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Innovation, quality management and learning: Short-term and longer-term effects

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ABSTRACT

Quality-orientated management change and innovation are central strategies for firms. Implementing both quality improvement and innovation poses significant managerial, organisational and technical challenges, and may also involve significant lags before benefits are realised. Here, using data on a large group of Irish manufacturing plants and econometric analysis, we establish the short- and longer-term influence of plants' adoption of quality improvement methods (QIMs) on product innovation performance. Our study highlights the short-term disruptive and longer-term beneficial effects of QIM adoption on product innovation performance. In addition, we find evidence of complementarities and learning-by-using effects from QIM adoption. Our results suggest that maximising the returns to innovation and quality improvement requires consideration of the soft and/or hard nature of individual QIMs and the timing and sequencing of their adoption.

1. Introduction

With increased market competition, the successful management of change is crucial to firm survival and success (Todnem By, 2005). Quality improvement and innovation have therefore become established strategies as firms seek to create and defend their competitive position (Pekovic and Galia, 2009). Some authors have argued that quality improvement and innovation are the central concepts of new forms of economic theory of the firm and models of business behaviour (Anderson et al., 1994; Black and Porter, 1996; Rungtusanatham et al., 1998), viz. 'Quality is a vital component of the business strategy, and quality improvement is a strategic variable employed in the highly competitive international business world' (Adam et al., 2001, p. 43). And, on innovation Baumol (2002 p. ix) comments: 'firms cannot afford to leave innovation to chance. Rather, managements are forced by market pressures to support innovation activity systematically … The result is a ferocious arms race among firms in the most rapidly evolving sectors of the economy, with innovation as the prime weapon'.

Within the management change literature, two paradigms of 'hard' and 'soft' management change emerge. Hard managerial changes typically emphasise rules, standardisation, conformity, discipline, stability, formality, whereas knowledge sharing/diffusion, reflection engagement, empowerment and intelligence gathering and are reflective of soft managerial changes. We use these contrasts to explore in more depth the relationship between product innovation performance and quality improvement methods (QIMs). Quality improvement and innovation are clearly inter-related although there is little agreement on whether this is of a complementary or opposing nature. Nowak (1997), for example, envisages a complementary relationship, commenting that: 'quality and innovation processes are inter-linked and should not be treated separately. Technical change not enhancing quality is illusive because it does not contribute to a sustained and improved strategic competitive advantage, nor does it increase the value creation potential of available resources through quality creation'. Other writers have seen quality improvement processes – which may involve mechanistic routinisation and standardised business processes – as restricting creativity and innovation (Glynn, 1996; Kanter, 1983; Perdomo-Ortiz et al., 2009a,b; Prajogo and Sohal, 2004). Where the relationship between quality improvement methods (QIMs) and product innovation has been explored empirically relationships are generally positive (Martínez-Costa and Martínez-Lorente, 2008; Hung et al., 2011, Prajogo and Sohal, 2004; Hoang et al., 2006; Zeng at al., 2015). Other studies, however, have found either neutral or negative relationships between QIMs and product innovation (Terziovski and Guerrero, 2014). With a growing recognition of the complementary nature of hard and soft managerial processes, recent studies highlight the benefit of incoporating a combination of hard and soft quality management practices for product innovation (Hoang et al., 2006; Zeng et al., 2015) and firm performance (Gadenne and Sharma, 2009; Calvo-Mora et al., 2013).

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One other commonality between quality improvement and innovation processes noted in the literature is that both are often difficult to implement leading to significant lags in the realisation of any related benefits. Pekovic and Galia (2009) comment, for example, that 'implementation of the ISO 9000 standard … concerns the whole organisation and involves changes in the fundamental behaviour and applied routine of employees' (Pekovic and Galia, 2009, p. 831). Likewise, innovation may result in short-term disruption before any longer-term performance benefits are accrued by the firm (Roper et al., 2008). Understanding the performance benefits of innovation and quality improvement, and their interactions, is therefore likely to require longitudinal data covering a period of years in which causal mechanisms are clearly identifiable.

Here, using data on a large group of Irish manufacturing plants we focus on the relationship between product innovation performance and the adoption of quality orientated hard and soft management change. We ask whether, and over what period, the adoption of QIMs (specifically ISO9000, TQM and Quality Circles) impacts on plants' innovation success (specifically sales generated from product innovation). Most, if not all, of the prior studies of the relationship between QIMs and innovation have been based on cross-sectional analysis making causality difficult to identify, and providing little information on the nature of the learning effects and lags involved in QIM adoption and its potential benefits for innovation. Our study makes several important contributions. First, our data allows us to identify the temporal profile of the performance benefits of individual QIMs, highlighting short-term disruption (negative) effects but longer-term (positive) benefits. Second, it seeks to explain the short-term and long-term aspects of the quality-innovation relationship within the context of the contrasting paradigms of hard and soft managerial change. Third, it highlights complementarities and learning by using effects for product innovation performance arising from the adoption of quality-orientated hard and soft managerial processes.

2. Concepts and hypotheses

2.1. Hard and soft management change

With increased market competition and developments in technology, the characteristics of business have changed drastically (Pekovic and Galia, 2009). The successful management of change is crucial to survive and succeed in the highly competitive and continuously evolving business environment (Todnem By, 2005). Organisational change management has been defined as 'the process of continually renewing an organisation's direction, structure, and capabilities to serve the ever-changing needs of external and internal customers' (Moran and Brightman, 2001). It means entering new territory and "playing the game by new rules" and moving the organisation from its current state to a more desirable improved state (Ragsdell, 2000). Two paradigms of organisational change emerge from the literature. In general, objectivist, scientific approaches are hard, while subjectivist, social approaches are soft. The terms hard and soft are commonly used across a broad range of organisational change practices, such as HRM practices (Storey, 1989), quality improvement practices (Zeng et al., 2015), Information and Communications Technology (ICT) (Arvanitis et al., 2013) and project management (Crawford et al., 2003).

The hard, positivist, paradigm promotes an understanding of the world as an objective reality – systems are mechanistic processes, with stable or predictably varying, relationships between the relevant variables (Crawford and Pollack, 2004). In practice, the hard paradigm often takes a top-down approach, following a rational hierarchical model that emphasises control and is expressed through formal structures and systems. Its language acts to superimpose a logic, order, and structure on an otherwise irrational social process (Crawford et al., 2003). The soft paradigm stems from interpretivist and constructivist schools of thought emphasising the inter-subjective creation of knowledge – people are continually developing and refining their views which informs their actions (Crawford and Pollack, 2004). These bottom–up models of organisational change recognise a non-linear, political and irrational process. Such models may be characterised as dynamic and fragmented, albeit interconnected, composed of competing perspectives and interested and supported by informal systems (Crawford et al., 2003).

While organisational practices can differ considerably, parallels exist in the demarcation of soft and hard practices across the spectrum. For instance, in project management, the hard paradigm assumes that goals and methods are already well defined, and the objective is to find the best solution to a particular problem, however 'best' is defined and measured. Contrastingly, the soft paradigm suggests that the aspects of a situation that cause it to be problematic are not easily defined or isolated. Therefore, it is necessary to engage with people at a qualitative level in the understanding that it is unlikely that there will be a unique 'best' solution (Midgley, 2000). Within the HR literature, similar differentiations apply. In general, soft management practices encourage knowledge sharing, engagement, empowerment and encourages intelligence gathering and reflection whereas hard management practices often are rule-based and require conformity, standardisation, discipline and stability (Jenkins and Delbridge, 2013). Furthermore, there is a growing realisation across the organisational change literature that hard and soft practices are more beneficial when introduced together. Within the project management literature, Crawford et al. (2003) report the need for both hard and soft perspectives when managing complex organisational change projects, particularly when changing aspects of organisations, such as working practices and culture. In addition, Arvanitis et al. (2013) report that the combination of hard and soft ICT capital has a positive effect on both process and product/services innovation

2.2. Quality orientated management change

Many firms have responded to the challenges they face by incorporating quality-based strategies into their change management approach (Foley et al., 1997). A commitment to quality can drive firms to make significant improvements in profitability, productivity and competitiveness (Deming, 1986; Morgan and Vorhies, 2001). Hard quality management is mechanistic in nature and emphasises stability, conformity and discipline, and comprises processes such as work design and statistical process control. These hard components relate to the control of processes and products to maintain uniformity, comply with quality standards and satisfy manufacturing specifications (López-Mielgo et al., 2009). Soft quality management stresses employee engagement, partnerships, and comparison with the market leaders. These soft aspects of quality management are more organic in nature and focus on leadership, empowerment and training, and encourage employees to scan the environment for new trends, approaches and technologies (Moura E Sá and Abrunhosa, 2007; McAdam, 2000). Soft quality management promotes the more human and developmental aspects of the quality system allowing the firm to adapt to its changing environment and promoting continuous improvement (López-Mielgo et al., 2009).

Three of the most widely recognised QIMs, which span the soft-hard range of management change practices, are Total Quality Management (TQM), Quality Certification (such as ISO9000) and Quality Circles. TQM has been described as a management philosophy that fosters an organisational culture committed to customer satisfaction through continuous improvement (Kanji, 2002). The TQM philosophy essentially comprises three key elements: customer focus, people involvement and continuous improvement (Moura E Sá and Abrunhosa, 2007). Quality Certification initiatives, e.g. ISO 9000, require detailed review and documentation of a firm's production processes, in accordance with the quality system requirements specified by ISO.[1] The ISO 9000 standard is based on eight principles that address the core values and concepts of quality management: customer focus, leadership, involvement of people, process approach, system approach to management, continual improvement and factual approach to decision making (Kartha, 2004). Quality Circles (QCs) are small groups of workers who meet regularly on a voluntary basis to discuss problems (not necessarily quality related) and determine possible solutions. Members of Quality Circles are generally given training in quality control and evaluation techniques (Trott, 2008). QCs improve problem-solving capabilities through employees' participation and team work (Bodas Freitas, 2008).

QCs are soft in nature where groups of workers meet on a voluntary basis to try to solve quality related problems. QCs aim to encourage a participative culture and would not be considered particularly onerous to initiate from a managerial perspective. TQM's three key elements of customer focus, people involvement and continuous improvement combine both soft and hard components with implications for a number of management practices such as leadership, training, employee-management, information and analysis, supplier management, process management, customer focus, and continuous improvement (Moura E Sá and Abrunhosa, 2007). While many of the principles of Quality Certification are similar to those of TQM, in practice, the programme's focus is on ensuring that organisations create consistent, stable processes through process documentation and adherence, which assures the delivery of quality products or services (Pekovic and Galia, 2009). Quality Certification is the most rule-based, mechanistic or hard of the QIMs lacking the soft elements of either TQM or quality circles.

Although, there is no clear consensus as to the impact of QIM in firms, many scholars conclude that TQM positively affects business performance (Sousa and Voss, 2002; Kaynak, 2003). For instance, Sadikoglu and Zehir (2010) in a comprehensive review of the literature, report positive relationships between TQM and business performance, including metrics such as market and financial performance, employee performance and customer satisfaction (see Table 1, p. 16). As with TQM, there is considerable evidence that ISO certification can deliver advantages for the firm, such as quality improvement (Douglas et al., 2003), sales growth (Terlaak and King, 2006), business performance (Terziovski et al., 2003), financial performance (Corbett et al., 2005), and firm productivity (Diaye et al., 2009). However, critics of ISO 9000 have claimed that the adoption of ISO9000 is costly and time-consuming, and is particularly difficult for small firms (Pekovic and Galia, 2009). While there is limited evidence of the influence of QCs on firm performance, there is evidence that human resource management practices, such as QCs, which empower and involve employees positively, influence employee motivation and behaviour with positive consequences for firm performance (Subramony, 2009).

In an investigation of the key hard and soft quality management practices adopted by Australian small and medium enterprises (SMEs), Gadenne and Sharma (2009) report improved overall performance appears to be favourably influenced by a combination of hard TQM factors such as benchmarking and quality measurement, continuous improvement, and efficiency improvement; and the soft TQM factors consisting of top management philosophy and supplier support employee training and increased interaction with employees and customers. They conclude that it is necessary to focus on a combination of soft or behavioural aspects and the hard 'system oriented' aspects of quality management to achieve an improvement in overall performance, and that to maintain customer satisfaction and return on assets it is just as important to focus on employee involvement and training, as it is to have a customer focus. In a more recent study, Calvo-Mora et al. (2013) examine the relationship between soft and hard TQM factors and key business results for 116 Spanish firms. They report that management leadership, HRM and a flexible culture oriented towards continuous improvement (soft factors) are key elements in the success of TQM initiatives. This commitment and involvement of the management and the people with the results, quality and continuous improvement must be embodied in the formulating and effective implementation of a set of strategies policies and actions related to the resources, partnerships and processes (hard factors).

2.3. Innovation and quality management

Innovation has been identified as a critical driver of business productivity and economic growth (Schumpeter, 1934; Romer 1990). Schumpeter (1934) argued that innovation involves the transformation of knowledge into new products, services or business processes. The relationship between innovation output and innovation inputs has been explored extensively (Crepon et al., 1998; McCann and Simonen, 2005; Griffith et al., 2008; Roper et al., 2008). Numerous scholars have attempted to explain why some firms are more likely to innovate, with firm characteristics, such as size, sector, ownership, and location being identified as influential drivers of innovation output (Audretsch and Feldman, 1996; Boschma, 2005; Gordon and McCann, 2005; Jordan and O'Leary, 2008; McCann and Simonen, 2005; Tether, 1998; Romer, 1990; Roper et al., 2008). The importance of R & D to innovation activity within firms has been established by many authors (Roper et al., 2008; Freel, 2003). Firms engaging in R & D increase their existing stock of knowledge resulting in commercial gains from the introduction of new products, processes and/or organisational innovations (Roper et al., 2004). Likewise, managerial capabilities have been highlighted as an important factor in firm level innovation. Successful innovation requires that firms and managers provide clear and consistent signals to employees about the goals and objectives of the firm (Barnes et al., 2006). There is also considerable evidence of the importance of external sources to innovation outputs (Mansury and Love, 2008). These external sources of knowledge may include linkages with customers, suppliers, competitors and/or research institutes (Roper et al., 2008)

It has long been recognised that innovation in processes is necessary when a company wants to increase productivity (Martínez-Costa and Martínez-Lorente, 2008), implying a potential link between innovation and quality management. We review existing literature on the quality-innovation relationship in the context of quality management's hard and soft dimensions, although it should be noted that many of the studies empirically examine a specific QIM and its impact on innovation outcomes rather than considering the soft and/or hard aspects of the approach. A notable recent exception is Zeng et al. (2015). See Table 1 for a summary of this review.

Focusing first on the hard QIMs and innovation, a small number of studies examine the links between Quality Certification (ISO9000) and innovation. Benner and Tushman (2002) find that the extent of process management activities in a firm are associated with an increase in exploitative innovations and exploitative innovation's share of total innovations in the paint and photography industry. Using two French microeconomic surveys, Pekovic and Galia (2009) also find that ISO 9000 certification is significantly and positively linked to seven out of nine innovation indicators. A more recent study reports that ISO900 certification stifles product innovation performance, but facilitates process innovation performance (Terziovski and Guerrero, 2014). In addition, Zeng et al. (2015) reports the importance of hard quality management for innovation.

In relation to the relationship between soft quality management and innovation, we are not aware of any quantitative studies which specifically relate Quality Circles to innovation. However, small group problem solving, employee suggestion schemes and employee training, have been shown to encourage joint problem solving, empower employees and encourage them to make suggestions for improvements to processes and update employees' skills and knowledge. Within the HRM and quality management literature, there is evidence of such soft

[1] ISO 9000 certification is undertaken by various certification bodies called registrars such as government laboratories, private testing organisations, early adopters of ISO, industry trade groups and accounting firms.

Table 1
Summary of Empirical QIM-Innovation Studies.

	Study	QIM	Hard/Soft Dimensions	Innovation Measures	Principal empirical results: QIM-Innovation relationship
1	Benner and Tushman (2002)	ISO9000	Hard QIM dimensions only	Exploitative innovations; Exploitative Innovation's share of total innovations	Positive for both innovation outcome measures
2	Pekovic and Galia (2009)	ISO9000 & other certifications	Hard QIM dimensions only	New or improved products for the firm; Turnover due to new or improved products; New or improved products on the market; Share of new or improved products to the market; Effect on processes; New or improved processes for the firm; Technologically new process; New process (non-technological); Effect on innovation activities; Total innovation expenditure	Positive for seven of nine innovation indicators
3	Terziovski and Guerrero (2014)	ISO9000	Hard QIM dimensions only	Product innovation performance; process innovation performance	Negative for product innovation performance; positive for process innovation performance
4	Moura E Sá and Abrunhosa (2007)	TQM	Combined Hard & Soft QIM dimensions	Adoption of technological innovation	A positive (weak) relationship for technological innovation
5	Martínez-Costa and Martínez-Lorente (2008)	TQM	Combined Hard & Soft QIM dimensions	Product and process innovation	A positive relationship between TQM and product and process innovation
6	Prajogo and Hong (2008)	TQM	Combined Hard & Soft QIM dimensions	R & D	TQM positively influences R & D
7	Hung et al. (2011)	TQM	Combined Hard & Soft QIM dimensions	Product, process and organisational innovation	A positive relationship between TQM and product, process and organisational innovation
8	Abrunhosa and Moura E Sá (2008)	TQM	Distinct Hard & Soft QIM dimensions	Adoption of technological innovation; Timing of adoption of innovations	Soft elements of TQM positively impact innovation
9	Prajogo and Sohal (2004)	TQM	Distinct Hard & Soft QIM dimensions	Product and process innovation	Soft elements of TQM positively impact innovation
10	Hoang et al. (2006)	TQM	Distinct Hard & Soft QIM dimensions	Innovation Indicator consisting of (1) new product or new service (2) Use of new materials or intermediate products. (3) New functional solution for an existing product or additional service based on an existing service. (4) New method of production (5) Entering a new market (6) New source of supply (7) New ways of organizing (re-arranging the company's human resource)	Both hard and soft TQM practices positively influence firm-level innovation
11	Perdomo-Ortiz et al. (2009a,b)	TQM	Distinct Hard & Soft QIM dimensions	Assessment of innovation performance relative to main competitors	Some soft TQM practices, such as HRM, positively influence innovation
12	Perdomo-Ortiz et al. (2006)	TQM	Distinct Hard & Soft QIM dimensions	Business Innovation Capacity	A significant, negative interaction effect with respect to the hard elements of TQM with different dimensions of BIC.
13	Zeng at al. (2015)	Process management and Quality information; Small group problem solving, Employee suggestion, and Task-related training for employees	Distinct Hard & Soft QIM dimensions	Product innovation; measured by speed of new product introduction and product innovativeness	Hard QIM affects Innovation; Soft QIM has indirect effect on innovation performance through its impact on hard QIM.

Note: We are not aware of any quantitative studies which specifically relate Quality Circles to Innovation.

practices benefitting innovation activity within firms (Nakata and Im, 2010; Laursen and Foss, 2014; Leiponen, 2005; Zeng et al., 2015).

To date, the majority of studies have focused on the relationship between TQM and innovation, which is typically found to be positive. Moura E Sá and Abrunhosa (2007), in an investigation of the Portuguese footwear industry report a positive relationship between TQM and innovation, although the relationship proves relatively weak. Martínez-Costa and Martínez-Lorente (2008), in a study of 451 Spanish companies, also report a significant and positive relationship between TQM and product and process innovation, while Prajogo and Hong (2008) find that TQM positively influences R & D in South Korean firms. More recently, Hung et al. (2011) examined the impact of TQM and organisational learning on innovation performance in the high-tech industry in Taiwan. They report that TQM has significant and positive effects on organisational learning, and TQM and organisational learning both have significant and positive effects on innovation performance. While many of these studies do not explicitly differentiate between the blend of soft and hard elements within TQM with respect to innovation outcomes, there is evidence that particular aspects of TQM influence innovation activity. In relation to the softer or more organic aspects of TQM, Abrunhosa and Moura E Sá (2008) report that communication, supportive people management practices and teamwork positively impact on innovation performance, whereas autonomy and consultation do not. Similarly, Prajogo and Sohal (2004), in an examination of the impact of TQM on product innovation within Australian firms, concluded that two elements of TQM – leadership and people management – positively influenced innovation.

Although, Hoang et al. (2006) find that both hard and soft TQM practices positively influence firm-level innovation, and illustrate how three specific dimensions of TQM, leadership and people management, process and strategic management, and open organisation have a positive impact on the innovation performance of firms in Vietnam. Interestingly, Perdomo-Ortiz et al. (2009a,b) find that only the soft human resource management element of TQM is linked positively to innovation in their study of 105 Spanish industrial firms. They conclude that TQM contains a set of best practices related to human resource management that promote better innovation performance. They also consider five other aspects of TQM – management support, information for quality, process management, product design, and relations with agents- finding no positive link to innovation. In an earlier study, Perdomo-Ortiz et al. (2006) examine the relationship between TQM and innovation while considering business innovation capacity (BIC) as both a moderating and mediating factor. They report limited evidence of a moderating effect. However, they find a significant, negative interaction effect with respect to the (hard) process management dimension of TQM with different dimensions of BIC. This suggests that the emphasis on the control and improvement of processes, in parallel with management practices of innovation, such as project planning, formulation and assessment, developing new knowledge and skills and external cooperation, may have a negative effect on technological innovation.

In general, quality improvement and innovation are seen as correlated functions within firms, and while quality management typically appears to benefit innovation; that relationship is not always positive. In addition, there may be very different behavioural or organisational mechanisms in play with respect to the hard and/or soft elements of the quality management practices when adopted. There is a growing recognition across the organisational change literature of the complementary relationship between hard and soft practices, whether project management, ICT, or HRM, for business performance. It is likely that this complementary relationship also exists in terms of hard and soft quality management and innovation, although we are only aware of one recent study which takes such an approach. Zeng et al. (2015) considered how soft quality management can play a supporting or mediating role in the hard quality management and innovation relationship. In summary, the studies reviewed here report the positive influence of QIMs with respect to product innovation (Martínez-Costa and Martínez-Lorente, 2008; Hung et al., 2011, Prajogo and Sohal, 2004; Hoang et al., 2006; Zeng at al., 2015); albeit with incomplete evidence as to if it is the hard routinized QIM processes or the softer, more organic elements of QIM which benefit product innovation.

2.4. Hypotheses

Although previous empirical studies have generally found a positive link between QIMs (whether embodying hard and/or soft managerial processes) and innovation, the use of cross-sectional data and analysis (e.g. structural equation models or correlation analysis) limits their ability to provide causal insights.[2] In particular, it has been suggested that innovation cannot be realised without first adopting effective quality practices. Perdomo-Ortiz et al. (2009a,b) state that ‘in general business practice first incorporates the concept of quality management and then gradually integrates innovation’. This argument draws on the resource-based and dynamic capabilities (RDBC) theory of the firm, which suggests that management priorities are path-dependent and that improving innovation performance requires greater organisational complexity than quality management (Perdomo-Ortiz et al., 2009a,b). Our review of the literature suggests that there are conflicting arguments concerning the relationship between (hard and/or soft) quality management and product innovation performance. Arguments for a positive relationship between quality management and innovation suggest that companies embracing quality in their system and culture will provide a fertile environment for innovation (growth) as quality embodies principles that are congruent with innovation (Pekovic and Galia, 2009). The motivation of both processes, quality and innovation, is meeting customer requirements with the need to make continuous improvements. Pekovic and Galia (2009) explain that the philosophy of quality management is that employees will be more satisfied and productive if they can contribute their thoughts and ideas to the achievement of the company goals, suggesting that both processes are interrelated. Consequently, quality can be seen as creating an environment that encourages innovation. On the other hand, it can be argued that quality improvement processes – which may involve mechanistic routinisation and standardised business processes – restrict creativity and innovation (Kanter, 1983; Glynn, 1996; Prajogo and Sohal, 2004).

The implication here is that the payoffs from the adoption of any QIM, whether a hard and/or soft QIM, may only occur in the longer term. As managerial attention is initially focused on successful adoption of the QIM, managers are likely to have less capacity to devote to innovation with the potential for short-term disruption and negative product innovation outcomes. An initial negative effect may be as a result of attention being drawn away from the development and/or commercialisation of new product innovations, with energies and focus being consumed in the implementation of a new QIM. In the longer term the principles and practices of the quality system are likely to become embedded in the mindset and behaviour of both management and shop-floor workers reducing the level of managerial resources necessary to maintain quality freeing resources to concentrate on activities such as product innovation (Perdomo-Ortiz et al., 2009a,b; Prajogo and Sohal, 2003; Pekovic and Galia, 2009). In addition, previous research has demonstrated that market response to improved product quality is not instantaneous but occurs over time (Tellis and Johnson, 2007). While product quality is considered a crucial element to competitive advantage (Tellis et al., 2009; Choi and Pucik, 2005; Calantone et al., 1996), Molina-Castillo et al. (2011) highlight the delayed long-term benefit of improved product quality to performance.[3] In view of

[2] In fact, many of the studies reviewed highlight the static nature of their analysis as a limitation, with calls for dynamic analysis of the quality-innovation relationship (Perdomo-Ortiz et al., 2009a; Martinez-Costa et al., 2008; Pekovic and Galia, 2009).

[3] Discussion of product quality tend to differentiate between extrinsic (external quality) or intrinsic (internal quality) cues as per the Zeithaml (1988) framework.

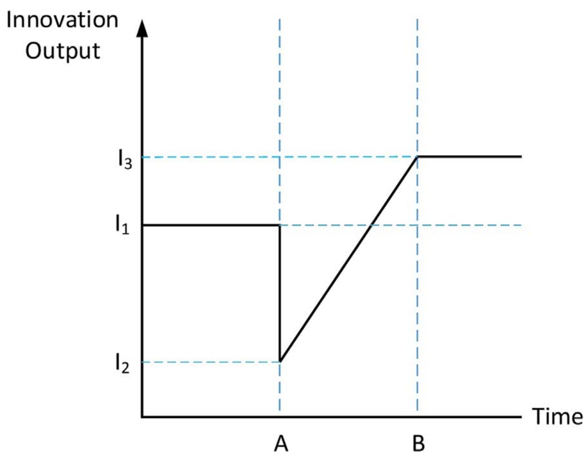

Fig. 1. Short and longer-term innovation effects of QIM adoption.

this relationship, it would be unwise to expect the adoption of QIMs to instantaneously impact product innovation performance. For example, it may be that the quality systems in place assist firms in making better decisions in relation to the innovations brought to market. In the longer-term, when QIMs are ideally well assimilated within firms, such systems may help the firm identify the 'best' innovations for commercialisation. So an increase in product innovation sales may be due to the commercialisation of 'better' innovations; or it may also be that an increased number of innovations are marketed in the long-term due to efficiencies from the now established quality systems. We therefore anticipate that the adoption of a QIM, whether comprising hard or soft dimensions or both, by a plant may result in negative disruption to product innovation in the short-term but yield longer-term positive benefits. For example, suppose as in Fig. 1 a firm has stable innovation performance of I_1, which we might think of as sales of new, innovative products.[4] At time A the firm introduces a new QIM which requires the focus of management and causes disruption to existing systems of production or service provision. This disruption reduces the resources available for innovation, causing a short term fall in innovative outputs to I_2 (Fig. 1). As the new QIM becomes more embedded in the firm's operating routines the extent of any disruption declines, and by time B innovative outputs rise again either to or beyond their previous level at I_3.[5] Hypothesis 1 relates to the potential for this short-term disruption and longer-term beneficial effect of QIMs on innovation:

H1a. *Adoption of QIMs will lead to a short-term negative, disruptive effect on product innovation performance.*

H1b. *Adoption of QIMs will lead to longer-term positive beneficial effects on product innovation performance.*

While we might anticipate this temporal profile of benefits from each type of QIM, variations may be evident between the soft and hard QIMs. For instance, some studies report that firms that adopt softer or more organic QIMs tend to be more innovative (Santos-Vijande and Álvarez-González, 2007; Moura E Sá and Abrunhosa, 2007; Abrunhosa and Moura E Sá, 2008; Hoang et al., 2006; Perdomo-Ortiz et al., 2009a,b) as the softer elements of QIM favour incremental innovations (Abrunhosa and Moura E Sá, 2008). In addition, some studies report the positive influence of the softer dimensions of QIM specifically with respect to product innovation (Perdomo-Ortiz et al., 2009a,b; Abrunhosa and Moura E Sá, 2008; Prajogo and Sohal, 2004). On the other hand, there is evidence that the mechanistic dimensions of hard QIMs may hinder innovation, in particular, radical innovation (Prajogo and Sohal, 2004; Benner and Tushman, 2002; Perdomo-Ortiz et al., 2009a,b). Terziovski and Guerrero (2014), in a cross-sectional study, report a negative relationship between hard QIMs (ISO9000) and product innovation. This is not particularly surprising as the rationality, efficiency and strict control of tasks required by mechanistic quality procedures inhibit creativity and improvisation (López-Mielgo et al., 2009).

This suggests that the potential disruption effects of introducing QIM will be strongest with hard QIMs, such as Quality Certification. This contrast is illustrated in Fig. 2. Conversely, the soft nature of QCs would suggest a less severe disruption effect with the benefits of adoption of QCs occurring sooner than the more mechanistic QIMs (Fig. 2). We expect a smaller disruptive effect from soft QCs due to their purely organic nature, whereas hard QIMs such as Quality Certification may involve significant short-term disruption. In summary:

H2. *Soft QIMs will have weaker short-term negative disruption effects on product innovation performance than hard QIMs*

Strategically, firms do not always adopt an individual QIM in isolation. Firms may adopt QIMs sequentially or simultaneously. Indeed, a crucial element in firms' strategic decision-making is the identification and effective harnessing of complementarities between different managerial activities, optimising resource use (Milgrom and Roberts, 1990, 1995).[6] Previously, Zeng et al. (2015) report that soft quality management has an indirect effect on innovation performance through its mediating effect on hard quality management. Thus, we might anticipate the complementary benefits of QIM adoption being strongest when the quality mechanisms have contrasting attributes, e.g. QCs and Quality Certification (Fig. 2). This suggests:

H3. *Positive complementarities, benefitting product innovation performance, will exist where QIMs adopted have contrasting soft and hard dimensions.*

In the innovation literature, discussion of complementarities has often been related to the benefits of experiential learning. Rosenberg (1972), for example, describes how a firm increases its' stock of knowledge based on its previous experience with technologies as 'learning-by-using'. Previous studies have also highlighted the benefit to firms of learning-by-using new technology for subsequent adoption decision-making (Stoneman and Kwon, 1994; Colombo and Mosconi, 1995; McWilliams and Zilbermanfr, 1996; Stoneman and Toivanen, 1997; Arvantis and Hollenstein, 2001). In the same way, the cumulative learning from earlier QIM adoption should ease the disruptive effects of subsequent QIM adoption. Fig. 3 depicts a situation in which a firm (represented by the solid line) successively adopts two QIMs, experiencing disruption and beneficial effects in each adoption episode (A1 to B1 and A2 to B2). Here, we envisage there will be learning-by-doing resulting in less disruption in the second adoption episode and stronger beneficial effects. Alternatively consider a firm (represented by the dotted line) which has no prior QIM adoption experience and is involved in a single adoption episode (A2 to B2). Here, in the absence of

(*footnote continued*)
External quality is based on customers' perception regarding extrinsic cues like brand, price, country of origin, or warranty. Whereas internal quality cannot be changed without altering the nature of the product itself and can be subjective (e.g. is based on customers' perception of features such as product image or product design) or objective (e.g. evaluates whether the product performs as it is supposed to, incorporates features customers do not expect, or has a low probability of failing) (Molina-Castillo et al., 2011). It is important to note that data limitations mean that we are unable to consider this differentiation in our research.

[4] We are grateful to an anonymous reviewer for suggesting this type of diagrammatic illustration.

[5] It is important to advance our understanding of the effects of time in and for organisations (Mitchell and James, 2001). While there is a clear conceptual rationale for the mechanisms which might drive a negative short-term and positive long-term QIM-product innovation relationship, neither the empirical or conceptual literatures provide any consistent insight on the likely *duration* of these 'short-term' and 'long-term' effects.

[6] In terms of human resource management (HRM), for example, Laursen and Foss (2003) consider complementarity between different HRM practices in terms of their impact on innovation outputs (see also Michie and Sheehan, 2003), while in a more general context Lhuillery (2000) examines the impact of a range of organisational practices on the innovation capability of French companies.

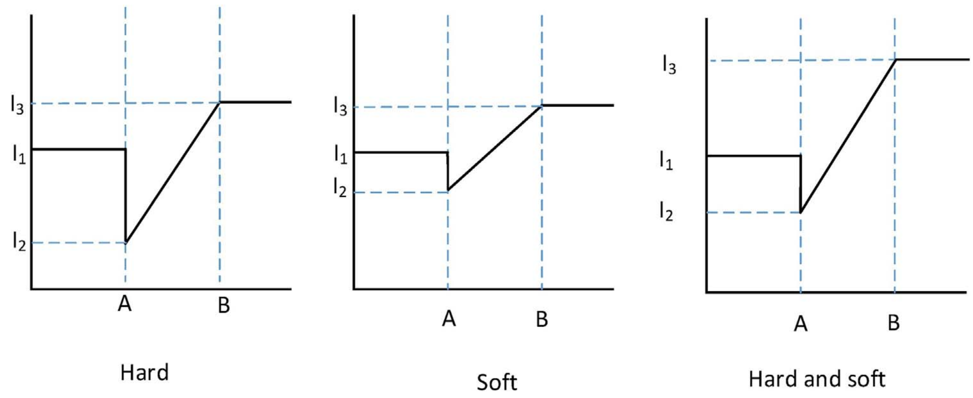

Fig. 2. Short and longer-term innovation effects of hard and soft QIM adoption.

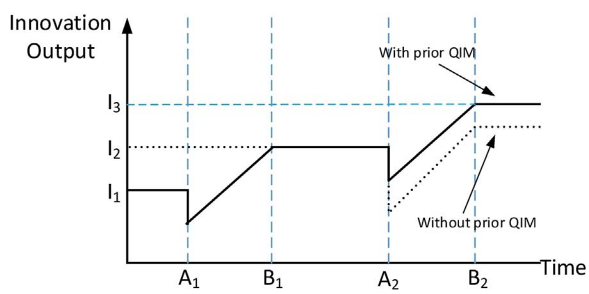

Fig. 3. The benefits of successive QIM adoption.

learning-by-using effects, we anticipate that the disruption effect will be greater and the beneficial effect less significant. This suggests:

H4. *Learning-by-using effects from prior QIM adoption will reduce disruption and increase the product innovation benefits of subsequent QIM adoption.*

3. Data and methods

Our empirical analysis is based on the Irish Innovation Panel (IIP) which provides data on the innovation activity and QIM adoption of around 1300 manufacturing plants in Ireland and Northern Ireland over the period 1994–2008. More specifically, this element of the IIP comprises five surveys or waves conducted using similar survey methodologies and common questions. Each of the five surveys covers the innovation activities of plants with 10 or more employees over a three-year reference period.[7] The resulting panel is highly unbalanced reflecting non-response in individual surveys but also the opening and closure of plants over the period covered.[8] Plants' innovation activity in the IIP is represented by the standard indicator used in the European Community Innovation Survey: the proportion of plants' total sales (at the end of each three-year reference period) derived from products newly introduced during the previous three years. This variable has been widely used as an indicator of plants' innovation output (Laursen and Salter 2006; Roper et al., 2008; Love et al., 2009; Laursen and Salter, 2006), and reflects not only plants' ability to introduce new products to the market but also their short-term commercial success. Across those elements of the IIP used in the current analysis, 17.4% of plants' sales were derived from newly introduced products (Table 2).

One rather unusual feature of the IIP is that alongside plants' innovation activity it also provides information on the timing of adoption of QIMs. Data was collected on the three QIMs identified earlier: Quality Circles, TQM and ISO 9000. Respondents were asked: 'Please indicate if you use any of the following production techniques. Also, please indicate the date when they were first introduced?' In terms of the timing of adoption, respondents were asked whether they had first introduced each QIM in the three year period covered by the survey, the previous three years, or prior to this.[9] For each respondent this provides an indication of whether they are using each QIM and an indication of the length of time since it was adopted by the plant. This allows us to capture the short- and longer-term effects of QIM adoption from each cross-section (wave) of survey respondents. For example, around 68% of IIP respondents reported adopting ISO 9000 with 35.6% adopting it in the previous three years, 19.7% adopting 3–6 years before the survey, and 13% earlier than that (Table 1). Quality Circles had been adopted by 15% of plants with TQM adopted by just over a third of plants.

The IIP also provides information on a number of other plant characteristics which previous studies have linked to innovation

Table 2
Sample Descriptives.
Source: Irish Innovation Panel 1994–2008 (waves 2–6).

Variable Name & Description	Observations	Mean	St. Dev.
Innovative Sales from New Products (%)	1358	18.493	23.110
Innovative Sales from New and Imp. Products (%)	1356	31.827	30.971
Quality Certification (Q Cert) Use	1358	0.683	0.466
Quality Circles (QC)Use	1192	0.150	0.357
Total Quality Management (TQM) Use	1238	0.365	0.482
Current Q Cert Adoption	1358	0.356	0.479
Previous Q Cert Adoption	1358	0.197	0.197
Early Q Cert Adoption	1358	0.130	0.130
Current QC Adoption	1232	0.062	0.364
Previous QC Adoption	1232	0.042	0.201
Early QC Adoption	1232	0.053	0.224
Current TQM Adoption	1295	0.154	0.361
Previous TQM Adoption	1295	0.107	0.309
Early TQM Adoption	1295	0.117	0.322
In-plant R & D	1358	0.606	0.489
Linkages with Clients	1358	0.345	0.475
Linkages with Suppliers	1358	0.370	0.483
Horizontal Linkages	1358	0.965	1.496
Employment (Log)	1358	4.110	1.132
Plant Vintage	1358	28.261	28.196
Externally Owned	1358	0.304	0.460
Workforce with Degree (%)	1358	10.354	11.190
Government Support for Innovation	1358	0.323	0.468
Export Sales (%)	1358	26.964	34.665

[7] Individual survey response rates were: 1994–96, 32.9%; 1997–99, 32.8%; 2000–02, 34.1%; 2003–05, 28.7%; 2006–08, 38.0% (Roper et al., 1996; Roper and Hewitt-Dundas, 1998; Roper and Anderson, 2000; Hewitt-Dundas and Roper, 2008).

[8] The structure of the estimation sample is as follows: 800 plants are present in one wave; 201 are present in two waves; 41 are present in three waves; 7 are present in four waves; and 1 plant is present in all five waves of the panel.

[9] In what follows we use the term 'adoption' to refer to the first use of a QIM by each plant.

outputs (Annex 1). For example, plants' in-house R & D activities are routinely linked to innovation performance in econometric studies with suggestions that the innovation-R & D relationship reflects both knowledge creation (Harris and Trainor, 1995) and absorptive capacity effects (Griffith et al., 2003). 54% of plants were conducting in-house R & D at the time of the IIP surveys (Table 1). Reflecting recent writing on open innovation (Chesbrough 2007; Chesborough 2006) external innovation relationships have also been shown to play an important role in shaping innovation outputs (Oerlemans et al., 1998; Ritala et al., 2013), complementing plants' internal capabilities (He and Wong, 2012; Cassiman and Veugelers, 2006; Arora and Gambardella, 1990; Belderbos et al., 2006). Here, we include three separate variables representing plants' external innovation co-operation with customers, suppliers and other organisations outside the supply chain. Around 30.0% of plants reported having innovation cooperation with customers, while 32.7% had backwards innovation cooperation with suppliers (Table 1). Links outside the supply chain could be with a variety of different types of organisation (e.g. universities, consultants) and here we construct a count variable representing the number of types of partner with which a plant was cooperating. On average, plants were cooperating with around 0.8 organisations outside the supply chain (Table 1).

We also include in the analysis a group of variables which give an indication of the quality of plants' in-house knowledge base – e.g. skills, plant size, multi-nationality, plant vintage, and whether or not a plant is exporting. Skill levels are reflected in the proportion of each plant's workforce which have a degree level qualification to reflect potential labour quality impacts on innovation (Freel 2005; Leiponen, 2005; Freel, 2005) or absorptive capacity. Multi-nationality is included here to reflect the potential for intra-firm knowledge transfer between national markets and plants, while plant vintage is intended to reflect the potential for cumulative accumulation of knowledge capital by older establishments (Klette and Johansen, 1998), or plant life-cycle effects (Atkeson and Kehoe, 2005). Finally, studies of the impact of publicly funded R & D have, since Griliches (1995), repeatedly suggested that government support for R & D and innovation can have positive effects on innovation activity both by boosting levels of investment (Hewitt-Dundas and Roper, 2009) and through its positive effect on organisational capabilities (Buiseret et al., 1995). Here, we therefore include a dummy variable where plants received public support for innovation.[10]

Our empirical approach focuses on the innovation or knowledge production function which represents the process through which plants' knowledge capital is transformed into innovation outputs (Griliches 1995; Love and Roper, 2001; Laursen and Salter, 2006; Griliches, 1995). If I_i is an innovation output indicator for plant i the innovation production function might be summarised in cross-sectional terms as:

$$I_i = \beta_0 + \beta_1 QIM_i + \beta_2 RD_i + \beta_3 FS_i + \beta_4 BS_i + \beta_5 HS_i + \beta_6 CONT_i + \delta_i \quad (1)$$

Where: QIM_i denotes plants' adoption of quality improvement methods, RD_i are plants' in-house R & D investments, FS_i, BS_i and HS_i are forwards, backwards and horizontal knowledge search respectively, and $CONT_i$ is a vector of other plant level controls (Annex 1). Typical of previous cross-sectional studies of the relationship between QIM and innovation, a positive association between QIM and innovation would here require $\beta_1 > 0$. Implicit in this formulation – and previous cross-sectional studies – is the restriction that the date of adoption of each QIM has no impact on its effect on innovation. For each observation in our data we have information on when plants adopted each QIM. To test our hypotheses – and inter alia this restriction − we therefor estimate a version of Eq. (1) explicitly identifying QIM adoption in the current (three-year) period and in two previous periods, i.e.

$$I_i = \beta_0 + \beta_{10} QIM_t + \beta_{11} QIM_{it-1} + \beta_{12} QIM_{it-2} + \beta_2 RD_i + \beta_3 FS_i + \beta_4 BS_i + \beta_5 HS_i + \beta_6 CONT_i + \delta_i \quad (2)$$

Our first hypothesis suggests that in the short-term the adoption of QIMs might create disruption to plants' innovation activity (H1a) with longer term benefits (H1b). Support for H1a requires $\beta_{10} < 0$, with H1b requiring $\beta_{11} > 0$ and/or $\beta_{12} > 0$. H2 relates to the relative size and impact of the alternative QIMs in equation (2).

Our third and fourth hypotheses relates to potential complementarities and learning-by-using effects between QIMs, denoted here QIM^A and QIM^B. If $QIM^B_{t-2} = 1$ where a plant is an early adopter of QIM^B and zero otherwise we estimate:

$$\begin{aligned} I_i = {} & \beta_0 + \beta_{101} QIM^A_t * QIM^B_{t-2} + \beta_{111} QIM^A_{t-1} * QIM^B_{t-2} + \beta_{121} QIM^A_{t-2} * QIM^B_{t-2} \\ & + \beta_{102} QIM^A_t * (1 - QIM^B_{t-2}) + \beta_{112} QIM^A_{t-1} * (1 - QIM^B_{t-2}) \\ & + \beta_{122} QIM^A_{t-2} * (1 - QIM^B_{t-2}) \\ & + \beta_2 RD_i + \beta_3 FS_i + \beta_4 BS_i + \beta_5 HS_i + \beta_6 CONT_i + \delta_i \end{aligned} \quad (3)$$

For Hypothesis 3, which reflects the complementary benefits of simultaneous adoption, we anticipate that early adoption of QIM^A in period t-2 will have greater benefits where a plant also adopts QIM^B in period t-2. Here, we test $\beta_{121} > \beta_{122}$. For Hypothesis 4 which reflects the potential learning-by-using effects from early adoption of QIM^B we test whether $\beta_{101} > \beta_{102}$ and/or $\beta_{111} > \beta_{112}$.

Our choice of estimation method is dictated largely by the fact that we are using plant-level data and that our dependent variables are percentages. We therefore make use of tobit estimators on observations pooled from the different waves of the IIP. We include in each model a set of sector controls at the 2- digit level, and a series of time dummies to pick up any secular differences between the waves of the IIP. Our estimation sample is restricted both by the structure of the IIP and missing values for some survey questions. Specifically, QIM adoption data is collected in waves 2–6 of the IIP for plants which reported undertaking some process innovation during the previous three years. Of the 3918 observations in waves 2–6 of the survey, 1403 plants undertook no process innovation, and so no QIM adoption data is available for these plants. In addition, 295 process innovators provided incomplete data on the timing of QIM adoption and we therefore exclude these plants from our estimation leaving a potential estimation sample of 2220 firms. This is further reduced by missing values for our dependent variable and control variables resulting in an estimation sample of around 1350 firms. Our estimation sample therefore represents a group of firms which are more strongly innovation-oriented that the general population of businesses. This is clear if we compare innovative sales from new products (and improved products) which averaged 18.5 (31.8)% among our estimation sample compared to 12.8 (19.9)% among non-process innovators which are excluded from the estimation sample (see Table 1).

4. Results

Replicating previous cross-sectional studies of the quality-innovation relationship, we first undertake a cross-sectional (static) analysis to determine whether QIM adoption benefits product innovation performance (Eq. (1)). As presented in Table 3, TQM adoption positively correlates with product innovation performance, although neither Quality Certification nor QC has a positive association with product innovation performance. In terms of TQM our results reflect those of previous studies which have also reported the benefits of adopting TQM, a QIM comprising hard and soft dimensions, for firm innovation (Moura E Sá and Abrunhosa, 2007; Martínez-Costa and Martínez-Lorente, 2008; Abrunhosa and Moura E Sá, 2008); and Zeng et al.'s (2015) study which reported innovation benefits when firms introduce

[10] Elsewhere we profile the range of public support initiatives for innovation in Ireland and Northern Ireland over the period covered by the IIP (Meehan, 2000; O'Malley et al., 2008).

Table 3
Static models: Tobit Models of Innovative Sales of New Products.

	Model 1	Model 2	Model 3
Q Cert Use	−1.896		
	(−1.401)		
QC Use		1.527	
		(−2.069)	
TQM Use			4.601***
			(−1.534)
In-plant R & D	5.194***	6.559***	5.829***
	(−1.364)	(−1.441)	(−1.43)
Linkages with Clients	1.621	1.391	1.692
	(−1.779)	(−1.884)	(−1.883)
Linkages with Suppliers	4.270**	4.036**	4.343**
	(−1.709)	(−1.784)	(−1.800)
Horizontal Linkages	0.053	0.311	−0.201
	(−0.538)	(−0.567)	(−0.563)
Employment (Log)	−0.523	−0.445	−0.899
	(−0.657)	(−0.690)	(−0.685)
Plant Vintage	−0.091***	−0.100***	−0.092***
	(−0.022)	(−0.024)	(−0.024)
Externally Owned	3.987**	3.725**	3.519**
	(−1.679)	(−1.784)	(−1.787)
Workforce with Degree	0.045	0.128**	0.086
	(−0.058)	(−0.065)	(−0.063)
Government Support	4.600***	3.399**	3.919***
	(−1.446)	(−1.54)	(−1.518)
Export Sales	0.028	0.014	0.019
	(−0.023)	(−0.025)	(−0.024)
Constant	11.584***	8.102**	9.402***
	(−3.186)	(−3.374)	(−3.341)
N	1358	1232	1295
Chi-squared	160.286	165.573	160.887
Pseudo − R^2	0.014	0.015	0.014

Notes: Standard errors in parentheses; $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. All the figures in the table are marginal effects generated from Tobit models. All models include industry and wave dummies.

both hard and soft quality management processes (Zeng et al., 2015). Our cross-sectional, static results contrast with the limited number of previous studies that have reported a positive association between the hard Quality Certification and innovation (Benner and Tushman, 2002; Pekovic and Galia, 2009).

A limitation of this static approach to the quality-innovation relationship is that empirically it reveals the correlations between quality systems and innovation, but it does not investigate a causal connection between QIMs and innovation. The QIM coefficients in the static analysis capture the effects of both current and lagged adoption. Our disaggregated analysis (Eq. (2)) removes this implicit restriction and allows us to test H1 which envisages a short-term disruption (H1a) and a longer term beneficial effect (H1b) from QIM adoption on product innovation performance. Temporal analysis of the impact of early (t-2), previous (t-1) and current QIM adoption on innovation performance is presented in Table 4 based on pooled cross-section estimates and utilising firms' responses on the date of their first QIM adoption. In relation to Quality Certification, we see significant disruption effects, and no evidence of longer-term beneficial effects. These significant disruption effects, which reduce innovative sales by 4.6%, may be due to the formalised, mechanistic and hard nature of Quality Certification. The absence of a positive relationship between Quality Certification and product innovation performance in our temporal analysis contrasts with results from previous (static) studies (Benner and Tushman, 2002; Pekovic and Galia, 2009). However, this finding is not altogether surprising as the adoption of Quality Certification concerns the whole organisation and involves considerable disruption to fundamental behaviour and routinised tasks (Pekovic and Galia, 2009).

In relation to soft QC, we find no significant disruption effect, but significant longer-term beneficial effects, increasing innovative sales by 5.5%. Early adoption of QC positively impacts on innovation, although

Table 4
Short-term and longer-term effects: Tobit Models of Innovative Sales of New Products.

	Model 1	Model 2	Model 3
Current Q Cert Adoption	−4.597***		
	(−1.643)		
Previous Q Cert Adoption	−0.936		
	(−1.820)		
Early Q Cert Adoption	1.585		
	(−1.979)		
Current QC Adoption		0.503	
		(−3.039)	
Previous QC Adoption		−3.700	
		(−3.630)	
Early QC Adoption		5.504*	
		(−3.006)	
Current TQM Adoption			2.111
			(−2.096)
Previous TQM Adoption			3.932*
			(−2.310)
Early TQM Adoption			7.372***
			(−2.084)
In-plant R & D	5.354***	6.579***	5.750***
	(−1.360)	(−1.439)	(−1.428)
Linkages with Clients	1.763	1.552	1.719
	(−1.777)	(−1.883)	(−1.881)
Linkages with Suppliers	4.042**	4.035**	4.260**
	(−1.705)	(−1.781)	(−1.799)
Horizontal Linkages	0.127	0.342	−0.116
	(−0.536)	(−0.566)	(−0.565)
Employment (Log)	−0.315	−0.447	−0.797
	(−0.658)	(−0.689)	(−0.687)
Plant Vintage	−0.083***	−0.101***	−0.090***
	(−0.022)	(−0.024)	(−0.024)
Externally Owned	4.299**	3.743**	3.636**
	(−1.676)	(−1.782)	(−1.786)
Workforce with Degree	0.041	0.123*	0.082
	(−0.058)	(−0.064)	(−0.063)
Government Support	4.474***	3.340**	3.818**
	(−1.441)	(−1.538)	(−1.516)
Export Sales	0.026	0.012	0.021
	(−0.023)	(−0.025)	(−0.024)
Constant	10.893***	8.218**	9.364***
	(−3.185)	(−3.370)	(−3.335)
N	1358	1232	1295
Chi-squared	170.69	169.872	165.252
Pseudo − R^2	0.014	0.016	0.014

Notes: Standard errors in parentheses; $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. All the figures in the table are marginal effects generated from Tobit models. All models include industry and wave dummies.

this relationship is not present for plants who adopted QC in the current or previous time periods. QCs are primarily organic in nature and therefore their adoption should not cause particular disruption to the plant compared to the more mechanistic QIMs. Practices, such as QCs, which empower and involve employees have been shown to positively influence employee motivation and behaviour (Subramony, 2009), and therefore the lagged beneficial effect is as anticipated.

For TQM, there is no significant disruption effect, but positive and significant beneficial effects. Plants that adopt TQM in the previous period realise innovative returns in the current period, and early adopters of TQM realise significantly larger returns, increasing innovative sales by 7.4% after six years (Table 4). The beneficial effects from TQM adoption are not particularly surprising given the strong positive relationship between TQM adoption and product innovation reported in our static analysis and previous (static) studies (Martínez-Costa and Martínez-Lorente, 2008). Furthermore, the lack of an initial disruption effect may be due to the informal, participative or organic components of TQM. For instance, previous studies have highlighted the returns to innovation from softer TQM elements, such as resource management, leadership, people management and open organisation (Perdomo-Ortiz et al., 2009a,b; Hoang et al., 2006; Prajogo and Sohal, 2004). The advantageous temporal profile of TQM may result from its multi-dimensionality nature. We hypothesised that QIM adoption would influence plant innovation in terms of a short term disruptive effect (H1a) and a longer term beneficial effect (H1b). We find support for H1a as Quality Certification adoption has a significant short-term disruption effect on plant innovation; and we find strong support for H1b with TQM and QC adoption resulting in longer-term beneficial effects for plant innovation.

In line with previous studies, we find plant characteristics, such as R & D, linkages with suppliers, plant vintage, eternally-owned plants and an educated workforce, strongly impact on plant innovation (Roper et al., 2004; Roper et al., 2008; Freel, 2003). In addition, we find that government support for innovation strongly and significantly impacts on innovation performance (Love et al., 2011).

4.1. Hard versus soft QIM effects

Next, we consider our results in the context of H2 which suggests that soft QIMs will have weaker short-term disruption effects than hard QIMs. Quality Certification, a hard QIM, results in significant short-term disruption for plants' innovative performance, whereas QCs and TQM, QIMs comprising full or partial soft components, impose none of these short-term disruption effects on plant innovation. While there is no evidence of long-term beneficial effects with Quality Certification, we do find long-term beneficial effects for plant innovation in the case of QCs and TQM. In addition, the beneficial effects from TQM adoption arise more quickly than in the case of QCs, and the returns from TQM adoption are greater. Our results therefore suggest that the soft or organic components of each QIM impacts the temporal profile of this disruptive –beneficial relationship. We find strong support for H2 as the softer QIMs, QCs and TQM, have no short-term disruption effects on innovation in contrast to the hard Quality Certification.

4.2. Complementarity and learning-by-using effects

In our investigation of complementarities and learning by using effects, we attempt to determine if simultaneous and sequential adoption of QIMs benefit product innovation performance. We hypothesise that simultaneous QIM adoption may generate positive complementarities increasing the benefits to innovation (H3), and that early adoption of one QIM will generate learning-by-using effects increasing the innovation benefits of subsequent QIM adoption (H4). Given the finding of a strong disruptive effect of Quality Certification on innovation (as reported in Table 4), we focus on this QIM for our complementarity and learning by using effect analysis.

Complementarities exist if the sum of the benefits of adopting QIMs separately is less than the benefit of adopting them simultaneously. Empirically, we are examining the influence of simultaneous early adoption of Quality Certification and softer QIMs (TQM and QC) on product innovation sales (see Table 5). For instance, in the first model in Table 5 we examine if early Quality Certification adoption and early QC adoption are complementarities for innovation. Specifically, we include two variables, one which captures the plants that are early Quality Certification and early QC adopters and another which captures those that are early Quality Certification adopters but not early QC adopters. The insignificant coefficients indicate that these two QIMs are not complementarities. The next regression model examines if early Quality Certification and early TQM adoption are complementary. Our analysis reveals that TQM and Quality Certification are complementary initiatives and the benefit of their simultaneous adoption is greater than if adopted individually. We find that benefits of TQM adoption are conditional on the simultaneous adoption of Quality Certification, and vice versa. Of particular interest is how simultaneous early adoption of Quality Certification and TQM offsets the short-term disruptive effects of Quality Certification.

Table 5
Complementarities and Learning by Using Effects: Tobit Models of Innovative Sales from New Products.

	Innovation Sales		Innovation Sales
Simultaneous QIM Adoption: Complementarities			
Early Q Cert Adoption: with/without early QC Adoption		*Early Q Cert Adoption: with/without early TQM Adoption*	
Early Q Cert with early QC	6.560	Early Q Cert with early TQM	11.70***
	(5.574)		(3.204)
Early Q Cert without early QC	1.148	Early Q Cert without early TQM	−0.322
	(2.090)		(2.276)
Sequential QIM Adoption: Learning by Using Effects			
Current & Previous Q Cert Adoption: with/without early QC adoption		*Current & Previous Q Cert Adoption: with/without early TQM adoption*	
Current Q Cert with early QC	6.245	Current Q Cert with early TQM	0.489
	(6.019)		(4.252)
Current Q Cert without early QC	−4.017**	Current Q Cert without early TQM	−3.438**
	(1.626)		(1.587)
Previous Q Cert with early QC	−2.889	Previous Q Cert with early TQM	5.023
	(7.985)		(4.510)
Previous Q Cert without early QC	0.142	Previous Q Cert without early TQM	−0.367
	(1.899)		(1.887)
In-plant R & D	5.343***		5.461***
	(1.362)		(1.356)
Clients Linkages	1.764		1.631
	(1.775)		(1.771)
Supplier Linkages	4.363**		4.304**
	(1.707)		(1.698)
Horz. Linkages	−0.00295		0.0329
	(0.538)		(0.535)
Employment (Log)	−0.421		−0.425
	(0.657)		(0.654)
Plant Vintage	−0.086***		−0.083***
	(0.022)		(0.022)
Externally Owned	4.177**		4.055**
	(1.677)		(1.677)
Workforce w Degree	0.0371		0.0358
	(0.0584)		(0.0580)
Govt. Support	4.588***		4.153***
	(1.447)		(1.441)
Export Sales	0.0265		0.0271
	(0.0232)		(0.0231)
Constant	11.09***		10.96***
	(3.190)		(3.174)
Observations	1358		1358
DV	Q Cert		Q Cert
conditional on	QC		TQM
Complementarities	0.88		10.7***
LBU Previous	0.14		1.35
LBU Current	2.89*		0.83

Next, we investigate whether early adoption of one QIM generates learning-by-using effects increasing the innovation benefits of subsequent QIM adoption. The motivation for investigating whether learning-by-using effects impact on plant innovation is that early adoption of one QIM creates the potential for learning and hence subsequent adoption of an additional QIM is likely to be less onerous. Essentially we are examining if early adoption of a soft (QC) or partially soft (TQM) QIM and subsequent adoption of a hard (quality certification) QIM benefit innovation. Empirically, we test for learning-by-using effects by including variables which capture sequential adoption patterns. For instance, in the first model in Table 5, we examine if early adoption of QC and subsequent quality certification adoption, in both the current (Current QCert* early QC & Current QCert*no early QC) and previous (Previous QCert*early QC & Previous QCert*no early QC) time periods, influence innovative sales. In the next model, we are examining if early TQM adoption and subsequent quality certification adoption benefits innovation. Interestingly, early adoption of QC and, to a lesser extent TQM, offset the disruptive effects of Quality Certification. Therefore, early adoption of QC generates learning-by-using effects for current Quality Certification adoption; the benefits (although still insignificant) of Quality Certification are conditional on prior adoption of QC.

We previously hypothesised that positive complementarities will be strongest where the QIMs adopted have contrasting hard and soft components (H3) and suggested that learning-by-using effects from prior QIM adoption will reduce disruption and increase the product innovation benefits of subsequent QIM adoption (H4). Our analysis reveals a complementary relationship between the hard Quality Certification and the soft-hard TQM for plant innovation. We find no evidence of a complementary relationship between the hard Quality Certification and soft QCs with respect to innovation performance. Therefore, we find little support for H3 that complementarities are strongest when QIMs comprise of contrasting hard and soft components. Our primary finding in relation to learning-by-using effects is that early adoption of QCs generates learning-by-using effects for subsequent Quality Certification. Therefore, we find support for H4 that prior QIM adoption will reduce disruption and increase the product innovation benefits of subsequent QIM adoption. Interestingly, learning by using effects exist when a soft QIM is adopted prior to a hard QIM benefitting product innovation performance.

4.3. Robustness tests

We conducted three robustness tests to evaluate our results further. These included running the analysis with an alternative measure of innovative output; using an alternative estimation approach allowing for the potential endogeneity of the 'treatment' represented by plants' QIM adoption (Maddala, 1983); and determining if our results are sensitive to the time period of adoption. First, in our main analysis we use a dependent variable which reflects plants' sales derived from new products. This reflects an emphasis on more radical innovation rather than either imitation or more incremental product change (Schnaars, 1994). To consider whether our results also hold for more imitative strategies we repeated the analysis using an alternative and more broadly defined dependent variable – innovative sales from *new and improved* products. Results were broadly similar to those reported in relation to our main dependent variable. In relation to the static analysis, and reflecting the weak results of the static analysis in Table 3, none of the QIMs have a significant effect on the broader measure of innovative sales. Likewise, temporal analysis with our alternative innovation output measure generates results which are broadly similar to those reported earlier (Table 4). In relation to Quality Certification, the coefficient signs indicate the same pattern of disruption and long term beneficial effects as for innovative sales from new products but the short term disruption effect is not statistically significant. For QC, we still see insignificant disruption effects but evidence of longer term beneficial effects is insignificant. There is clear evidence of long term beneficial effects from TQM adoption, although these are generally weaker than for innovative sales. In summary, effects from QIM adoption are stronger for innovative sales from new products than the broader dependent variable which captures innovative sales from new and improved products.

We also repeated the learning-by-using and complementarity analysis using innovative sales from new and improved products as the dependent variable. Results from this robustness test are broadly similar to those reported in relation to the narrower dependent variable of innovative sales from new products (Table 5). The strong and significant complementary benefit of early Quality Certification and early TQM is also evident in relation to the broader dependent variables of innovative sales from new and improved products. However, there is no evidence of a learning-by-using effect from early QC adoption influencing the benefits to this broader definition of innovation from subsequent Quality Certification adoption. The results from these robustness tests are therefore similar to those reported for the narrower dependent variable of innovative sales from new products, although we do not find support for H4 here.

In a second robustness test we sought to allow for the potential endogeneity of the adoption of each of the QIMs, i.e. the possibility that the determinants of adoption may also be the determinants of innovation outcomes. We estimated two-stage models estimating first a model for the probability of adoption and then including the implied Inverse Mills Ratio (IMRs) in Eqs. (1)–(3) (Heckman 1979). For both our main and alternative dependent variables the IMRs proved insignificant with the coefficients of interest also remaining unchanged in sign and significance.

Finally, we undertake a robustness test to determine if the QIM-innovation relationship differs by time period of adoption. The rationale for this test is that each of the QIMs may be subject to a diffusion pattern which sees variation in uptake, peak and decline in adoption through time and across the waves of the survey. We partition the three QIM measures using the five waves of the survey and re-run our static estimations (Table 3). Testing the equality of coefficients between waves reveals F-tests which are all insignificant. This indicates that the QIM effects on product innovation performance are not significantly different between survey waves, i.e. through time.

4.4. Discussion

Previous cross-sectional studies have suggested a positive correlation between QIMs and innovation, with a focus on the TQM-innovation relationship (Moura E Sá and Abrunhosa, 2007; Martínez-Costa and Martínez-Lorente, 2008; Abrunhosa and Moura E Sá, 2008). In cross-sectional terms our data also suggests a positive relationship between TQM and product innovation performance although we find no relationship, however, between either QC or Quality Certification and product innovation performance (Table 3). As our analysis of the short and long-term effects suggests, however, these cross-sectional relationships hide some rather complex temporal effects on product innovation performance, effects which differ markedly between QIMs (Table 4). In particular, we find evidence that QIMs can cause short-term disruption to product innovation activity before the development of longer-term benefits.

In considering these results, it is important to acknowledge that due to survey limitations our analysis is based on a sub-sample of plants which undertook some process innovation, and which are more strongly innovation-oriented than the general population of plants. Evidenced by higher than average levels of innovative sales, these firms are also likely to have strong internal resources and routines associated with innovation such as R & D capacity and engagement with collaborative networks. Even for this group of innovation-oriented firms, however, we still find that the adoption of Quality Certification causes a significant short-term disruption effect. For other, less innovation-oriented firms in the population, or firms with less experience of implementing process innovations, we might anticipate even stronger disruption effects, and potentially weaker longer-term innovation benefits.

We can also consider these results in the context of the soft-hard dimensions of the QIMs. For instance, these disruption effects are most significant for hard Quality Certification, reducing innovative sales by 4.6%, but prove weaker for soft QIM, such as Quality Circles. TQM – which combines soft and hard components also has no significant disruption effect. Those QIMs with soft components – TQM and QC –have the most significant long-term benefits increasing innovative sales by 5.5–7.4% (Table 4). Quality Certification has no significant longer-term effect on innovation.

Our findings are broadly in line with previous studies which have examined how the soft and hard dimensions of QIMs influence innovation. Some studies report that firms that adopt soft QIMs tend to be more innovative (Santos-Vijande and Álvarez-González, 2007; Moura E Sá and Abrunhosa, 2007; Abrunhosa and Moura E Sá, 2008; Hoang et al., 2006; Perdomo-Ortiz et al., 2009a,b) as the organic elements of QIM favour incremental innovations (Abrunhosa and Moura E Sá, 2008). The weaker disruption effects reported for soft QCs and the more significant disruption effect for hard Quality Certification is therefore not particularly surprising. The longer-term beneficial effects are strongest for TQM which comprises both soft and hard components, and it is likely that the beneficial effects owing to its organic components may come into effect sooner and off-set the short term disruptive effect caused by its more mechanistic components.

Two implications follow from our analysis of short-term and long-term effects. First, our analysis suggests the potential trade-off between the short-term disruption and longer term product innovation benefits which result from the adoption of QIMs. Benefitting from the adoption of QIMs takes some considerable time as firms revise and optimise organisational routines. Second, the relationship between QIMs and product innovation performance differs markedly between those QIMs which have a strong organic component (i.e. TQM, QCs) and more mechanistic initiatives such as Quality Certification: hard QIMs have negative product innovation effects, while QIMs with a soft dimension have strong long-term product innovation benefits.[11]

These contrasts between the implications of alternative QIMs are also reflected in our results on the benefits of combinations of QIMs. For example, complementarities between QIMs adopted at the same time prove strongest between Quality Certification and TQM which share hard dimensions, although TQM also has soft components. Conversely, we find no evidence of complementarities between contrasting QIMs such as QC and Quality Certification. Quality Circles do, however, generate significant learning-by-using effects, enhancing the innovation benefits of both Quality Certification. The implication is that adoption of a soft QIM such as Quality Circles may have a dual advantage for innovation: a direct longer-term benefit and also an indirect longer-term benefit through its impact on enhancing the effects of hard QIMs.

5. Conclusion

Our paper contributes to the research literature on quality and innovation highlighting the short-term disruptive and longer-term beneficial effects of individual QIMs on product innovation performance. It also highlights the role of complementarities and learning-by-using effects in shaping the quality–innovation relationship.

Our empirical analysis of the quality-innovation relationship reveals complex temporal effects not evident from previous studies. The IIP data allows us to establish the temporal profile of the – short-term disruptive and longer-term beneficial – effects of QIMs on product innovation performance (H1a & H1b). Of particular interest is our finding that soft QIMs have weaker short-term disruption effects than hard QIMs on product innovation performance (H2).

Our examination of the benefits of combinations of QIMs supports our hypotheses that simultaneous and sequential QIM adoption generates positive complementarities and learning-by-using effects respectively enhancing innovation benefits. However, we find little support for H3 that complementarities are strongest when QIMs comprise of contrasting hard (quality certification) and soft components (QCs); although we do find a complementary relationship between the hard Quality Certification and the soft-hard TQM for plant innovation. In addition, we also found significant learning-by-using effects for subsequent Quality Certification were generated from early adoption of QCs indicating that learning by using effects exist when a soft QIM is adopted prior to a hard QIM benefitting product innovation performance.

Two main managerial implications follow from our analysis.[12] First, it is clear that the adoption of QIMs has significant implications for plants' product innovation outputs, albeit with some time lags as internal routines are optimised. Quality improvement strategies and implementation plans need therefore to consider their innovation implications and any consequent impact on firm performance. Secondly, the synergies we identify between QIMs suggest the value in strategies which maximise complementarities and gains from learning-by-using. In particular, we find that the early adoption of Quality Circles – a relatively straightforward and low cost QIM – significantly enhances the value of Quality Certification where these are adopted subsequently. It may be, for example, that the adoption of a soft QIM is stimulating an initial focus or interest in quality improvement in the firm which is then formalised in the adoption of a hard QIM. QC or soft QIM adoption may also be helping firms to overcome attitudinal barriers related to change and the implementation of more formal quality management systems. Our results, which highlight the temporal nature of the relationship between QIMs and product innovation performance and between QIMs themselves, also emphasise the limitations of analyses based on cross-sectional data. In particular, cross-sectoral analyses inevitably see QIM adoption − as a uniform treatment, obscuring opposing short-term and long-term effects and/or interactions between QIMs.

Our analysis suffers from some limitations. First, our analysis focuses on Irish manufacturing plants only and may therefore be influenced by specific national circumstances. The 1994–2008 period considered here, however, was a period of rapidly changing institutions in Ireland as well as marked changes in the nation's economic fortunes – the Irish recovery of the late 1990s, the 2000–02 high-tech crash, and a period of rapid subsequent growth. Second, due to the structure of our survey data our analysis is restricted to plants which introduced process innovations. This group are likely to more innovation-orientated than other non-innovating firms, and this needs to be borne in mind in considering our estimation results. Third, unlike some other – albeit static – studies we are unable to identify separately those elements of each QIM linked to changes in human resource management, quality management etc. This limits our ability to investigate the relationships between different dimensions of quality management and innovation and between different elements of QIMs. Both are areas in which future research would be valuable. Finally, our analysis is based on survey data and a number of our key variables of interest and controls are therefore categorical in nature. Exploring alternative data sources which may provide a greater range of continuous variables would allow a richer contextualisation of the QIM-innovation relationship. Our analysis also suggests a number of potential avenues for future research. First, the focus of the current paper is the relationship between QIM adoption and product innovation success. Future studies could also usefully consider the impact of QIM adoption on process efficiency reflected in broader measures of productivity, unit cost or resource costs. In addition, the spatial and temporal contrasts in the adoption of QIMs is itself an interesting avenue for future research. Finally, we have not considered here the potential for firms' other characteristics (e.g. skills, levels of prior innovation) to moderate the QIM-innovation relationship. This too might be interesting to consider.

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[11] This is not to say, of course, that adopting hard QIMs such as Quality Certification has no positive effects on wider business performance. Simply, that it has negative effects on product innovation performance.

[12] The pseudo-R^2 for the econometric models are quite low (see Table 3). Therefore we would advise caution in being overly explicit with respect to managerial implications, particularly as this is the first empirical investigation of the short- and longer-term effect of quality management on innovation.

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Annex 1. Variable Definitions

Innovation	
Innovative sales (new) (% sales)	An indicator representing the percentage of plants' sales at the time of the survey accounted for by products which had been newly introduced over the previous three years.
QIM variables	
Current user	Static binary measure taking value 1 if the plant had adopted the QIM at the time of the survey and zero otherwise.
Current adopter	Time specific binary variable taking value 1 if the plant had first introduced the QIM in the previous three years and zero otherwise.
Early adopter	Time specific binary variable taking value 1 if the plant had first introduced the QIM 4–6 years prior to the survey date and zero otherwise.
Previous adopter	Time specific binary variable taking value 1 if the plant had introduced the QIM more than 6 years prior to the survey date and zero otherwise.
Control variables	
In plant R & D	A binary indictor taking value one if the plant has an in-house R & D capacity
Clients Linkages	A binary indicator taking value one if the plant is co-operating with customers as part of its innovation activity.
Supplier Linkages	A binary indicator taking value one if the plant is co-operating with suppliers as part of its innovation activity.
Horiz. Linkages	A count indicator of the breadth of plants' other innovation partnering activity. Takes values 0–7 depending on how many different types of partner the plant is working with: consultant, competitor, joint venture, government laboratory, university, private laboratory, industry research centre.
Employment	Employment at the time of the survey.
Plant vintage	The time in years between the establishment date of the plant and the date of the survey.
Externally owned	A binary indicator taking value 1 if the plant was externally-owned. For plants in Ireland this means owned outside the country. For plants in Northern Ireland this means plants owned outside the region.
Workforce with degree	The percentage of the workforce with a degree or equivalent qualification
Government support	A binary indicator taking value one if the plant had received government support for product innovation over the previous three years.
Export sales	A binary indicator taking value one if the plant was selling outside the UK and Ireland at the time of the survey and zero otherwise

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