC takes a functional form of an interactive type, if conceived of as a complementary asset to TQM, or a mediation type, if we were to accept the simple idea, based on the theoretical perspective of the RBDC, that to innovate, a firm requires the capability for innovation. We therefore explore which of these roles the BIC plays.

The paper consists of four more sections. In the next section, we present different alternatives for the relationship between TQM and technological innovation and articulate them in the form of research hypotheses. The methodology and data analysis appear in the third section, and we discuss the results in the fourth section. Finally, we end with a summary of the main implications of this research.

2. Relationship between TQM and technological innovation

2.1 *A universal-type relationship*

An important line of research focuses on analysing the effects of TQM on business performance (Sousa and Voss 2002, Kaynak 2003). Although such research recognises that no robust and consolidated evidence concerning the positive relationship between TQM and business performance exists, it has reached consensus regarding the empirical validity of a positive effect of TQM on operational-type performance, such as productivity, flexibility, on-time delivery of goods and services, quality and customer satisfaction in general (Kaynak 2003, Rahman and Bullock 2005).

Although the objectives and performance of technological innovation are not included as generic competitive priorities in a great part of operations management research, these being essentially efficiency, flexibility, quality and delivery time (Wheelwright 1984, Corbett and Wassenhove 1993), they are considered to be emerging research topics and are becoming a growing competitive priority for operations management (Pannirselvan *et al.* 1999). Therefore, by analogy, the best practices fostered by TQM should have a positive influence on technological innovation, in the form of operational business performance.

In turn, and considering that the implementation of TQM best practices preserves the spirit postulated by Deming of moving from continuous improvement to continuous innovation, we posit a universal-type relationship between TQM and technological innovation, as in the following working hypothesis.

Hypothesis 1. The implementation of business practices suggested by TQM has a positive and direct effect on technological innovation.

Despite this reasoning, our review of the scarce literature on this topic reveals that empirical results both support and deny the proposed relationship (Flynn 1994, Gustafson and Hundt 1995, McAdam *et al*. 1998, Terziovski and Samson 1998, Prajogo and Sohal 2003, 2004, Singh and Smith 2003). Arguments to justify these contradictory results often address the way the TQM 'program' is implemented and posit that the kind of TQM practices on which the firm focuses can influence technological innovation (Sitkin *et al*. 1994, Dow *et al*. 1999, Martínez-Lorente *et al*. 1999, Wang and Ahmed 2002). But it is also possible that the TQM program represents a contingent subject and that the nature and intensity of its effects on technological innovation depend on, and may be explained by, certain contextual circumstances. For example, in line with the RBDC view, to obtain better innovation performance, a BIC must first exist, fostered by a philosophy of total quality (Perdomo-Ortiz *et al*. 2006). It is thus consistent to argue that the relationship between TQM and technological innovation may be contingent on building BIC.

2.2 *Contingent relationships*

Both studies of the relationship between TQM and business performance and those focusing specifically on the effects of total quality practices on technological innovation recognise the possibility of a contingent-type relationship (Nowak 1997, Prajogo and Sohal 2001). That is, the effects of TQM on performance are not independent of the context in which the program is implemented; thus, no best management practices focused on quality actually promote innovation.

The theoretical perspective of contingency or strategic fit identifies three broad factors: organisational structure, competitive strategy and competitive environment (Van de Ven and Drazin 1985, Prescott 1986, Fry and Smith 1987, Venkatraman 1989). For the specific case of the relationship between TQM and technological innovation, the literature suggests that it may be contingent on the type of organisational culture, the type of competitive strategy in the firm and the level of sectoral and competitive dynamism. Likewise, but with a more exploratory approach, other studies identify as contingent variables knowledge management, organisational learning, research and development activities and technology and product cycles (Nowak 1997, Martínez-Lorente *et al*. 1999, Haner 2002, Wang and Ahmed 2002).

In accepting the contingent perspective as relevant, we consider that the relationship between TQM and technological innovation may be subject to a strategic fit that originates in a critical contingency factor represented by the BIC. This concept, already utilised in classic literature on innovation theory and defined as a firm's skill in successfully adapting or implementing new ideas, processes or products (Burns and Stalker 1961), has taken on new theoretical relevance since the emergence of the RBDC approach (Tidd *et al*. 1997). Although no consensus exists concerning how to understand and measure innovation capabilities, the literature deals with the same concept using different terms, such as absorptive capacity, organisational innovation, innovative organisations or innovativeness. With respect to how to measure this capability, two significant trends exist: an expression of the performance or the set of activities, practices and behaviour that precedes performance as potential for action.

According to this theoretical perspective, the generation of competitive advantage depends on the accumulation of strategic resources and capabilities, the latter of which are understood as those that are imperfectly imitable by competitors (Rumelt 1984, Barney 1991). The BIC fulfils the criteria to be considered a source of competitive advantage and is thus strategic for firms (Rumelt 1984, Barney 1986, 1991, Grant 1991). We argue that BIC is a critical contingency factor in the relationship between TQM and technological innovation with a moderating functional form or, alternatively, a mediating functional form, as we outline in Figure 1.

2.2.1 *The BIC as a moderating variable*

Strategic fit through moderation suggests that the relationship between TQM and technological innovation varies as a function of the different levels that the BIC reaches. An interaction between TQM and BIC alters the direction or intensity of effects on technological innovation. Three types of arguments can be posed for considering the BIC as a moderating factor. First, work by Imai (1986) considers that continuous improvement (*Kaizen*) is not a substitute for innovation, and that, rather, it sets the basis for implementing and suitably exploiting radical innovations. If we emulate Imai's argument, the interaction between continuous improvement (TQM) and innovation skills (BIC) strengthens the effects on technological innovation.

Second, strategic objectives of quality and innovation might be considered complementary, not substitutes. After the appearance of the work of Porter (1985), which defends the inconsistency of simultaneously seeking the strategic objectives of cost leadership (quality in the restrictive sense) and differentiation leadership (innovation as

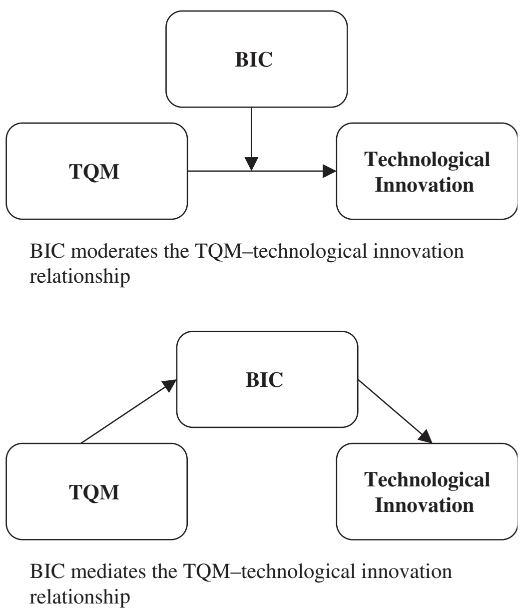

Figure 1. Contingency relationships between TQM and technological innovation.

an instrument), an intense academic debate led to the acceptance of the possibility that firms engage in parallel quests for efficiency and differentiation (Hill 1988). Thus, between the strict quest for efficiency and that for innovation practices as instruments of differentiation, their interaction may achieve greater levels of technological innovation.

Third, derived from the existence of complementary assets for attaining competitive advantage, as suggested by the RBDC view and considered as a mechanism of imperfect imitability (Rumelt 1984), if firms consider TQM programs as an ideal path for attaining competitive advantages but fail in them, a complementary resource or asset may be needed. For the relationship we discuss, the literature identifies a so-called 'organisational culture' (Powell 1995, Nowak 1997). The organisational culture necessary for the TQM program to succeed in innovation can be assimilated with BIC practices. Therefore, the interaction between TQM and BIC, within the contingent relationship with respect to technological innovation, can be understood as the search for complementarity among 'assets'.

In short, the relationship between TQM and technological innovation may reflect a relationship of contingency, with BIC as the moderating variable. It therefore makes sense to verify whether the following working hypothesis applies.

Hypothesis 2. The BIC moderates the relationship between the implementation of business practices suggested by TQM and technological innovation.

2.2.2 *The BIC as a mediating variable*

The second contingency approach suggests that strategic fit occurs because of a mediation effect of the BIC on the relationship between TQM and technological innovation. In other words, the BIC works as a mechanism of intervention between the two variables and functions through an indirect effect that accounts for a significant part of the relationship between TQM and technological innovation.

Arguments supporting this relationship have been fuelled by the evolutionist view of RBDC (Teece *et al.* 1997, Foss 1998). In essence, firms build different types of dynamic capabilities to create competitive advantage by following a path of accumulation and learning. A dynamic capability in this sense is defined as "a learned and stable pattern of collective activity through which the organisation systematically generates and modifies its operating routines in pursuit of improved effectiveness" (Zollo and Winter 2002, p. 340).

Taking up the conceptual framework of evolutionary theory and from an analytical perspective of the evolution of production systems, Bell and Pavitt (1993) suggest that firms build technological capabilities by following patterns of accumulation that, through learning processes, modify their technological resources, routines and activities. In synthesis, they consider that firms draw paths of learning and accumulation of technological capabilities. As a consequence, and according to the degree of complexity of the activities and routines involved in the production systems, technological capabilities progress from basic production to innovation capabilities. Although, in some periods, basic and advanced technological capabilities overlap, depending on whether the competitive environment is dynamic or stable, in general, firms move forward along a path of accumulating technological capabilities.

Therefore, considering the concept of dynamic capabilities and paths of accumulation in production systems, firms that implement a TQM program may enter a path of accumulation of technological capabilities that improves their production capabilities and thus provides a basis for building innovation capabilities. In turn, and according to the RBDC view, the firm achieves innovation performance because it has the capability to do so. In terms of strategic fit, the BIC intervenes in the TQM–technological innovation relationship as a mediating variable, which leads us to pose our third working hypothesis.

Hypothesis 3. The BIC mediates the relationship between the implementation of business practices suggested by TQM and technological innovation.

3. Methodology and analysis

3.1 *Data*

To test the hypotheses, we take as an objective population Spanish firms with 100 or more employees in the industrial sectors of industrial machinery and equipment and instruments and related products (standard industrial classification codes 35 and 38), which are usually inclined toward developing innovation processes. According to the European Commission (2003), these sectors have high and medium high intensity in R&D expenditures. We obtained an initial list of companies from the Dun & Bradstreet census of the 50,000 largest Spanish firms. After excluding firms that had closed or changed activity, a total of 220 firms remained in the list, 185 of which belonged to the machinery sector and 35 to the instrument sector. To collect information, we sent a questionnaire by mail to all these companies after conventional pre-tests conducted in both academic and business environments. After intense telephone back-up work, we obtained a response rate of 47.7%, a total of 105 valid questionnaires.

3.2 *Measurements*

3.2.1 *Total Quality Management (TQM)*

To measure TQM, we employ the measurement instrument developed by Flynn *et al.* (1994), which distinguishes seven dimensions derived from 63 items, and adapts it to one of six scales (dimensions) and 24 items with a seven-point Likert-type response format. This adaptation is eminently practical; the questionnaire addressed to firms had to contain measurement elements for both quality and innovation, and maintaining the number of items to measure both concepts was problematic in terms of both questionnaire effectiveness and its influence on the response rate.

We assess the measurement instrument using the three-stage methodology suggested by Nunnally (1978) and used by several studies that build prior TQM instruments (e.g. Flynn *et al.* (1995), Ahire *et al.* (1996), Black and Porter (1996) and Saraph *et al.* (1989)). The summarised results appear in Table 1. To evaluate the unidimensionality of the measurement scales, we conduct principal component analysis for each scale and, on the basis of the results, eliminate three items. Cronbach's α serves to evaluate the reliability analysis of the TQM measurement scales and indicates values higher than 0.6 for all scales, which demonstrates a suitable level of internal consistency (Lord and Novick 1968, Nunnally 1978, Jones and James 1979). To evaluate the construct validity, we consider the factor loadings of each item of the different scales. The criterion for identifying the critical loading value emerges from calculations of Hair *et al.* (1999) based on the sample size, which, for this study, is calculated as a critical factor loading of 0.55 with a significance level of 0.05. As can be seen from Table 1, all items load above this value, except for one

Table 1. Evaluation of the TQM measurement instrument.

		Mean (SD)	Cronbach's α	Factor loadings	% Variance explained
Management support (TQM1)			0.7718		60.1503
Q11	Definition of a quality strategy	5.76 (1.22)		0.851	
Q12	Involvement of management with quality	5.57 (1.49)		0.752	
Q13	Fixing of long- and medium-term earnings	5.07 (1.62)		0.593	
Q14	Existence of guidelines on quality	5.25 (1.34)		0.874	
Information for quality (TQM2)			0.7512		66.8412
Q21	Information available for employees	4.97 (1.65)		0.856	
Q22	Use of statistical techniques for quality control	4.41 (1.69)		0.810	
Q23	Periodical evaluations of work quality	3.82 (1.76)		0.785	
Process management (TQM3)			0.7986		62.4267
Q31	Documenting production processes	5.42 (1.31)		0.782	
Q32	Process design with problem identification	5.03 (1.20)		0.836	
Q33	Orderly and clean work areas	5.35 (1.33)		0.744	
Q34	Emphasis on preventive maintenance	5.08 (1.33)		0.797	
Product design (TQM4)			0.6420		49.1516
Q41	Quality over cost in product design	4.94 (1.47)		0.478	
Q42	Product design to customers' requirements	6.33 (0.77)		0.735	
Q43	Functional and supplier integration in product design	5.49 (1.13)		0.728	
Q44	Technical reliability tests before commercialisation	5.79 (1.33)		0.817	
Human resource management (TQM5)			0.6668		50.4416
Q51	Creation of problem-solving teams	5.25 (1.43)		0.789	
Q52	Training of personnel in matters of quality and teamwork	4.75 (1.50)		0.788	
Q53	Incentive systems based on quality	3.32 (1.94)		0.640	
Q54	Selection of personnel based on criteria of work competence	4.60 (1.51)		0.605	
Q55	Similar or undifferentiated services for all employees*				
Relationship with suppliers and customers (TQM6)			0.6317		73.0834
Q61	Long-term relationships of trust with suppliers	5.74 (0.97)		0.855	
Q62	Information from customers and suppliers for product improvement	5.59 (1.02)		0.855	
Q63	Quality over price in the selection of suppliers*				
Q64	Few suppliers to ensure supply*				

Note: *Eliminated items.

(on the product design scale) that had a factor loading lower than 0.55. However, we retain this item for practical reasons and because of its theoretical relevance. According to Hair *et al.* (1999), an item loading between 0.40 and 0.50 has important practical, if not statistical, significance if the sample is larger than 100 observations. Moreover, implementing a TQM philosophy promotes the importance of quality over costs in product design.

3.2.2 *Business Innovation Capability (BIC)*

Following a similar approach, we adapt the measurement instrument designed by Tang (1999) to measure BIC. Most previous measures of innovation as a dynamic capability design scale for business consulting and do not employ the rigorous perspective of academic empirical research. Tang (1999) provides an exception; we design an instrument consisting of six scales and 23 items with a seven-point Likert-type response format on the basis of the nine scales and 46 items offered by this author.

Our evaluation of the measurement instrument for the BIC follows the same procedure as that for the TQM measurement instrument. We provide the results in Table 2. We first verified the unidimensionality of each scale, which required an adjustment to the number of items, and eliminated three items. The reliability and validity of the instrument are verified; the Cronbach's α values are greater than the critical value of 0.6, and the factor loadings are greater than 0.55 for all items.

3.2.3 *Technological innovation*

To measure innovation performance (technological innovation), we derive a measurement scale with four items that represent success in innovation (see Table 3), similar to previous literature (e.g. Schroeder *et al.* (1989), Chiesa *et al.* (1996), Hollenstein (1996), Subramanian and Nilakanta (1996), Tidd *et al.* (1996) and Galende and de la Fuente (2003)). Each respondent rated his or her company's position compared with that of its main competitors on a five-point scale (1 = very inferior, 3 = similar, 5 = very superior). This measurement approach, based on relative perceptions, offers a suitable and reliable alternative to objective measurements (Dess and Robinson 1984). All measurements loaded onto a single factor with weightings greater than 0.55 (critical value according to Hair *et al.* (1999)) and Cronbach's α well above 0.60 (see Table 3).

3.3 *Hypotheses testing*

To test Hypothesis 1, regarding the universal nature and direct effect of TQM on technological innovation, multiple regression analysis is the most appropriate technique. To avoid problems of interpretation deriving from the collinearity between variables, we chose to study seven models with technological innovation as the dependent variable. Each of the six TQM dimensions was incorporated, respectively, into the first six models. All the dimensions were incorporated into the seventh model, but their entry was conditioned by a stepwise procedure. In this way, only those dimensions capable of explaining something about innovation performance that the rest of the priorities cannot explain are entered into the model. That is, the procedure not only allows us to identify whether the TQM dimensions are capable of explaining a significant part of technological innovation, but also allows us to identify which dimensions have greater explanatory

Table 2. Evaluation of the BIC measurement instrument.

		Mean (SD)	Cronbach's α	Factor loadings	% Variance explained
Planning and commitment of the management (BIC1)			0.6541		74.3001
I11	Definition of a technological innovation strategy	4.81 (1.44)		0.862	
I12	Specific budget for innovative ideas	4.13 (1.74)		0.862	
I13	There is still a lot to learn in day-to-day work*				
Behaviour and integration (BIC2)			0.6470		49.2509
I21	There are benefits to be had from project failure and error	5.02 (1.62)		0.596	
I22	Permanent interest in others' work	3.82 (1.45)		0.745	
I23	Exchange of information and knowledge among work groups	4.87 (1.34)		0.596	
I24	Several people take the initiative in new projects	4.21 (1.52)		0.840	
Projects (BIC3)			0.7316		55.7166
I31	Formulation of innovative projects	5.27 (1.32)		0.746	
I32	Projects with suitable programming and resources	4.88 (1.26)		0.784	
I33	Projects help to reduce the risk of innovation	5.18 (1.04)		0.810	
I34	Evaluation of technical, economic and commercial feasibility of ideas	5.05 (1.37)		0.633	
Knowledge and skills (BIC4)			0.7131		63.7324
I41	Own knowledge is generated (R&D)	5.20 (1.41)		0.806	
I42	Knowledge protection systems	4.48 (1.44)		0.856	
I43	Periodical evaluations of practices and routines	4.36 (1.61)		0.728	
I44	Processes require skills that are difficult to acquire*				
Information and communication (BIC5)			0.8095		63.8316
I51	Permanent information flow	4.66 (1.33)		0.835	
I52	Management of documentation and information	5.42 (1.22)		0.823	
I53	Information system as a stimulus for new ideas	4.28 (1.36)		0.821	
I54	Supervision system and technology transfer	4.39 (1.40)		0.713	
External environment (BIC6)			0.7974		62.3025
I61	Innovation projects in cooperation	4.15 (1.77)		0.806	
I62	Relationship with centers or universities	4.15 (1.92)		0.803	
I63	Technological comparison with the competition	4.95 (1.61)		0.822	
I64	Participation in federations, chambers or associations	4.88 (1.48)		0.724	

Note: *Eliminated items.

Table 3. Measurement scale of technological innovation.

		Mean (SD)	Cronbach's α	Factor loadings	% Variance explained
Technological innovation			0.7583		58.4570
TI1	Range of products and launch rhythm	3.23 (0.91)		0.593	
TI2	Technical novelty in production systems	3.40 (0.88)		0.753	
TI3	Expenditure on technological innovation	3.24 (1.02)		0.887	
TI4	Generation of patents	2.85 (1.04)		0.795	

power (seventh model). Table 4 shows the results obtained from the estimation of these models. In this case, only the human resource management dimension appears to have a positive and significant effect on technological innovation (see model 5) and this is the only dimension entering in model 7. As in other studies that attempt to explain innovation performance or innovative behaviour (e.g. Braga and Willmore (1991) and Furukawa and Goto (2006)), the predictive power (R^2) of the models is low, because innovation depends on many factors and circumstances other than those studied herein (Kumar and Saqib 1996, Galende and Suárez 1999, Kannebley *et al.* 2005).

To test Hypothesis 2, pertaining to the existence of a moderated contingent relationship between technological innovation and TQM, we perform moderated regression analysis. For each pair of dimensions TQM_i and BIC_j, we estimate three regression models: (1) considering TQM_i only as the independent variable; (2) including BIC_j as a new independent variable; and (3) incorporating the interaction effect between TQM_i and BIC_j. The existence of a moderating effect of BIC_j on the relationship between technological innovation and TQM_i depends on whether the increment of the predictive power (R^2) of model 3 with respect to model 2 is significant and/or whether the coefficient of the interaction term $TQM_i \times BIC_j$ is significant (Jaccard *et al.* 1990).

Table 5 shows those cases (out of the 36 pairs of dimensions) for which a moderating effect was found. The moderating effects of BIC are significant only for the relationship between technological innovation and the process management dimension of TQM. Specifically, the relationship between technological innovation and the process management dimension (TQM_3) is shown to be negatively moderated by four dimensions of BIC (i.e. planning and management commitment BIC_1, projects BIC_3, knowledge and skills BIC_4, and external environment BIC_6).

Finally, to test Hypothesis 3, regarding the intervention of BIC as a link between TQM and technological innovation, we use structural equation modelling to estimate the bottom model in Figure 1 for each pair of dimensions TQM_i and BIC_j. However, this hypothesis makes sense only for those TQM dimensions that showed a direct effect on technological innovation (i.e. just for TQM_5) since a variable cannot mediate a relationship if this relationship does not exist (Judd and Kenny 1981, Baron and Kenny 1986). Figure 2 shows graphically the results of this analysis for the case of TQM_5 and BIC_3. Table 6 shows the goodness-of-fit indexes and the standardised coefficients for the six estimated models (one for each dimension of BIC as mediating variable between TQM_5 and technological innovation). Although the fit is poorer for BIC_2 and BIC_6, the results support the idea that the effect of TQM_5 on technological innovation is mediated by the dimensions of BIC.

Table 4. Regression analysis between technological innovation and TQM.

	Technological innovation						
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Constant (β)	2.593*** (0.367)	3.145*** (0.244)	2.758*** (0.379)	2.417*** (0.506)	2.600*** (0.295)	3.035*** (0.492)	2.600*** (0.295)
TQM1: Management support	0.109 (0.067)						ns
TQM2: Information for quality		0.008 (0.063)					ns
TQM3: Process management			0.081 (0.071)				ns
TQM4: Product design				0.135 (0.089)			ns
TQM5: Human resource management					0.129** (0.064)		0.129** (0.064)
TQM6: Relations with agents						0.026 (0.086)	ns
R^2	0.026	0.000	0.013	0.023	0.039	0.001	0.039
F	2.665	0.023	1.290	2.325	4.124**	0.089	4.124**

Notes: Typical errors between parentheses; ns = not significant.
**Coefficient significant at 5%.
***Coefficient significant at 1%.

Table 5. Moderated regression analysis between technological innovation and TQM.

Independent variable	Constant	β Coefficient			R^2	F	ΔF
TQM3: Process management	2.758***	0.081			0.013	1.290	
TQM3, BIC1: Plan. and management commitment	2.530***	−0.014	0.162***		0.087	4.778***	8.175***
TQM3, BIC1, TQM3×BIC1	0.842	0.342	0.597**	−0.088*	0.116	4.325***	3.208*
TQM3: Process management	2.758***	0.081			0.013	1.290	
TQM3, BIC3: Projects	2.269***	−0.028	0.207**		0.058	3.086**	4.834**
TQM3, BIC3, TQM3×BIC3	−0.899	0.636	0.881***	−0.137**	0.099	3.617**	4.463**
TQM3: Process management	2.758***	0.081			0.013	1.290	
TQM3, BIC4: Knowledge and skills	2.431***	−0.055	0.222***		0.105	5.888***	10.367***
TQM3, BIC4, TQM3×BIC4	0.633	0.317	0.630**	−0.082*	0.131	4.978***	2.931*
TQM3: Process management	2.758***	0.081			0.013	1.290	
TQM3, BIC6: External environment	2.563***	0.022	0.111*		0.047	2.472*	3.621*
TQM3, BIC6, TQM3×BIC6	0.655	0.409*	0.576**	−0.092*	0.079	2.817**	3.3387*

Notes: Dependent variable: technological innovation.
*Coefficient significant at 10%.
**Coefficient significant at 5%.
***Coefficient significant at 1%.

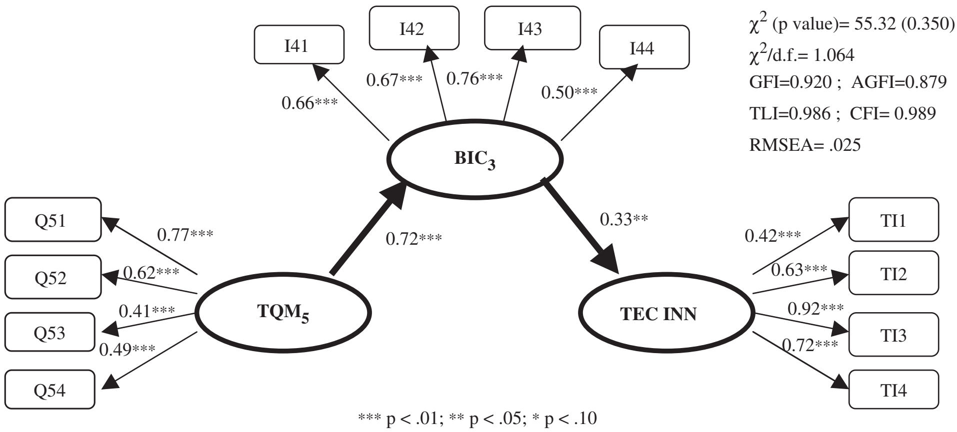

Figure 2. Structural equation modelling of BIC_3 as mediator of the relationship between TQM_5 and technological innovation.

4. Discussion of results

The different theoretical and empirical approaches to the relationship between TQM and technological innovation yield interesting results. In the first place, we find that not all the business practices integrated within the concept of total quality have a positive and significant effect on technological innovation performance and that we cannot therefore talk of a comprehensive influence of the TQM approach on technological innovation, but of specific and fine links between these two elements. Indeed, only total quality practices associated with human resource management show a positive effect on technological innovation (Table 4). This result, in particular, has been confirmed by recent studies that find a direct and positive relationship between human resource management practices and technological innovation (Laursen and Foss 2003, Lau and Ngo 2004). Moreover, the characterisation of innovative firms indicates which TQM-related human resource practices, such as emphasis on team-work, training and work motivation, represent recurrent traits in the type of firm that enjoys superior performance in innovation (Cooms and Rosse 1992, Cascio 1996, Gómez-Mejía and Saura 1996, Hybels and Barley 1996, Balkin *et al.* 2000).

In short, although TQM as a business management model cannot be viewed as widely linked to technological innovation, it contains a set of best business practices related to human resource management that promotes better innovation performance. Thus, we find partial support for Hypothesis 1.

Furthermore, as the results in Table 5 indicate, we find limited evidence regarding the existence of a moderating effect of BIC on the relationship between TQM and technological innovation. The only statistically significant, though negative, interaction effect is that of the process management dimension of TQM with different dimensions of BIC. This result suggests that emphasis on the control and improvement of processes, in parallel with management practices of innovation—especially those related to project planning, formulation and assessment, developing new knowledge and skills and relating external cooperation—may have a negative effect on technological innovation. That is, a positive relationship between TQM and technological innovation is not promoted

Table 6. Measurement of overall fit of the alternative models and saturated model.

Mediating variable	χ^2 (p) rv: $\rho > 0.05$	χ^2/d.f. rv: ≤ 3	RMSR rv: ≤ 0.10	GFI rv: ≥ 0.90	AGFI rv: ≥ 0.80	TLI rv: ≥ 0.90	CFI rv: ≥ 0.90	$TQM_5 \rightarrow BIC_j$	$BIC_j \rightarrow$ Tec innov
BIC_1	**30.672 (0.584)**	**0.929**	**0.000**	**0.944**	**0.906**	**1.014**	**1.000**	0.71***	0.37**
BIC_2	78.750 (0.010)	**1.514**	**0.071**	0.889	**0.833**	0.879	**0.905**	0.80***	0.32**
BIC_3	**55.322 (0.350)**	**1.064**	**0.025**	**0.920**	**0.879**	**0.986**	**0.989**	0.72***	0.33**
BIC_4	**51.503 (0.149)**	**1.226**	**0.047**	**0.917**	**0.870**	**0.956**	**0.967**	0.74***	0.37**
BIC_5	**62.213 (0.157)**	**1.196**	**0.044**	**0.911**	**0.866**	**0.963**	**0.971**	0.82***	0.27**
BIC_6	85.722 (0.002)	**1.649**	**0.079**	0.884	**0.827**	0.876	**0.903**	0.60***	0.30**

Notes: rv: recommended value (based on Chau (1997)); coefficients in bold fit the recommended values.
***$p < 0.01$; **$p < 0.05$.

by BIC and sometimes even the contrary can happen. Thus our analysis does not support Hypothesis 2.

This result may imply that quality and innovation are sequential, rather than complementary, priorities. Prajogo and Sohal (2003), in taking up the approach of Nowak (1997), find empirical evidence for the impact of TQM on quality and innovation performance and, in particular, the existence of sequentiality in achievement, namely, primary effects on quality and secondary effects on (process and product) innovation. Thus, the accumulation and learning paths of firms over time seem to provide a more plausible explanation for the presence of links between quality and innovation. From this perspective, Imai's (1986) proposal concerning the existence of processes of continuous improvement, as support for innovation practices and performance, appears effective only within a time framework and therefore requires maturation and learning processes over time.

Finally, empirical evidence indicates that the effects of TQM-based human resource management practices on technological innovation take place because of the potential of these practices to build BIC. The results of the structural equation modelling acceptably confirm the existence of a sequential causal order or mediation between this dimension of TQM and technological innovation (Figure 2, Table 6), that is, we find support for Hypothesis 3 as far as the human resource management practices suggested by TQM are taken into account. Thus, there is not a single level of dependence between TQM and technological innovation, as a universal or direct relationship might imply, but rather at least two levels of dependence generated by the need to build a BIC to achieve a positive impact on the levels of technological innovation. In short, empirical acceptance of the existence of strategic fit due to the mediation effect of BIC on the previously identified link between TQM and technological innovation provides a good reason to believe that accumulation paths of learning concerning technological capabilities exist in firms (i.e. from basic production capabilities to complex innovation capabilities).

5. Conclusions

5.1 *Theoretical implications*

This article clarifies the ongoing debate concerning the relationship between the practices associated with TQM models and innovation performance. A theoretical point of view poses arguments both in favour of, and opposed to, the relationship between TQM and technological innovation. In particular, some theoreticians postulate that attaining performance in innovation does not constitute a portion of the TQM perspective, understood as an integral management model. As a consequence, its scope would be limited to achieving customer satisfaction, and its repercussions would affect only business operations and financial performance. Alternatively, more recent trends suggest the concept of continuous innovation, similar to TQM's principle of continuous improvement, to postulate that the management models focused on total quality promote better performance in innovation, in combination with those principles associated with continuous improvement, customer orientation and workplace integration.

Extant empirical literature on the relationship has yielded divergent results, so this article provides an alternative explanation for the relationship between TQM and technological innovation. As we show, there are no identical effects of all the TQM practices on innovation performance. Whereas human resource management practices suggested by TQM show a positive effect on innovation performance, control and improvement practices can worsen performance when combined with certain innovation management practices. Furthermore, evidence also indicates that TQM-based human resource management practices are proactive for the building of a BIC, which, according to the RBDC view, offers a basis for technological innovation. Thus, we find a mechanism of transmission from TQM to innovation performance.

This idea of a mechanism of intervention and transmission between TQM and technological innovation is based on a contingent or strategic fit approach. Although it has appeared briefly in the few theoretical papers pertaining to the relationship between quality and innovation, fit as mediation has not been postulated previously. Theoretical support for contingent fit by mediation emerges from RBDC theory, which suggests accumulation paths of strategic capabilities for attaining competitive advantages. Therefore, evidence of an intervention mechanism between some TQM practices and technological innovation enables us to suggest that firms evolve by starting with the formation of basic production capabilities, encouraged and improved by certain TQM practices, and then move to complex innovation capabilities, fostered by practices associated with BIC.

From another perspective, learning curves in firms start with the prioritisation of strategic objectives and their sequential structure. For example, as suggested by Prajogo and Sohal (2003), firms evolve from objectives and quality performance to objectives and innovation performance.

5.2 *Managerial implications*

Our results clearly indicate that firms cannot consider TQM simply a passing administrative fashion or a panacea for achieving sustainable competitive advantage over time. Rather, TQM fosters accumulation paths of technological capabilities through its human resource management practices. Therefore, TQM cannot be dismissed as just an administrative trend, because it provides a typical organisational resource on which firms may build a durable competitive advantage.

Managers can find in TQM human resource practices a tool to promote innovation capabilities and improve innovation performance. They should also understand the logical sequence between quality objectives and innovation objectives. In other words, firms must be able to evolve from quality control approaches to those centred on continuous learning.

5.3 *Limitations and future lines of research*

The limitations of this research mainly derive from our use of a cross-sectional sample to test the hypotheses pertaining to relationships of causality. We need to find alternative methods for empirical measuring and testing, particularly when seeking to evaluate dynamic relationships that stem from the RBDC view. From this perspective, it is necessary to resort to case study, panel data or time-series methodologies.

Further research might explore the multi-dimensional nature of business performance and its relationship with TQM and BIC, particularly by testing hypotheses of sequentiality for specific objectives and their complementary nature. Finally, and following the recent theoretical inclination to assume a complex relationship between quality and innovation, it would be worthwhile to demonstrate new relationships of contingency that consider both classic variables (i.e. strategy, structure, environment) and variables more specific to the relationship between TQM and technological innovation, such as organisational learning, intellectual capital or specific research and development activities.

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