1. Introduction

Since the publication of 'Japanese Manufacturing Techniques' (Schonberger, 1982) lean manufacturing has spread remarkably as companies such as Toyota and Boing succeeded and other companies follow their leadership (Jayaram *et al*., 2008; Shook, 2008). Internal lean practices (ILP) refers to the implementation of manufacturing practices focused on reduction of waste and non-value added activities , e.g. overproduction, inventory, or any other factor that can disrupt the swift even flow of goods through the supply chain, from a firm's internal manufacturing operations (Li *et al*., 2005; Yang *et al*., 2011). To capture the perceived benefits of ILP, companies have promulgated its adoption through supply chain relationships (Jayaram *et al*., 2008; Perez *et al*., 2010). In particular, buyers have sought to leverage supplier capabilities in efforts to improve performance (Stuart, 1993). They have done so by bringing suppliers closer by engaging them in planning and problem solving (Li *et al*., 2006; Swink *et al*., 2007) and even in the design and development of products (Liker and Sobek II, 1996). As such, there has been an emphasis of focus in the literature on upstream relationships (e.g. So and Sun, 2010). However, recent research has revealed the importance of downstream relationships (Droge *et al*., 2012), which have been overlooked within the lean literature (Martínez-Jurado and Moyano-Fuentes, 2013). It thus seems pertinent to consider supply chain relationships, both upstream and downstream, and their impact on ILP.

Herein we have adopted resource dependence theory (RDT) to explain the association between supply chain relationships and ILP. RDT posits that critical resources for organizations can be obtained from external sources (Pfeffer and Salancik, 1978). So to achieve reliable delivery performance of frequent small batches, practices which are central for lean, implicit forms of behaviour such as information sharing and cooperation between trading partners is central (Handfield, 1993; Buvik and Halskau, 2001). Accordingly, RDT suggests that close interaction between buyers and suppliers will enable ILP.

ILP has been associated positively with operational performance (Shah and Ward, 2003); however, empirical work has not been unified in its findings (e.g. Sakakibara *et al*., 1997; Callen, 2000; Swink *et al*., 2005). Similarly, while lean operations have been generally shown to be associated with improved organizational performance (i.e. market-and financial oriented performance) (Fullerton *et al*., 2003; Eroglu and Hofer, 2011), there are still studies offering mixed results (e.g. Balakrishnan *et al*., 1996; Fullerton *et al*., 2003; Kannan and Tan, 2005, Jayaram *et al*., 2008, Cannon, 2008). It has been suggested that inconsistent findings may be attributed to the complexity of the manufacturing practices-performance link, which is often regarded as self-evident and demands further understanding (Swink *et al,* 2005). A potential explanation for the inconsistency in the results lies in contingency theory (CT), which suggests that no universal set of strategies applies to every business situation (Lawrence and Lorsch, 1967; Ginsberg and Venkatraman, 1985) and that no single strategy is successful in every context. While the contingency view is not new in the lean literature, studies are either exploratory (e.g. Dean and Snell, 1996; Shah and Ward, 2003; Browning and Heath, 2009), or have used internal characteristics of the firm (e.g. plant characteristics) as contextual variables (e.g. Lowe *et al*., 1997; White *et al,* 1999; Cua *et al*., 2001; Shah and Ward, 2003, Crute *et al*., 2003). However, the role of external variables such as environmental dynamism remains comparatively unexplored (Shah and Ward, 2003). Environmental dynamism has been described in the literature as a multi-dimensional construct (e.g. Lawrence and Lorsch, 1967; Miller and Friesen, 1983); however, technological turbulence (TT), as one main dimension, has been under-researched in the lean literature (e.g. Chavez *et al*., 2012; Azadegan *et al*., 2013). TT refers to the rate of technological change over time within an industry (Slater and Narver, 1994; Trkman and McCormack, 2009), which arises from fast technological change in products and breakthroughs in manufacturing processes (Hsu and Chen, 2004; Song *et al*., 2005; Kandemir *et al*., 2006). Accordingly, this research extends the lean literature by investigating the ILP-performance link contingent upon TT.

Thus this research adds to the SCM and lean manufacturing bodies of knowledge by addressing three research questions: (1) To what extent do up and downstream supply chain relationships impact ILP, (2) To what extent does ILP impact performance, and (3) To what extent does TT affect the ILP and performance relationship. This study contributes to the building the RDT perspective to explain SCM and Lean manufacturing phenomena (Handfield, 1993; Paulraj and Chen, 2007). By investigating the relationship between ILP and performance, in particular by considering the role of TT, this study will clarify current understanding of the topic. Importantly, this study will explore the role of external variables such as TT in impacting performance related to ILP.

2. Theoretical background and hypotheses development

2.1 Resource dependence theory

RDT suggests that organizations rely upon other entities (e.g. trading partners) to obtain resources critical to their continuing existence (Pfeffer and Salancik, 1978). The need to obtain resources creates interdependence between organizations (Barringer and Harisson, 2000). However, since this interdependence is not necessarily symmetric or balanced environmental uncertainty is created (Pfeffer and Salancik, 1978). Two strategies have been put forward to manage interdependence, and thus reduce uncertainty. One states that organizations should acquire control of critical resources - absorbing the environment- thereby decreasing dependence on other organizations. However, this strategy tends to create positions of strength, which can be exploited at the expense of weaker trading partners. Alternatively, firms can participate in inter-firm relationships and coordination efforts -negotiating the environment- in order to obtain access to critical resources and increase their power relative to competitors (Handfield, 1993: Barringer and Harisson, 2000). This study focuses on the latter form of reducing uncertainty: negotiating the environment.

RDT represents an important theoretical perspective for conducting empirical research in SCM as supply chains rely on sequential interdependence, which benefits from coordination (Paulraj and Chen, 2007). For instance, buyers can cause their suppliers to become over-dependent on them, potentially creating dissonance between both parties. According to Ketchen and Hult (2007), this strategy describes traditional supply chains wherein trading partners take advantage of resource dependence. Conversely, describing best value supply chains, interdependence and collective actions should be used to create trust rather than opportunistic behavior (Ketchen and Hult, 2007). In this research, RDT is used to emphasize how supply chain relationships are a viable mechanism for managing interdependence, thus reducing uncertainties and increasing predictability and stability of demand and supply (Paulraj and Chen, 2007).

With regard to the lean perspective, it has been argued that lean manufacturing depends on predictability and coordination, which are associated directly with supply chain relationships (Simpson and Power, 2005). Specifically, in accordance with RDT, it has been argued that buyer-supplier cooperation and coordination are associated with "implicit" forms of behaviour such as suppliers reduction, information sharing, the creation of channels of communications for information sharing, and the commitment of support between the parties involved, which are a preliminary step for lean manufacturing practices such as JIT (Handfield, 1993; Buvik and Halskau, 2001). For example, Handfield (1993) explains that in this type of cooperative supply chain contexts suppliers can obtain more and better information to manage deliveries to their JIT customers, while buyers can provide more accurate schedules of requirements to suppliers so this latter can plan better their capacity more efficiently. Also in line with RDT, Buvik and Halskau (2001) argue that JIT practices imply significant structural changes towards long-term and stable buyer-supplier relationship compared to more traditional buyer-supplier relationships. These relationships provide, in turn, the necessary grounds to share insight about manufacturing process, demand patterns and quality assurance, which are key issues for lean manufacturing (Buvik and Halskau, 2001). Accordingly, RDT and, specifically, the concept of negotiating the environment provide a useful theoretical context to explain lean phenomena (Handfield, 1993), and thus we expect that close interaction between buyers and suppliers will translate into implicit benefits such as cooperative behavior and information sharing, which are necessary to reduce uncertainty and regarded as a preliminary steps in the direction of ILP (Handfield, 1993).

2.2 Supplier partnership, customer relationship and ILP

Supplier partnerships are mutually beneficial relationships between suppliers and buyers designed to leverage their individual resources and capabilities with the objective of improving performance (Stuart, 1993; Li *et al*., 2006). Supplier partnership is characterized by common elements, including supplier involvement, supplier development and supplier management (Vickery *et al.*, 2003). Supplier partnership presupposes mutual planning and problem solving, and a fundamental shift away from the transactional mode of doing business towards a more cooperative relationship (Li *et al*., 2006; Swink *et al*., 2007). Benefits associated with mutual planning and problem solving with suppliers include breaking down boundaries to improve communication and collaboration, coordination, increased speed, commitment, customer-focused culture, adaptability and flexibility (Drew and Coulson-Thomas, 1996). Supplier partnership also entails the early supplier involvement in new product development and the sharing of supplier technological capabilities (Vickery *et al*., 2003; Petersen *et al*., 2005; Li *et al*., 2006; Jayaram *et al*., 2008). Furthermore, supplier partnership also refers to working closely with suppliers to improve their quality levels (Handfield *et al*., 2000), and sharing the benefits of such collaboration (Vickery *et al*., 2003).

Customer relationships are often seen as a necessary and their management an important competency for supply chains (Closs and Savitskie, 2003; Tracey *et al*., 2005). It has been suggested that market orientation - through close customer relationship - and SCM are inextricably intertwined (Min and Mentzer, 2000). Traditionally, competitive advantage has been the result of cost reduction and product portfolio strategies; however, competitive environments demand a customer-driven approach, which considers the final customer as an integral part of the supply chain (McAdam and McCormack, 2001). According to Kumar (2001), providing goods or services to customers does not terminate with the delivery. Rather, installation, customer education, and after sales service are essential components of how the customer perceives the quality of the delivered product or service. Similarly, customer-focused practices such as determining and communicating customer's future needs, obtaining customer's feedback, and participating in the customer's marketing effort should be considered for fast response (Vickery *et al*., 2003). In other words, customer relationships depend upon the firm's ability to determine its customers' preferences and needs, which, in turn, enable companies to differentiate from their competitors (Day *et al*. 2000), improve operational performance (e.g. Vickery *et al*., 2003; Closs and Savitskie, 2003), and generate competitive advantage (Vickery *et al*., 2003; Li *et al*., 2006; Swink *et al*., 2007). We conceptualise the customer relationship as a set of activities that organizations use for the purpose of managing customer complaints, building strategic customer relationships and improving customer satisfaction (Tan *et al*., 1998; Li *et al*., 2006).

The term "*lean*" refers to a production system pioneered by Toyota, which focuses on the elimination of all forms of waste and non-value added activities (Womack *et al*., 1990). Waste in this context refers to overproduction, waiting time, transport, inventory, defective goods or any other factor that can disrupt the smooth flow of goods along the transformation process (Cusumano, 1994; Slack *et al*., 2009). Practices associated with the lean philosophy include pull-production systems such as just-in-time (JIT), process set-up time reduction, and quality management (Cua *et al*., 2001; Shah and Ward, 2003; Simpson and Power, 2005; Li *et al*., 2005; Jayaram *et al*., 2008; So and Sun, 2010). Pull-production systems produce only what is demanded by the customer and only at the necessary time and quantity (Sugimori *et al*., 1977). JIT eliminates waste through the simplification of production processes (Kannan and Tan, 2005), and complements process set-up time reduction initiatives and quality management as part of a comprehensive strategy to reduce inventories and efficiently use resources (Karlsson and Åhlström, 1996; Kannan and Tan, 2005). Process set-up time reduction is an important tool in reducing waste because it facilitates smaller batch sizes, which, in turn, enables work-in-process inventory reductions (Karlsson and Åhlström, 1996). With regard to quality management, ILP encourage mutual effort between participants who strive for continuous improvement and zero defects (Womack and Jones, 1994). Accordingly, lean manufacturing includes a set of integrated practices such as pull-production systems, JIT techniques, reduced process machine set-up time, and quality management (Li *et al*., 2005; Simpson and Power, 2005). However, the literature shows that lean practices have been implemented as complete systems or particular elements have been grouped together as distinct bundles of manufacturing practices such as flow elements, quality elements and employee involvement (McLachlin, 1997; Yang *et al*., 2011). We therefore conceptualize ILP as the implementation of manufacturing practices focused on reduction of waste and non-value added activities from a firm's internal manufacturing operations (Li *et al*., 2005; Yang *et al*., 2011).

While ILP have enhanced the efficiency of individual organizations, greater benefits can be obtained when considering its implementation in a supply chain context (Hines, 2004; Shah and Ward, 2007). In this regard, lean manufacturing concerns not only internal manufacturing processes, but also external operations of the supply chain (So and Sun, 2010). There are some studies that have investigated the role of internal lean operations together with external SCM practices (e.g. Tan, 2002; Li *et al*., 2005; Li *et al*., 2006; Wong *et al*., 2005; Zhu and Benton, 2007). For instance, Li *et al*. (2005) conceptualised, developed and validated a set of SCM practices, which included ILP, strategic supplier partnership, customer relationship, information sharing, information quality and postponement. These studies have combined SCM practices into a composite (multi-dimensional) construct that contains many activities from both internal and external (upstream and downstream) sides of the supply chain. While these studies have provided a more unifying conceptual framework of SCM practices including ILP, investigating the relationships between these practices can be of equal importance and has been encouraged in the literature (Li *et al*., 2005; Li *et al*., 2006).

It has been suggested that a lean strategy requires collaborative relationships between supply chain members for implementation (Lamming, 1996; Perez et al., 2010). ILP require that buyers and suppliers invest in the relationship and accept potential opportunities, risk, and costs associated with the bilateral dependence (Wiskerke and Roep, 2007). For instance, lean strategies entail close relationships with suppliers to achieve high quality standards and on-time delivery (Levy, 1997; Simpson and Power, 2005). Similarly, for both frequency of deliveries and elimination of quality controls, buyers and suppliers need to closely coordinate their operations (McIvor, 2001). In a manner consistent with RDT, tight coordination between supply chain partners can be the mechanism used to secure required resources employed to facilitate ILP implementation (Jayaram *et al*., 2008). For instance, resources such as the creation of communication channels and information sharing are often the result of inter-firm relationship efforts, which lean operations require for process synchronization (Handfield, 1993; Pérez *et al*., 2010).

With regard to supplier partnerships, the lean perspective has been linked to supply management from the beginning (Lamming, 1996). This is understandable given that seminal work in the area focused on industry sectors such as automotive, where many components are sourced from suppliers (Womack *et al*., 1990; McIvor, 2001) and effective supplier partnership are vital to ensure frequent timely deliveries and the elimination of quality checks (Wu, 2003). As such, supplier coordination constitutes a relational platform that enables information integration between buyers and suppliers thus facilitating lean practices (So and Sun, 2010; Durmusoglu *et al*., 2014). Within lean initiatives, close coordination with suppliers enables the manufacturer to decrease inventories through information sharing, reduce business risks through joint research and development, enhance product quality, and provide stable supply prices (Sheth and Sharma, 1997; So and Sun, 2010). This is also supported by Cocks (1996) who argued that true reduction of waste in lean processes depends to a great extent on honest and open relationships, which are elements of relational norms of close supplier partnership.

With regard to customer relationships, manufacturing plants use customer relationship practices to understand and incorporate customer preferences and needs, and thus react more effectively (Vickery *et al*., 2003; Jacobs *et al*., 2007). Previously, the main focus of the lean perspective was the shop floor; however, there has been a gradual widening of focus that includes the identification of customer preferences, which goes beyond the single factory to include upstream and downstream sides of the supply chain (Hines *et al*., 2004). As noted previously, ILP are characterized by pull production systems which produce only that which is required by the customer at the time needed (Sugimori *et al*., 1977); accordingly ILP rely on customer needs and desires transmitted up the supply chain. For instance, demand rate stabilization, which is achieved through customer information coordination, enables firms to plan machine set-up activities more effectively (Jayaram *et al*., 2008). Similarly, ILP includes continuous improvement systems centerd on customer needs (Abdulmalek and Rajgopal, 2007).

Despite this argument, there is little empirical evidence that investigates the role of supply chain relationships in lean practices (e.g. Kannan and Tan, 2005; Wiskerke and Roep; 2007; Jayaram *et al*., 2008; So and Sum, 2010; Perez *et al*., 2010). For instance, exploratory research in food supply chains found evidence of a tendency towards trust and collaborative behaviour (between buyers and supplier) in lean operations (e.g. Wiskerke and Roep; 2007; Perez *et al*., 2010). Kannan and Tan (2005) explored the association between elements of lean practices (e.g. JIT), SCM, and total quality management and found that various practices associate significantly with one another. This suggests there are elements of lean, SCM, and total quality management that reinforce one another. Jayaram *et al*. (2008) examined the association between relationship building and lean practices such as JIT, set-up time reduction, and cellular manufacturing. Their results reveal that relationship building in the supply chain was associated with enhanced lean practices. However, they used an aggregated construct for relationship building that did not differentiate between suppliers and customers. More recently, So and Sun (2010) studied and found support for the association between supplier integration, including key aspects of supplier partnership, and lean manufacturing. However, So and Sun (2010) did not consider the role of customer relationships as another potential enabler of lean manufacturing. Accordingly, based on the above logical, empirical, and theoretical support drawn from the literature we offer the following hypotheses:

H1: Supplier partnership is positively associated with ILP
H2: Customer relationship is positively associated with ILP

It is self-evident that long term firm viability requires operational, financial, and market success. Hence resources that facilitate this success are critical in the RDT sense. As such there should logically be a connection between IPL and performance given the RDT perspective. Fortunately the literature has examined the association between ILP and performance. This will be discussed in the following section.

2.3 ILP and performance

Operational performance has been conventionally characterized in terms of the competitive priorities from which companies choose to compete (Narasimhan and Das, 2001). Lean manufacturing practices are generally shown to be associated with competitive priorities such as quality, delivery, flexibility and cost (Shah and Ward, 2003) and the reduction in trade-offs among them (Harmozi, 2001; Yusuf and Adeleye, 2002; Jayaram *et al*., 2008). Numerous studies have found support for the positive relationship between lean manufacturing and dimensions of operational performance (e.g. Norris *et al*., 1994; Flynn *et al*., 1995; Koufteros *et al*., 1998; Shah and Ward, 2003; Kannan and Tan, 2005; Hallgern and Olhager, 2009; Rahman *et al.,* 2010); quality is one dimension that has received attention for example (e.g. Nakamura *et al*., 1998; Fullerton and McWatters, 2001, Kannan and Tan, 2005; Narasimhan *et al.,* 2006). Lean manufacturing strives for high levels of quality through a zero-defect policy and by continuously identifying and reducing sources of waste (Nakamura *et al*., 1998; Li *et al*., 2005). Lean manufacturing is also associated with improved delivery (e.g. Nakamura *et al*., 1998; Fullerton and McWatters, 2001; Cua *et al*., 2001). In particular, studies have focused upon the reductions in variability and throughput time (Naylor *et al*., 1999; Fullerton and McWatters, 2001). With regard to flexibility, some authors have indicated flexibility can be limited in certain lean environments (Cusumano, 1994; Naylor *et al.*, 1999; Mason-Jones and Towill, 2000; Christopher, 2000) whereas others suggest that changeover and process flexibility are improved in lean manufacturing contexts (e.g. Gerwin, 1993; Upton, 1995; Fullerton and McWatter, 2001; Swink *et al*., 2005). Finally, as the aim of lean manufacturing is to increase productivity and efficiency (Cua *et al*., 2001), it is not surprising that cost improvement is regarded as the direct and most common benefit associated with lean manufacturing (Naylor *et al*., 1999); many studies support this assertion (e.g. Lawrence and Hottenstein, 1995; Huson and Nanda, 1995; Nakamura *et al*., 1998; White *et al*., 1999; Callen *et al*., 2000; Cua *et al*., 2001; Fullerton and McWatter, 2001; Swink *et al*., 2005; Browing and Heath, 2009). As such, we offer the following hypothesis.

H3: ILP are positively associated with operational performance

Organizational performance refers to how well an organization achieves its market and financial goals (Li *et al*., 2005). While market-oriented performance includes indicators such as share growth, sales volume growth, competitive positions and customer responsiveness (Rosenzweig *et al*., 2003; Chen and Paulraj, 2004; Green *et al*., 2008), financial indicators include indicators such as profitability, earnings per share, return on investment (ROI), return on assets (ROA) and return on sales (ROS) (De Toni and Tonchia, 2001). While financial indicators are dominant in the literature (Chen and Paulraj, 2004), the literature warns against the sole use of financial indicators, which can be complemented by market-oriented indicators for a more balanced performance framework (Gunasekaran *et al*., 2004).

The literature suggests that lean practices generally translate into higher organizational performance (Fullerton *et al*., 2003; Eroglu and Hofer, 2011). For instance, market-associated indicators such as customer service and market share can be increased due to lean practices such as improved quality levels, short set up time and preventive maintenance (Fulleton *et al*., 2003). With regard to financial indicators, lean practices such as JIT can impact them in various ways (Fulleton *et al*., 2003). First, lean practices free up assets and working capital, which will increase asset turnover all else equal. Second, lower finished goods inventory levels reduce the asset base, which again improves assets turnover. Third, the reduction of inventory buffers throughout the system exposes potential problems such as defects and stock-outs, which have an impact on profitability.

Multiple empirical studies have found support for the positive association between lean practices and dimensions of organizational performance such as profitability (e.g. Huson and Nanda, 1995; Callen et al., 2000; Fullerton and McWatters, 2001; Kinney and Wempe, 2002), return on investment (e.g. Inman and Mehra, 1992), return on assets (e.g. Fullerton and McWatters, 2001; Kinney and Wempe, 2002; Eroglu and Hofer, 2011), return on sales (e.g. Fullerton and McWatters, 2001; Eroglu and Hofer, 2011), earnings per share (e.g. Huson and Nanda, 1995), and market-oriented indicators such as market share (e.g. Inman and Mehra, 1992; Norris *et al*., 1994). Based on the findings reported in the above literature, the relationship between ILP and organizational performance is expected to be positive and significant. Accordingly, it is hypothesized that:

H4: ILP are positively associated with organizational performance

2.4 Contingency theory, ILP and TT

While several studies have found support for the positive association between lean manufacturing and operational performance, there are several others that fail to find total support (e.g. Sakakibara *et al.,* 1997; Callen *et al*., 2000; Swink *et al*., 2005). For instance, Sakakibara *et al*. (1997) found no support for a relationship between ILP practices, such as set up time reduction and *Kanban* systems, and operational performance. Similarly, Callen *et al*. (2000) found that not all lean dimensions appeared to be associated with operational performance improvement when comparing JIT plants. For instance, JIT plants that claimed to be more successful at controlling lean-related process quality tended to have higher total costs. Similarly, Swink *et al*. (2005) found that ILP such as process quality management and JIT are not significantly associated with all operational performance dimensions. This lack of consistency in the results may be attributed to the complexity of the link between manufacturing practices and performance, which is not fully understood (Skinner, 1969; Swink *et al*. 2005).

Similarly, some studies also fail to significantly connect ILP to organizational performance (e.g. Balakrishnan *et al*., 1996; Fullerton *et al*., 2003; Kannan and Tan, 2005, Jayaram *et al*., 2008, Cannon, 2008). For instance, comparing JIT adopter and non-adopters, Balakrishnan *et al*. (1996) could not find support for the adoption of JIT practices and improved ROA. Similarly, Jayaram *et al*. (2008) found that lean manufacturing showed no significant effect on financial performance (ROA, ROI and ROS). Kannan and Tan (2005) found that JIT factors such as commitment to JIT and JIT material flow were not significantly associated with organizational performance factors such as ROA, market share, competitive position and customer service. Testing the benefits of inventory leanness on financial performance (ROA, ROI and market value added of the firm), Cannon (2008) did not find support for the role of inventory reduction as a robust indicator for financial performance. Moreover, Fullerton *et al*. (2003) found that the implementation of JIT practices decreased financial indicators such as ROA, ROS and cash flow.

Given the foregoing, it is evident there are inconsistencies in the results of studies that investigate the relationship between ILP and performance. A potential explanation for this inconsistency lies in contingency theory (CT), which is based on the premise that no universal set of strategies applies to every business situation (Lawrence and Lorsch, 1967; Ginsberg and Venkatraman, 1985). CT indicates that organizations are not closed systems and as such are exposed to organizational and environmental factors that affect the strategy (Hofer, 1975; Schoonhoven, 1981). Furthermore, recognizing the contingency should improve the strategy and lead to improved performance (Hofer, 1975). Therefore, a contingency framework focuses on the relationships between contingency variables, the strategy, and firm performance (Ginsberg and Venkatraman, 1985; Schoonhoven, 1981). In other words, a firm's performance is maximized when there is a fit or match between an organization's structure/processes and its environment (Flynn *et al*., 2010; Wong et al., 2011). Accordingly, drawing on the contingency view, the lack of association between ILP and performance may be attributable to contextual differences (Cua *et al*., 2001; Shah and Ward, 2003; Hines *et al*., 2004; Browning and Heath, 2009).

While there are empirical studies that considered contextual variables in the lean literature, they are either exploratory (e.g. Dean and Snell, 1996; Shah and Ward, 2003; Browning and Heath, 2009), or have used internal characteristics of the firm (e.g. plant characteristics such size) as contextual variables (e.g. Lowe *et al*., 1997; White *et al,* 1999; Cua *et al*., 2001; Shah and Ward, 2003, Crute *et al*., 2003; Bayo-Moriones, *et al*., 2008). However, it has been suggested that the role of external contextual variables such as environmental dynamism remains comparatively unexplored in the lean literature (Shah and Ward, 2003). Environmental dynamism refers to the rate of change and the degree of instability within an industry (Li and Simerly, 1988), which has been characterized in the literature as a multi-dimensional construct, which arises from many sources, including the rate of change in innovation, introduction of new products/services, the hostility of competitors (competitive intensity), the unpredictability of customers' behaviour (customer/demand type) and technological change/turbulence (Lawrence and Lorsch, 1967; Miller and Friesen, 1983; Miller, 1987; Fynes *et al*., 2005; Trkman and McCormack, 2009).

Recent empirical studies have considered the effect of various dimensions of environmental dynamism on lean operations (e.g. Chavez *et al*., 2013; Azadegan *et al*., 2013); however, technological turbulence (TT), as an important dimension (Fynes *et al*., 2005; Trkman and McCormack, 2009), remains comparatively unexplored. TT refers to the rate of technological change over time within an industry (Slater and Narver, 1994; Trkman and McCormack, 2009), and arises from rapid technological changes in products and manufacturing processes (Hsu and Chen, 2004; Song *et al*., 2005; Kandemir *et al*., 2006). Organizations that work with state-of-the-art technologies may be able to obtain competitive advantage through fast technological innovation (Jaworki and Kohli, 1993); however, competitive advantage is only a temporary advantage since product obsolescence occurs more quickly in these fast-pace technological environments (Calantone *et al*., 2003).

For instance, Azadegan *et al*. (2013) concluded that the effect of lean operations on organizational performance (i.e. ROA, ROS, earnings per share, profit, and market share) varies due to environmental dynamism. Azadegan *et al*. measured environmental dynamism through the rate of change in the modes of production, innovation, government regulations, consumer demographics and competition. However, hostile environments in terms of market competition and restrictive government legislation are not necessarily turbulent (Calantone *et al*., 2003) or technologically intensive (Zhou *et al*., 2005). Chavez *et al*. (2013) found that given the level of product change, the effect of internal lean operations on operational performance is not monotonic. However, environments characterized by permanent introduction of new products are not always technologically advanced (Jacobs, 2007); instead new products often use simpler technologies or new ideas of business operations (Zhou *et al*., 2005). Therefore, as dynamic environments are not only those in which competition, rates of new product introduction, and demand variability are high but also technological change is high (Miller, 1987; Calantone *et al*., 2003), it is important to study the role of TT to better complement the understating of environmental dynamism in the lean literature and the results of recent empirical work.

Conceptual studies have generally posited that environments characterized by high technological change can have an effect on the benefits of lean operations, e.g. JIT and waste reduction (Cusumano, 1994; Christopher, 2000; Christopher and Towill, 2001; Hines, 2004). For example, Christopher (2000) indicates that the benefits obtained from the lean thinking such as meeting the customer's requirements and quality specifications are more evident internally at a factory level, but when characteristics of the external environment are considered, namely turbulence and volatility, lean practices could be limiting. Turbulence often creates considerable change, uncertainty, and unpredictability (Calantone *et al*., 2003) which are not always compatible with lean practices such as machine set-up time reductions that require low variability and repetitive processes (Jayaram *et al*., 2008). Lean management strives for zero defects through continuous improvement programmes (Womack and Jones, 1994); however, tech-based products often require radical improvement rather than continuous and incremental change (Zhou *et al*., 2005). Lean management is based on pull-production systems and thus a market-oriented philosophy, which only produces products demanded by the customer (Sugimori *et al*., 1977). However, technological orientation reflects the push-production philosophy or "technological push", which is based on technological superiority, creativity and invention rather than ideas that better satisfy the customer (Zhou *et al*., 2005). Despite the relevance of synchronization of tasks between supply chains partners for lean practices such as JIT (Wu, 2003), studies show that strong supply chain relationships do not necessarily contribute to performance in technological turbulent environments (Fynes, 2005). In this respect, firms can take advantage of technological change to alter the architecture of their supply chains (Zhou *et al*., 2005) from lean operations to flexible operations (Fisher, 1997).

On the empirical front, there is some case-based evidence that certain industries characterised by TT such as the computer, electronics, media, and telecommunications industries (Calantone, et al., 2003, Taj, 2008) can influence the effectiveness of lean operations on performance aspects (e.g. Naylor *et al*.1999; Mason-Jones *et al*., 2000; Yusuf and Adeleye, 2002; Eroglu and Hofer, 2011). Using a case study of the personal computer industry, Naylor *et al*. (1999) and Mason-Jones *et al*. (2000) found that the sole use of lean operations (such as the elimination of inventory) can be counterproductive to performance improvement, e.g. continual reliable delivery of products, and it should be complemented by more agile manufacturing operations. This combination of strategies helped in avoiding rapid obsolescence of products and achieving bottom-line benefits. Using multiple industries, Yusuf and Adeleye (2002) found that lean manufacturing may not improve organizational performance, e.g. market share, sales turnover, and net profit, in environments characterized by rapid change in manufacturing technology; however, their use of a single measure for change in manufacturing technology might not have captured the construct accurately. Conversely, investigating the implementation of lean manufacturing across multiple Chinese industries, Taj (2008) found that the relationship between ILP and performance can be positive even in industries characterized by TT. Taj found that plants in high-tech industries can not only be leaders in the implementation of lean practices, such as process layout and handling, but also excel through on-time delivery, flexibility, and quality aspects. This evidence points to the need for further empirical research to verify the negative effect of TT on the lean - performance relationship. More recently, Eroglu and Hofer (2011) found that the effect of lean practices such as inventory reduction on financial performance, e.g. ROA and ROS, may vary due to industry-specific characteristics. However, a limitation of their study was that it did not study the specific effect of this characteristic on the lean-performance link. As such they urged future studies to investigate the appropriateness of lean operations under different industry-level factors such as technological change in products. Although the above empirical evidence has significantly furthered our understanding of lean operations in technology-intensive environments, the literature lacks empirical studies that specifically address the effect of TT, as an important dimension of environmental uncertainty, on the lean-performance link. Accordingly, considering the above literature review and drawing upon the contingency perspective we argue that:

H5: Technological turbulence negatively moderates the relationship between internal lean practices and operational performance

H6: Technological turbulence negatively moderates the relationship between internal lean practices and organizational performance

The research model is presented in Figure 1.

3. Research methodology

3.1 Sampling and data collection

The data was collected through a postal survey, and the mailing list was obtained from Kompass Ireland, one of Ireland's most accurate and up-to-date national and international business databases. Our main population was the top 2,500 companies (turnover, profitability, and size) in the Republic of Ireland. Only manufacturing companies were selected since the different activities incorporated in the survey focused on manufacturing practices. This excluded from the sampling frame other sectors not directly involved in the visible transformation of products such as primary extraction, agriculture, forestry, fishing and services. An initial listing of 705 manufacturing companies were selected; however, some companies had gone into liquidation or moved to Eastern Europe or China, and thus were excluded from the sample. This resulted in a final sampling frame of 655 manufacturing companies. An important reason for focusing on manufacturing firms in the Republic of Ireland is that there has been a growing trend to outsource labour intensive activities to lower cost countries due to Ireland's high cost basis (Huber and Sweeney, 2007). This justifies the need for an efficient use of resources, and thus the use of lean manufacturing can secure savings across the supply chain (Cua *et al*., 2001).

To ensure the accuracy and completeness of the responses, managers in relevant areas such as supply chain and operations management were identified in each company as the key informants of this study (Malhotra and Grover, 1998). In order to increase the response rate, each respondent was contacted by telephone and email to obtain his or her consent to participate in the study (Ward *et al*., 1998; Dillman, 2000). Further, a benchmark score of each company's practices and performance relative to their industry sector was offered as an incentive. A copy of the questionnaire was finally sent to the production plant of each company as the unit of analysis. After three follow-up contacts, a total of 236 questionnaires were received, 228 of which were usable. This gives an overall response rate of 36 percent, which is above the minimums considered to be satisfactory in this type of survey-based studies (Malhotra and Grover, 1998; Frohlich, 2002). Table 1 provides details of the sample characteristics.

--Table 1---

3.2 Non-response bias and common-method bias

To examine possible non-repose bias and the generalizability of findings to the population (Miller and Smith, 1983), we compared the early and late responses following the approach suggested by Armstrong and Overton (1977). Five items used in the questionnaire were randomly selected to compare the first and last twenty returned questionnaires using the chi-square test. All the significance values of the selected items were above 0.01, which implies an absence of non-response bias. Common-method bias has been regarded as another concern since the data for this study were obtained from single respondents (Podsakoff *et al*., 2003). Some statistical techniques can be employed to identify the potential effects of common-method bias such as Harmans single factor (one-factor) test (Boyer and Hult, 2005; Podsakoff *et al*., 2003). Following this approach, all the variables were loaded into an exploratory factor analysis (EFA). The results of EFA show seven distinct factors with eigenvalues above 1.0, explaining 60.09 % of total variance. The first factor explained 25 % of the variance, which is not majority of the total variance. The corresponding results indicate that common method bias is not a threat in this study. As a second test of common method bias, confirmatory factor analysis (CFA) was applied to Harman's single-factor model (Flynn *et al*., 2010; Podsakoff *et al*., 2003). The model fit indices of χ^2/df (1379.53/405) = 3.4, RMSEA =

0.103, RMR = 0.085, NNFI = 0.80, CFI = 0.83 and IFI = 0.83 were outside the recommended values and significantly worse than those of the measurement model. This suggests that a single factor model is not acceptable and that common method bias is unlikely. To further assess common method bias, a latent factor representing a common method was added to the measurement model, which is the strongest test of common method bias (MacKenzie, *et al*., 1993; Podsakoff *et al*., 2003; Zhao *et al*., 2011). The resulting fits were not significantly different from those of the measurement model (χ^2/df = 1.94 vs. 1.60 for the model with the common method factor, RMSEA = 0.06 vs. 0.05; RMR = 0.05 vs. 0.04, NNFI = 0.93 vs. 0.95, CFI = 0.94 vs. 0.96 and IFI = 0.94 vs. 0.96). Also, the item loadings for their factors are still significant in spite of the inclusion of a common latent factor. Therefore, we conclude that common method bias is not an issue in this study.

3.3 Measure validation and reliability

The validation process for the survey instruments was completed in three steps: content validity, construct validity and reliability (Carmines and Zeller, 1979, O'Leary-Kelly and Vokurka, 1998; Zhou and Benton Jr., 2007). For content validity a draft questionnaire was pre-tested and timed with a panel of academic experts in the area such as operations management and SCM. As practitioners, executive MBA students were contacted and sent a copy of the modified draft-questionnaire. These practitioners held managerial positions in various industry sectors, and thus it was expected that they were knowledgeable and able provide expert feedback for further improvement. Following their suggestions, the questionnaire’s layout and wording were modified and pilot-tested with the target population to verify its suitability for this group. For this, a total of thirty questionnaires were sent to randomly selected companies in our sampling frame and ten were returned. Terminology was again adapted to better suit the target population. For instance, target respondents suggested that the term “Pull” in one of the ILP items should be changed to “our firm produces only what is demanded by customers when needed (e.g. JIT)”, since the term “Pull” was not very clear for some of the respondents. Apart from these changes, no difficulty in completing the questionnaire was reported.

Construct validity was established through convergent validity and unidimensionality of the constructs. Convergent validity was assessed through CFA using Lisrel 9.1. Convergent validity refers to the degree to which individual items in the questionnaire measure the same underlying construct, which can be evaluated through analysing whether the items' standardized coefficient are statistically significant and greater than twice its standard error (Anderson and Gerbing, 1988). As shown in Table 2, all indicators in their respective constructs have statistically significant ($p < 0.001$) factor loadings greater than twice its standard errors. Furthermore, factor loadings are greater than 0.50, which indicate convergent validity of the theoretical constructs (Anderson and Gerbing, 1988). CFA also allows examining the measurement model adequacy. The overall fit for the measurement model was good: of χ^2/df (746.31/390) = 1.913 and RMSEA = 0.063. An RMSEA between 0 and 0.05 indicates a good fit, and between 0.05 and 0.08 is acceptable (Hu and Bentler, 1999; Shin *et al.,* 2000; Byrne, 2001; Hair *et al*., 2006). Table 2 reports all other relevant measures (RMR = 0.051; NNFI = 0.930; CFI = 0.937; IFI = 0.938), which are also within an acceptable range (Kline, 2005; Hooper *et al*., 2008).

Discriminant validity measures the extent to which individual items intended to measure one latent construct do not at the same time measure a different latent variable (De Vellis, 2003). Discriminant validity was tested through inter-factor correlations (Anderson and Gerbing, 1988). Although it is expected some degree of correlation, a very strong correlation between factors indicates that they are measuring the same construct (Anderson *et al.,* 2002). Table 3 shows that discriminant validity is present (Anderson and Gerbing, 1988). In order to estimate reliability, the Cronbach's α coefficient was used, as it is a common method for assessing reliability in the empirical literature (Carmines and Zeller, 1979). As shown in Table 2, all the scales show α values above 0.7, which indicates that the scales are reliable for further analysis (Nunnally, 1978).

--Table 2--
--Table 3--

3.4 Measures

Supplier partnership was measured using a four-item scale, based on items developed by Li *et al*. (2006). The scale included questions on continuous improvement programmes for key suppliers and their involvement in planning activities and new product development programmes. *Customer relationship* was measured with scales based on Li *et al*. (2006), and included five questions on customer interaction, information sharing and the evaluation of customer expectations and changing needs.

ILP scales are based on those developed by Li *et al*. (2005), and included questions on the implementation of JIT and process set-up time reduction. Some original items displayed low factor loadings and were deleted from the analysis to ensure the quality of the measures (See Appendix section). For instance, the following items were deleted from the ILP construct: 1) our firm has continuous quality improvement programs, 2) our firm seldom pushes suppliers for shorter lead-time (order entry to shipment), and 3) our firm streamlines ordering, receiving and other paper work. With regard to the first deleted item, its poor loading may be explained by firms that attempt to implement particular (rather than all) elements of lean since it has been suggested that some elements of lean are simpler to implement and provide quick returns. However other core elements of lean, such as quality require more time and commitment but provide greater benefits in the long run (McLachlin, 1997). Deleted *ILP* items 2 and 3 focused on lean operations with suppliers/buyers, and thus have an external orientation. A possible explanation of their poor loading is that the major focus of lean manufacturing is still the shop floor, and thus the internal plant-level operations (Hines *et al*., 2004). According to Hines *et al*., external lean integrative approaches are relatively recent and companies need to rely more on external lean efforts for competitive advantage. Although from a theoretical perspective the deleted items were important for the constructs, the removal was based entirely on standard statistical conventions.
Technological turbulence (TT) was measured with scales based on Jaworski and Kohli (1993), and included questions on technological change (industry and product). The above scales items asked respondents to evaluate the extent to which they agree or disagree with respect to their business using a five-point Likert scale (being 1 = strongly agree and 5 = strongly disagree). *Operational performance* was measured by scales developed by Ward *et al*. (1998), who focused on a production line, and thus on internal operational performance measures. We included scales addressing four internal operational performance dimensions: quality, delivery, flexibility and cost.
Organizational performance was measured using a seven-item scale developed by Li *et al*. (2006), and included questions on market share, ROI, profitability and overall competitive position. The latter scales asked respondents to evaluate how their firm compares to their major industrial competitor using a five-point Likert scale (being 1 = superior and 5 = poor or low end of the industry). It has been suggested that firms in some industries are more likely to improve performance from the implementation of manufacturing and SCM practices (e.g. Meijboom *et al*., 2005), and thus we decided to

include it as a control variable. Two dummy variables were used to control for the impact of different industries (pharmaceuticals and electronics).

4. Data analysis and results

The hypothesized relationships between the various constructs were analysed using structural equation modelling (SEM). SEM estimates were generated through Lisrel 9.1 with maximum likelihood estimation method. Table 4 indicates the goodness of fit for our model: χ^2/df (674.61/364) = 1.853, RMSEA = 0.061, RMR = 0.047, NNFI = 0.934, CFI = 0.941 and IFI = 0.941. These fit indices suggest a good overall fit of the structural model (Hu and Bentler, 1999; Shin *et al.,* 2000; Byrne, 2001; Hair *et al*., 2006). Table 4 shows the results of hypotheses tests 1-4 SEM. First, there are statistically significant positive relationships between supplier partnership and ILP, and between customer relationship and ILP, which lends supports for H1 and H2. Second, there are significant and positive relationships between ILP and operational performance, and between ILP and organizational performance. Thus, H3 and H4 are supported. We also found that our control variable: industry type, through the pharmaceuticals and electronics industry, had no significant impact on operational performance and organizational performance.

---Table 4---

In order to test the moderating effect of TT on the relationship between ILP and operational performance, and between ILP and organizational performance two different models were used, one for each dependent variable; operational performance and firm performance (Ray *et al*., 2005). Ordinary least square (OLS) analyses were carried out following a hierarchical process (Zhao *et al*, 2011). In the first step, we entered our control variables and the corresponding dependent variable. In the second step, we added the independent variables: ILP and TT (the moderator variable). In the third step of the regression analysis, the interaction term was introduced (ILP*TT). Table 5 presents the results of the OLS regression analyses.

---Table 5---

Firstly, we hypothesized in H5 that TT moderates negatively the relationship between ILP and operational performance. Table 5 shows that, in the third step of the regression analysis, the interaction term was found to be significant and negative (β = -0.260; $p \leq 0.01$), and contributed to a significant change in the variance explained (change in: $R^2 = 0.067$, F= 18.492, $p \leq 0.01$). Accordingly, there is full support for H5. Secondly, we proposed that TT moderates negatively the relationship between ILP and organizational performance (H6). In the third step of the regression analysis, the two-way interaction term contributed to a change in the variance explained (change in: $R^2 = 0.040$, F= 10.178, $p \leq 0.01$), with the interaction term identified as significant and negative ($\beta = -0.203$; $p \leq 0.01$). Based on the above results, we found support for H6. As illustrated in Table 4, the first step of the regression analyses revealed that the effect of industry type, the pharmaceuticals industry and electronics industry, on both operational performance and organizational performance were not significant.

For the purpose of further interpretation, we calculated regression equations for the relationship between ILP and operational performance, and between ILP and organizational performance at high and low levels of TT. We define high and low levels of TT dividing the dataset into two subgroups using the median of TT as the dividing criteria. Table 6 shows that under low TT, ILP are significantly associated with operational performance ($\beta = 0.224$, $p \leq 0.05$), but no significance was reported when TT is high ($\beta = -0.027$, ns). Similarly, results shows that ILP are only significantly associated with organizational performance when TT is low ($\beta = 0.174$, $p \leq 0.05$) than when TT is high ($\beta = 0.202$, ns). These results are also illustrated by the plots of the two-way interaction effects (Aiken and West, 1991) in Fig. 1 and 2, which show that ILP have only a positive impact on operational performance and organizational performance when TT is low. We discuss these results in the following pages.

--Figure 2--

--Figure 3--

5. Discussion

The first objective of this study was to empirically test the positive effect of both supplier partnership and customer relationship on ILP. The results supported the hypothesis of a positive relationship, providing insights into the strategic role of relationship building in the supply chain for ILP. Secondly, by investigating the effect of ILP on both operational performance and organizational performance this study clarifies inconclusive findings on the lean-performance link. The third objective of this study was to identify the moderating effect of TT on the lean-performance link. The results support hypothesized relationships thus providing valuable insight into the role of contextual factors such as TT for ILP implementation. An outcome of this test is the revelation of the differential impact of TT on operations and organizational performance. Further, the findings contribute to the advancement of RDT and CT perspectives in lean manufacturing. The significance of these contributions will be discussed in the following paragraphs.

5.1 Theoretical implications

Despite the importance of close coordination and synchronization with suppliers and customers for lean manufacturing (Wu, 2003), few empirical studies have investigated the association between these constructs (Jayaram *et al*., 2008). Therefore, this study extends and complements existing studies by testing an integrated model that includes both supplier partnership and customer relationship, and provides strong confirmation of their positive association with ILP. Further, the findings are consistent with the expectations of RDT, which assert that firms will attempt to engage in inter-organizational relationships to obtain access to unique and valuable resources (Pfeffer and Salancik, 1978). Cooperation and coordination between buyers and suppliers are associated with relational aspects such as information sharing, which are a preliminary step for lean manufacturing practices (Handfield, 1993; Buvik and Halskau, 2001). Specifically, critical external resources, e.g. commitment of support between the parties involved, sharing of strategic information on future planning, goals and NPD, and sharing of customer satisfaction and future expectations, are associated with cooperation efforts in the supply chain. These cooperation efforts are in turn central aspects for the implementation of lean manufacturing practices such as JIT, which require higher levels of process synchronization (Handfield, 1993). Overall, the findings provide empirical support for the argument that lean manufacturing is impacted directly through supply chain relationships (Simpson and Power, 2005), namely supplier partnership and customer relationship.

Turning to the association between ILP and operational performance, the results are consistent with various empirical studies (e.g. Norris *et al*., 1994; Flynn *et al*., 1995; Koufteros *et al*., 1998; Shah and Ward, 2003; Kannan and Tan, 2005; Hallgern and Olhager, 2009; Rahman *et al*., 2010) and influential work such as Womack *et al*. (1990) and Narasimhan *et al*. (2006), who found that firms that implement lean practices appear to be associated with operational performance dimensions that emphasize efficiency, quality, reliability and certain levels of flexibility. Furthermore, the results show that ILP not only improves operational performance but also organizational performance such market-and financial-oriented performance (e.g. Inman and Mehra, 1992; Huson and Nanda, 1995; Callen *et al*., 2000; Fullerton and McWatters, 2001; Kinney and Wempe, 2002; Eroglu and Hofer, 2011), although to a lesser extent.

An important and novel contribution of this study is the contingency effect of TT on the lean-performance link. The results show that TT negatively moderates the relationship between ILP and operational performance. The results also show that TT negatively moderates the relationship between ILP and less strongly but just as significantly organizational performance. TT is an important contextual dimension of dynamic environments, which has not been studied in the lean literature. Accordingly, our study offers the first contribution to the lean literature that specifically studies the contingency role of TT and complements recent empirical work (Browning and Heath, 2009; Azadegan, 2013; Chavez *et al*., 2013). Overall, the results provide support for the contingency argument that a firm's performance is maximized when there is a fit between an organization's processes and its environment (Flynn *et al*., 2010; Wong et al., 2011). Thus, ILP enables improvement in operating performance and organizational performance only when environments are characterized by low levels of TT. Hence this study offers an explanation (TT) for why some prior studies did not find performance benefits from ILP and as such, at least partially, resolves the paradox in the literature.

In view of the results above, this research makes three main contributions to the literature. First, it shows the importance of supply chain relationships for ILP. Second, it confirms the positive and differential association between ILP and performance, namely operational and organizational. Third, it helps to understand the circumstances under which ILP can impact on performance. This contingency view of lean manufacturing incorporates TT as a moderating variable.

5.2 Managerial implications

This study also has important managerial contributions. The results show that supplier partnership and customer relationship are associated with ILP implementation. This highlights the strategic importance of managing and developing strategic relationships not only with suppliers but also buyers in lean manufacturing contexts (Martínez-Jurado and Moyano-Fuentes, 2013). Managers are continually challenged by how manufacturing practices are related and affect one another in the supply chain

(Chen and Paulraj, 2004) and this study demonstrates that 'lean' can be regarded as a stimulator of operational performance (Schonberger, 1995; Flynn *et al*., 1999; Jayaram *et al*., 2008) and firm performance (Fulleton *et al*., 2003). However, this study reveals that lean benefits are not universally applicable and as such managers should consider the context in which lean is to be implemented (Jina *et al*., 1997). In particular, the study provides managers with evidence that environments characterized by technological change can have an impact on the effectiveness of lean. Specifically, the results show that lean has a positive effect on both operational performance and organizational performance in industry environments where change in technology is not dramatic. Accordingly, before implementing lean practices, a thorough understating of the pace in technological change is recommended. Further, it has been suggested that certain industries are characterized by TT such as the computer industry; however, all industries at some point may experience TT of varying degrees. Practitioners in various industries can thus use the validated measures of TT provided in this study to assess the levels of technological change in their industries.

6. Conclusions

This study contributes positively to theory by confirming empirically that supplier partnerships and customer relationships are significantly and positively associated with ILP. Another contribution is the finding of a significant impact of ILP on operational performance and organizational performance. Finally, as a novel contribution to the literature, the study confirms a negative moderating role of TT on the relationship between ILP and operational performance, and between ILP and organizational performance. As suggested by Browning and Heath (2009), technological-intensive and complex environments can represent an "extreme case" for studying phenomena of theoretical interest, e.g. lean manufacturing implementation. We believe we have addressed this issue and thus further clarified the contingency perspective in the literature.

While this study contributes to theory and practice, there are certain limitations that should be considered. One of the main limitations of this study is the number of items that reflect the ILP construct. This was due to three items manifesting low factor loading, which were not considered further in the analysis to ensure the quality of the measurement scale. However, we argue that the items used to represent ILP are central to lean manufacturing since the scales are reflective and various studies have systematically included them as part of their lean manufacturing constructs (e.g. McLachlin, 1997; Shah and Ward, 2003; Li *et al*., 2005; Jayaram *et al*., 2008; So and Sun, 2010; Browing and Heath, 2009). Further, according to McLachlin (1997), not all firms implement a complete system of lean practices and, thus, firms concentrate on particular elements or bundles of practices such as flow elements, e.g. setup reduction and pull systems. Future research can expand the construct to include other related activities. This study focused on the impact of customer relationship and supplier partnership on ILP; however, since the research methodology of this study is cross-sectional, it ignores the possible recursive relationships. While we used the RDT as an implicit and attractive research framework to support this relationship, it could be possible that ILP enhanced levels of supply chain relationships. Further, this research ignores the possible temporal effect of ILP and practices such as JIT. For example, it was suggested that timing, scale, and extent of lean implementation can be important determinants of its success (Handfield, 1993; Browning and Heath, 2009). Accordingly, alternative research designs such as a longitudinal studies, ethnography, action research, and triangulation could be used to clarify causation between variables (Mangan *et al*., 2004; Boyer and Swink, 2008). Another limitation lies in the responses from single key informants, which may cause common-method bias. While this research targeted key respondents holding relevant managerial positions, multiple respondents could have possibly provided more accurate results. Nevertheless, this likely would have reduced the response rate and the associated cost was prohibitive. There have been recent calls to incorporate a more contingency perspective in the lean manufacturing literature using industry-specific characteristics such as the product type and supply chain demand characteristics (Eroglu and Hofer, 2011). Further, the literature review on environmental dynamism in our study is not exhaustive. Most notably, future research should include other environmental dimensions (e.g. supply risk) that were not explored in this study (Fynes *et al*., 2004) and investigate their contingency effects. Finally, further research is called to investigate the association between ILP and other less traditional performance indicators such as environmental and social performance (Pagell and Wu, 2009).

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Figure(s)

Figure 1: Research model

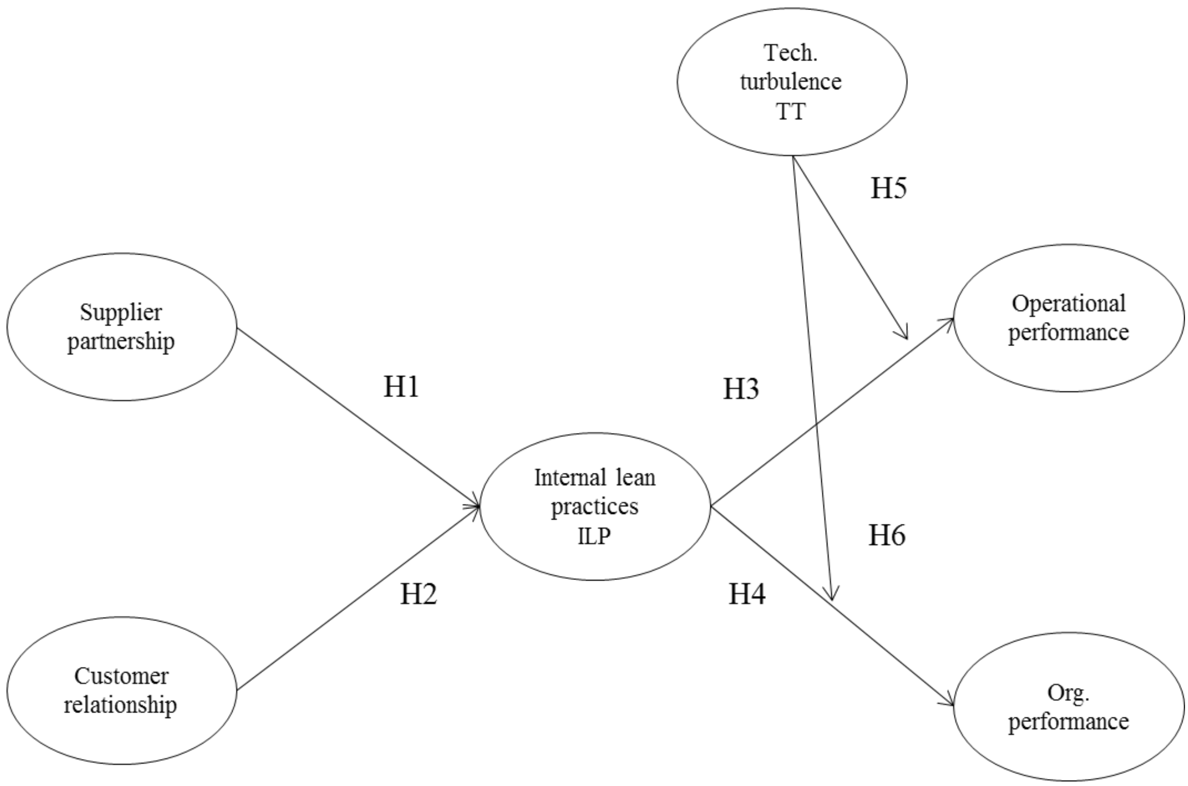


Figure 2: ILP and operational performance in low/high TT environments

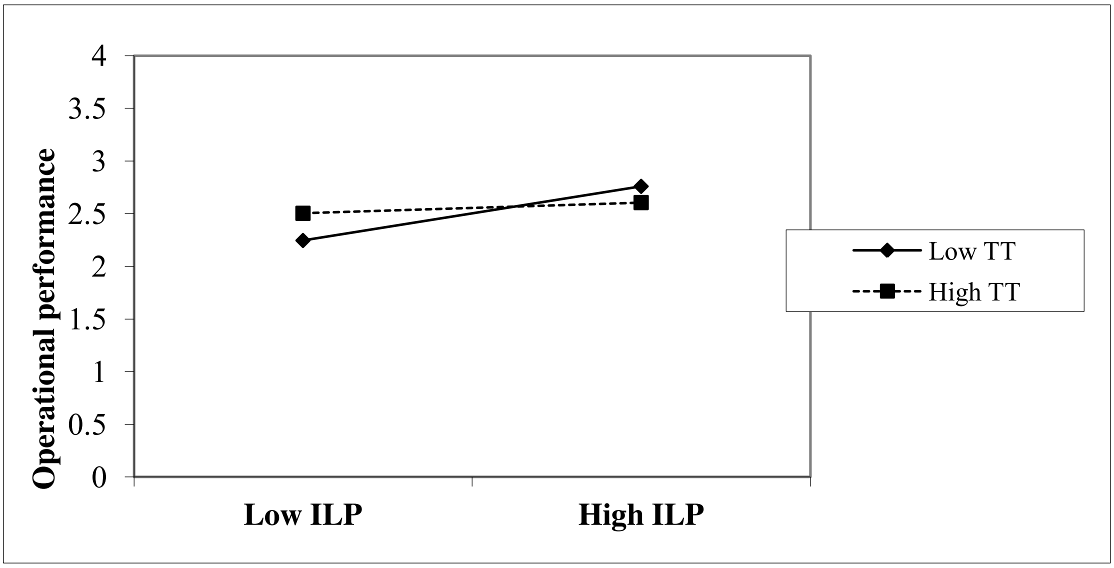
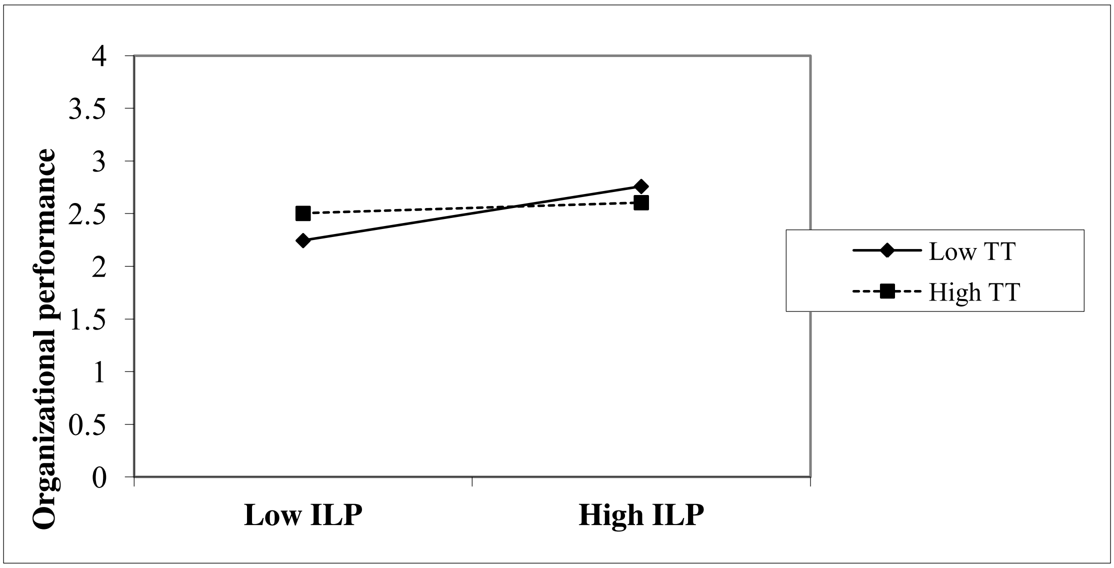


Figure 3: ILP and organizational performance in low/high TT environments



Table(s)

Table 1: Demographics of the sample

	Sample (%)		Sample (%)
Respondent's job title		**Industry sector**	
Production manager	32.6	Manufacturing of food	16.8
Operations manager	25.0	Machinery	12.8
Supply chain manager	18.4	Pharmaceuticals	12.0
General Manager/Director	17.0	Electronics	10.2
Other managerial areas	7.0	Medical devices	9.7
No. of Employees		Plastics	8.4
Under 100	44.1	Chemicals	7.5
100-299	33.9	Fabricated metal products	7.1
300-499	8.3	Motor vehicles and parts	4.4
500+	13.7	Wood/products of wood	4.0
Majority ownership		Basic metals and other minerals	3.5
Irish	43.0	Textiles and apparel	1.8
USA	29.0	Pulp, paper and paper products	1.8
Rest of Europe	17.9		
UK	5.4		
Other countries	4.7		

Table 2: Inter-factor correlations

Construct	Mean	S.D.	1	2	3	4	5
1. Supplier partnership	2.358	0.658					
2. Customer relationship	2.001	0.568	0.328**				
3. ILP	1.861	0.637	0.315**	0.372**			
4. Operational performance	2.374	0.548	0.266**	0.368**	0.349**		
5. Organizational performance	2.508	0.617	0.290**	0.340**	0.279**	0.501**	
6. Technological turbulence	2.668	0.738	0.132*	0.214**	0.195**	0.109	0.082

* Sign. at the 0.05 level
** Sign. at the 0.01 level

Appendix: Measurement scales

Constructs
Please evaluate the extent to which you agree or disagree with respect to your business
Internal lean practices (ILP) (Li *et al*., 2005)
Our firm reduces process set-up time (time required to prepare or refit equipment/workstation for production)
Our firm has continuous quality improvement programs*
Our firm produces only what is demanded by customers when needed (e.g. JIT)
Our firm seldom pushes suppliers for shorter lead-time (order entry to shipment)*
Our firm streamlines ordering, receiving and other paper work*
Supplier partnership (Li *et al*., 2006)
We consider quality as our number one criterion in selecting suppliers*
We rarely solve problems jointly with our suppliers*
We have helped our suppliers to improve their product quality
We have continuous improvement programs that include our key suppliers
We include our key suppliers in our planning and goal-setting activities
We actively involve our key suppliers in new product development processes
Customer relationship (Li *et al*., 2006)
We frequently interact with customers to set reliability, responsiveness, and other standards for us
We frequently measure and evaluate customer satisfaction
We frequently determine future customer expectations
We facilitate customer's ability to seek assistance from us*
We hardly ever evaluate the importance of our relationship with our customer*
We inform customers in advance of changing needs
Customers share proprietary information with us
Technological Turbulence (Jaworski and Kohli, 1993)
The technology in our industry is changing rapidly
Technological changes provide big opportunities in our industry
A large number of new product ideas have been made possible through technological breakthrough in our industry
Technological development in our industry are rather minor
Please evaluate how your firm compares to your major industrial competitor
Operational performance (Ward *et al*., 1998)
Production cost
Labour productivity
High product performance (order-entry to shipment)
Ease (cost and time) to service product (well-designed product for and effective service)
Ability to introduce new products into production quickly
Ability to adjust capacity rapidly within a short time period
Delivery on due date (ship on time)
Reducing production lead time (order-entry to shipment)
Organizational Performance (Li *et al*., 2006)
Market share
Return on Investment (ROI)

Growth of market share

Growth of sales

Growth in ROI

Profit margin on sales

Overall competitive position

*Item removed in the final scale

Table 3: Construct measurements

Constructs	Standardised loading	t-value	Standard error
Supplier partnership(α = 0.756)			
We have helped our suppliers to improve their product quality	0.60	8.84	0.04
We have continuous improvement programmes that include our key suppliers	0.70	10.69	0.06
We include our key suppliers in our planning and goal-setting activities	0.75	11.47	0.06
We actively involve our key suppliers in new product development processes	0.62	9.29	0.06
Customer relationship (α = 0.751)			
We frequently interact with customers to set reliability, responsiveness, and other standards for us	0.65	9.87	0.05
We frequently measure and evaluate customer satisfaction	0.67	10.15	0.05
We frequently determine future customer expectations	0.59	8.79	0.05
We inform customers in advance of changing needs	0.70	10.72	0.04
Customers share proprietary information with us	0.50	7.27	0.06
ILP (α = 0.721)			
Our firm reduces process set-up time (time required to prepare or refit equipment/workstations for production)	0.61	7.86	0.06
Our firm produces only what is demanded by customers when needed (e.g. JIT)	0.71	8.82	0.06
Operational performance (α = 0.801)			
Production cost	0.62	9.62	0.05
Labour productivity	0.52	7.76	0.06
High product performance	0.59	9.08	0.05
Ease (cost and time) to service product (well-designed product for an effective service)	0.60	9.30	0.04
Ability to introduce new products into production quickly	0.55	8.40	0.07
Ability to adjust capacity rapidly within a short time period	0.60	9.30	0.06
Delivery on due date (ship on time)	0.58	8.93	0.05
Reducing production lead time (order-entry to shipment)	0.60	9.37	0.05
Organizational performance (α = 0.856)			
Market share	0.61	9.68	0.06
Return on Investment (ROI)	0.67	11.00	0.05
Growth of market share	0.68	11.05	0.05
Growth of sales	0.66	10.65	0.05
Growth in ROI	0.77	13.26	0.04
Profit margin on sales	0.66	10.71	0.05
Overall competitive position	0.77	13.21	0.04
Technological turbulence (α = 0.744)			
The technology in our industry is changing rapidly	0.71	10.58	0.07
Technological changes provide big opportunities in our industry	0.67	9.91	0.06
A large number of new product ideas have been made possible through technological breakthrough in our industry	0.68	10.09	0.06
Technological development in our industry are rather minor	0.54	7.71	0.08
Model fit statistics: χ^2/d.f. = 1.913; RMSEA = 0.063; RMR = 0.051; NNFI=0.930; CFI=0.937; IFI=0.938			

Table 4: Results of hypotheses 1-4 using SEM

Hypotheses	Standardised coefficient	t-value	Outcome
Supplier partnership →ILP (H1)	0.25*	2.43	Supported
Customer relationship →ILP (H2)	0.51**	4.72	Supported
ILP → Operational performance (H3)	0.47**	5.64	Supported
ILP → Organizational performance (H4)	0.41**	9.10	Supported
Model fit statistics: χ^2/d.f. = 1.853; RMSEA = 0.061; RMR = 0.047; NNFI=0.934; CFI=0.941; IFI=0.941			

* Sign. at the 0.05 level
** Sign. at the 0.01 level

Table 5: Results of OLS analyses

Variables	Standardised Coefficients			
	Step 1	Step 2	Step 3	Outcome
Operational performance				
Control variables:				
Industry type: Pharmaceuticals	-0.076	-0.011	-0.006	
Industry type: Electronics	0.083	0.102	0.090	
Independent variables:				
ILP		0.340**	0.310**	
Moderator: TT		0.046	0.064	
Interaction term:				
ILP * TT			-0.260**	H5: supported
R^2	0.014	0.134	0.201	
R^2 Change	-	0.120	0.067	
F	1.622	8.631	11.145	
F Change	-	15.433	18.492**	
Organizational performance				
Control variables:				
Industry type: Pharmaceuticals	-0.060	-0.011	-0.007	
Industry type: Electronics	-0.029	-0.015	-0.024	
Independent variables:				
ILP		0.272**	0.249**	
Moderator: TT		0.026	0.040	
Interaction term:				
ILP * TT			-0.203**	H6: supported
R^2	0.004	0.079	0.119	
R^2 Change	-	0.075	0.040	
F	0.455	4.784	6.020	
F Change	-	9.081	10.178**	

** Sign. at the 0.01 level

Table 6: Results of OLS between low and high TT

Variables	Standardised Coefficients	
	High TT *(n = 121)*	**Low TT** *(n = 134)*
Operational performance		
Control variables:		
Industry type: Pharmaceuticals	0.194*	0.126
Industry type: Electronics	-0.002	0.022
Independent variables:		
ILP	-0.027	0.224*
Moderator: TT	-0.093	0.101
Interaction term:		
ILP * TT	0.159	-0.317**
Organizational performance		
Control variables:		
Industry type: Pharmaceuticals	0.029	0.002
Industry type: Electronics	0.069	-0.007
Independent variables:		
ILP	0.202	0.174*
Moderator: TT	0.036	0.039
ILP * TT	-0.065	-0.259*

* Sign. at the 0.05 level
** Sign. at the 0.01 level