2015

Supply Chain Integration Configurations: Process Structure and Product Newness

Christos Tsinopoulos
Durham University

Carlos Mena
Portland State University

Citation Details

Christos Tsinopoulos, Carlos Mena, (2015) "Supply chain integration configurations: process structure and product newness", International Journal of Operations & Production Management, Vol. 35 Issue: 10, pp.1437-1459, https://doi.org/10.1108/IJOPM-08-2013-0369

Supply chain integration configurations: Process structure and product newness

Abstract

Purpose: To explore the configurations of supply chain integration.

Design/methodology/approach: We use qualitative data from manufacturers shortlisted for the UK's Manufacturing Excellence awards over three years. Detailed processes and policies of 68 manufacturers are analysed.

Findings: Process structure and product newness require different supply chain configurations, which change as products mature. Supply chain integration is dynamic, and the extent of collaboration between suppliers and customers will be different at different moments in time. We define and discuss four key supply chain configurations: customised; ramp-up; recurring; coordinated.

Research limitations/implications: Future studies on supply chain integration should be controlled for the variation in our configurations. A limitation is the use of data which were derived for an award. We explain how we have mitigated the associated risks.

Practical implications: The configuration of integration will change as the manufacturing plant becomes more familiar with a product. Additionally, different suppliers may provide better support at different stages of a product's lifecycle. To yield better performance, supply chain integration would need to take different forms. Efforts to integrate with suppliers should not be avoided as, when certain conditions are met, integration can lead to improved performance.

Originality/value: We have identified manufacturers' main process structures and products' newness as two strategic characteristics that differentiate integration approaches with customers and suppliers, and defined four integration configurations. To the authors' knowledge this is the first study to argue that these also define the configuration of supply chain integration.

Keywords: supply chain, integration, product newness, configuration, process structure

Article Classification: Research paper

Introduction

Supply Chain initiatives that lead manufacturing organisations towards greater integration are generally perceived as positive developments (Mitra and Singhal 2008). Integration with customers and suppliers across certain operational dimensions can improve information sharing and decision making, and ultimately lead to sustainable competitive advantage (Barratt and Oke 2007). Such dimensions include the implementation of technologies that allow the quick sharing of information, and the development of relationships between a manufacturer, its customers and its suppliers. These integration dimensions are therefore likely to combine in ways that lead to different configurations, i.e. the degree to which a manufacturer strategically collaborates with its supply chain partners and collaboratively manages their intra- and inter-organisation processes (Flynn *et al.* 2010) will vary.

The emerging literature on supply chain integration identifies several such dimensions and mechanisms and explores how they are configured. Many such studies have been based on surveys with the use of perceptual measures of integration dimensions (Frohlich and Westbrook 2001; Rosenzweig *et al.* 2003; Swink *et al.* 2007). Although this approach has helped draw attention to the performance implications of integrating with customers and suppliers, it has not advanced our understanding of the context within which supply chain integration takes place. With a few notable exceptions (Lockstrom *et al.* 2010), this process largely views integration as a *monolithic* concept (Swink *et al.* 2007), i.e. it submerges variations on the basic configuration of integration between different organisations. Flynn et al. (2010), for instance, provide a detailed summary of the literature, looking into different dimensions of integration and the impact of integration on performance; they reveal some critical dimensions such as its direction, its scope, and its focus.

A number of studies have examined contextual factors that can influence the level of integration and moderate the relationship with performance. Table 1 outlines a summary of the contextual dimensions influencing supply chain integration.

Take in Table 1

Questioning the assumption of integration as a monolithic concept has led to research that explores the contextual factors and mechanisms (Swink *et al.* 2007) that can affect the relationship with performance. Although such studies have analysed the supply chain context, they have focused on the supply chain more generally and not on integration. Furthermore, although the efforts to link integration with performance have an apparent practical merit, they may lead to incomplete and potentially simplistic theoretical development of the detailed determinants of the contextual factors that determine integration.

By adopting a configuration theory approach (Miller 1986), it is possible to argue that different dimensions of supply chain integration configure into a number of common types that describe a large proportion of integrations (Lejeune and Yakova 2005). This view suggests that for each organisation there would be a different configuration of integration. Such configurations would depend on a number of contingent factors and not simply on the strength or the extent to which integration activities are carried out (Flynn *et al.* 2010).

In this paper we aim to explore the configurations of supply chain integration by asking:

What are the dimensions that determine the configurations of supply chain integration?

How do integration mechanisms differ between configurations?

The paper is structured as follows: In the next section we review the literature on the key dimensions of the supply chain. We then describe the methodology we followed to analyse the data. Then we present two key dimensions that emerged from our analysis which determine supply chain integration, process type, and a product's newness. We then discuss four different types of integration according to these dimensions. We conclude by discussing the implications of our findings for research and practice.

Literature Review

Conceptualisations of supply chain integration have focused on various dimensions leading to many different interpretations and classifications (Gimenez *et al.* 2012). Efforts have been made to classify integration practices (Das *et al.* 2006) and to analyse different forms of integration (Swink *et al.* 2007). Yet, both the definition and measurement of the concept remain ambiguous. For instance, a recent review of survey scales used to measure supply chain integration has identified more than 20 different constructs (van der Vaart and van Donk 2008).

Research into the nature of supply chain relationships has viewed integration as being shaped by the strength of the ties between customers and suppliers (Michelfelder and Kratzer 2013). The success of such relationships and their potential to lead to competitive advantage is determined by a complex set of factors including causal ambiguity, perceived buyer knowledge, prior relationship history, product customisation, and technological uncertainty (Athaide and Klink 2009). The effectiveness of supply chain relationships, therefore, is influenced by the ability of the focal organisation and its supply chain partners to effectively configure their integration mechanisms.

Previous attempts to define and identify such mechanisms have focused on internal and external factors that determine the degree to which manufacturers integrate with their customers and suppliers. Internal factors focus on the interaction and collaboration of functions within an organisation, e.g. between operations, purchasing and logistics (Pagell 2004), or across multiple strategic levels (Stevens 1989). External ones focus on the direction and levels of integration at the customer and supplier sides (Frohlich and Westbrook 2001; Flynn *et al.* 2010). A key presumption of these studies has been that suppliers and customers who collaborate by sharing information on and investment in various business processes, such as product development and production planning, are able to respond quickly and efficiently to changing environmental pressures. Integration will therefore strengthen the supply chain, which in turn will improve operational performance (Mitra and Singhal 2008).

Product Development

Integration in new product development relates to the degree to which customers and suppliers collaborate, and share ideas, processes and investment to bring new products to the market (Koufteros *et al.* 2005). Studies that have explored the dimensions used to define and subsequently measure the effect of integration mechanisms in product development have focused on the strategic perspective (e.g. Menguc *et al.* 2013) the process (e.g. Cousineau *et al.* 2004), and the scope and direction (e.g. Droge *et al.* 2000).

Strategic Level Integration

At the strategic level, Petersen *et al.* (2005), explored integration mechanisms by focusing on the nature of the relationships between customers and suppliers. They identified two integration types: (1) ‘grey box’ integration relates to customers and suppliers working together to increase product innovation; and (2) ‘black box’ integration where suppliers work independently. A different classification of supplier relationships was proposed by Blindenbach-Driessen and Van Den Ende (2010), who distinguished between project-based and non-project-based firms and argued that organisational configurations, complexity of the operational process and project management capabilities determine how project-based organisations operate. They argue that although project-based firms are strong in innovating their clients' systems, they seem to be less successful in creating their own products.

Process level Integration

At the process level, supply chain integration in product development has been operationalised by exploring the degree to which customers and suppliers are sharing processes to test ideas for the development of new products (Tsinopoulos and Al Zu'bi 2012). A common approach to exploring the mechanisms of integration has been to break down the product development project's lifecycle, i.e. idea generation to product launch (Song and Di Benedetto 2008), and then to explore the degree to which external parties collaborate during each stage to shape a new product (Carbonell *et al.* 2009). Using such an approach, for instance, Jean *et al.* (2014) explored co-designing with suppliers and found an inverted U-shaped relationship between integration and performance. Process level dimensions have helped explore the link with performance, but have not explored the dimensions that determine how manufacturers and suppliers organise their integration efforts.

Scope and Direction of Integration

Another approach used to explore the mechanisms of integration in product development has focused on its scope and direction. For instance, Droge *et al.* (2004) explored this within the context of time-based performance for designing new products. Although, such studies find that internal integration supports external integration, which in turn affects performance

(Flynn *et al.* 2010), they, again, do not account for the different dimensions of integration configurations or the associated mechanisms of working with customers and suppliers.

At a more detailed organisational level, supply chain integration mechanisms are dependent on the functions and teams used to cooperate with external parties. van Beers and Zand (2014), argue geographical diversity of teams can support the incremental improvement of existing products whereas functional and team diversity can support the development of radically new products. Further, Brattström and Richtnér (2014) have explored how integration across the R&D and procurement teams can affect the relationship with external suppliers. They suggest that supplier collaboration with different functional teams may play different roles and have different levels of impact.

Summary

Our literature review on supply chain integration in new product development is not exhaustive. Yet, it clearly indicates that manufacturers employ different mechanisms to integrate with their customers and suppliers when developing new products. Furthermore, it indicates that research on the configurations of integration has mainly been focusing on the mechanisms that can lead to improved performance. As integration with suppliers and customers is a dynamic, relation-specific attribute, configurations of mechanisms of integration would differ from manufacturer to manufacturer. On the other hand, and given the constraints associated with the management of product development processes, it would be reasonable to expect that there exists a set of common dimensions that determine the configurations of integration.

In the following section we briefly review the literature on the second functional area on which we have focused – production planning – before explaining how we conducted our research to identify the common dimensions that we propose later in the paper.

Production Planning

Integration in production planning relates to the degree to which a manufacturer and its supply chain partners share information, such as forecasts and customer orders, to manage their daily operations (Vanpoucke *et al.* 2009). Studies that have focused on the integration of production planning mechanisms have focused on the strategic (Gimenez *et al.* 2012), or the process (Lee *et al.* 1997) levels.

Strategic level integration

Stevens (1989), in his seminal work, focused on the strategic level by focusing on partnerships and identified materials and information flows as two critical dimensions of integration; a view that has been supported by a number of authors since (Pagell 2004). Organisations integrating their material flows rely on production planning considerations such as capacity, inventory, lead times, batch sizes, and delivery frequencies (Power 2005). These are supported by the integration of information flows, which aim at predicting and meeting customer demand and at organising the production systems accordingly (Hill and Hill 2009). Sharing of forecasts, orders, inventory, and capacity related data, can lead to increased day-to-day flexibility across the supply chain, reduced distortions in demand and, consequently, reduced operational costs (Lee *et al.* 1997). Given the differences in systems, markets, and types of data, the dimensions that enable integration across the supply chain are likely to be different in different contexts.

The mechanisms used for integrating production planning processes depend on the partners' collaborative behaviour (Mena *et al.* 2009). Such mechanisms are underpinned by trust (Humphries and Wilding 2001) and may include the development of collaborative and bilateral communication processes (Das *et al.* 2006). From a production planning perspective the choice between the different mechanisms for collaboration are the result of differences in style, focus, content of planning (Lambert *et al.* 1996) and degrees of power and trust (Ireland and Webb 2007). As with product development, the literature supports the view that integration in production planning has a positive impact on performance (Flynn *et al.* 2010). Yet, it does not clearly explain the different dimensions of integration configurations and the associated mechanisms of working with customers and suppliers.

Process level integration

On the process level, integration across the supply chain can have an impact on various elements of performance, including asset/cost efficiency, customer service, marketing advantages and profit stability and growth (Pagell 2004; Flynn *et al.* 2010). To achieve these benefits, organisations across the supply chain aim to harmonize their processes (Silvestro and Lustrato 2014) to match demand and supply (Stevens, 1989). As a result, a number of tools have been developed, including Collaborative Planning Forecasting and Replenishment (Barratt and Oke 2007), aimed at sharing customer information such as forecasts and delivery schedules (Huang *et al.* 2014). The differentiation in the implementation of such tools, increases the complexity of the supply base (Choi and Krause 2006) and moderate the relationships of integration on performance (Vaart *et al.* 2012).

Summary

The above literature on supply chain integration in production planning is not meant to be exhaustive. As with our review of product development, however, it clearly indicates that manufacturers employ different mechanisms to integrate with their customers and suppliers when managing their daily operations. Although most of the integration mechanisms aim at coordinating the flow of information from across the supply chain, the process of doing so depends on several relation-specific characteristics. As with product development however, there are several constraints associated with the sharing of such information and it would thus be reasonable to expect that there exists a set of common dimensions that determine the configurations of integration.

Methodology

A key premise of this paper is that the process of integrating with customers and suppliers is multidimensional (Flynn *et al.* 2010) and depends on context (Gimenez *et al.* 2012). Many of the previous studies that have acknowledged the multidimensionality of integration have employed a positivist approach to develop and test their theoretical propositions. Such approaches have helped draw attention to the performance implications, but have had to reduce integration to a limited number of items which could be reliably quantified. We argue that this has led to an inevitable loss of multidimensionality, overlooking some of the context needed to identify the dimensions that determine the configuration of supply chain integration. As a result we opted for a qualitative method that helps us capture both its contextual and multidimensional nature (Soltani *et al.* 2014), while we accept that this may limit the generalizability of the findings.

Data and analysis procedures

We used the responses of the UK's Manufacturing Excellence (MX) Awards from 2008, 2009 and 2010. The MX Awards® is a yearly competition for the best manufacturer in the UK organised by the Institution of Mechanical Engineers (IMechE). It requires entrants to complete a thorough questionnaire on several areas of their practices and report both qualitative and quantitative data. The awards, which have been running in their current form since 2000, assess the organisational processes at the manufacturing plant level in several functional areas (Garside and Tsinopoulos 2004). In total, the questionnaire consists of approximately 200 questions seeking both qualitative and quantitative answers.

For this paper we focused on the answers to the questions of the shortlisted manufacturers that a) required a qualitative response, and b) requested the reporting of processes that could disclose information on supplier and customer integration. In total, we used 21 questions, the list of which is available from the authors upon request. A group of these questions explicitly asked respondents about their integration processes (e.g. *What is your customers' and/or suppliers' involvement in manufacturing process innovation?*), whereas the remaining asked them to describe processes where, should integration exist, they would have explained how the customers or suppliers are involved. For instance, when there is close integration in the development of the production plan, the answer to '*How is the master production schedule structured and collated for managing operations and the supply chain, in both the long and short term?'* could also include reference to the supplier, e.g. *by considering the available capacity within our suppliers' operations*. A typical response explained in about 300 words a participant's practice in a given area and included supporting evidence. The total number of companies included in this study was 68, excluding any repeat entries, and their answers to the questions we used amounted to 478 pages or 1,425 passages.

The data provide a good fit for the research aim of this paper because the responses explore the contextual insights of manufacturers' integration practices and as a result help identify the dimensions that determine the configuration of supply chain integration. In addition, the procedures used to collect and analyse the data meet the criteria often associated with such studies (Symon and Cassell 2012), namely, credibility, conformability, dependability and transferability (Guba and Lincoln 1989). To meet the first two we followed several processes. To meet the dependability and transferability criteria, we provide quotes and detailed information about the responses we used in the following sections aiming to enable "the reader to judge why certain decisions were made and how the eventual understanding of the research situation was achieved" (Symon and Cassell 2012 p. 208).

Credibility was assured during both the data collection and analysis. During data collection, the process of collating the questionnaire required input from several departments and therefore provided a detailed description of each manufacturer's practices. Furthermore, one of the two authors of this paper has been engaged in the process of the awards since 2000 and as a result there has been sustained engagement with both the process of collecting and verifying the data. To meet the credibility criterion during the analysis of the data, two steps were followed: the quotes from the responses were first categorised into the process areas (production planning and product development); the concepts that emerged from the responses were then coded and categorised. The analysis was facilitated using QSR NVivo qualitative analysis software, which helped us keep a trail of the analysis we conducted, ensuring that the second quality criterion, conformability, was also met. The categorisation resulted in a fairly even split between the two process areas.

To ensure that previous literature informed the coding process (Miles and Huberman 1994), we started by reviewing how supply chain integration has been measured in previous studies that have used survey methods (e.g. Rosenzweig *et al.* 2003; Cousins and Menguc 2006; Koufteros *et al.* 2007; Swink *et al.* 2007; Flynn *et al.* 2010). Since supply chain integration cannot be measured directly, these studies have used perceptual measures as indicators of the extent of the integration of a manufacturer with its suppliers across various dimensions. This review provided us with the initial codes which were used in the next stage of the analysis. Although our resulting list of dimensions was not exhaustive, it included the key areas that previous studies have used to define and subsequently measure supply chain integration. A similar review has also been conducted by van der Vaart and van Donk (2008).

The purpose of the coding process was to identify salient categories through constant comparison and to identify the main relationships between codes, including the contextual factors, to build an explanation of the supply chain integration categorisations. As is customary in qualitative studies (Miles and Huberman 1994), the coding process was iterative. After defining the initial codes, we went back to the data and identified themes which related to them. During subsequent iterations, they were refined and reclassified, leading to the emergence of several new codes. The new ones covered aspects of the business processes that had not been explicitly covered in the first step. Each new code was discussed amongst the researchers and a definition was agreed. Following this process, 84 codes emerged.

The coding process was conducted by two coders to ensure reliability of the coding judgments. The level of agreement between the coders was 75% which is considered to be an acceptable reliability rate for this type of study (Neuendorf 2002). We resolved the differences of the remaining 25% through discussion and consensus.

The codes were then categorised using the following iterative process. First, they were grouped in terms of the process area they were describing and in terms of the similarity of the configurations they were describing for integrating those process areas. For instance, when explaining the production plan, answers that were describing similar configurations for the integration of suppliers in the development and sharing of forecasts, e.g. through the use of information systems, were grouped together. This iterative process was repeated several times until all responses were grouped into one category each.

As noted earlier, to ensure transferability (Guba and Lincoln 1989), we provide details on the context of the analysis as well as several examples of quotes that were used to describe their integration practices. Furthermore, as shown in Table 2, our resulting sample consists of a relatively good representation of industrial sectors and types of business. It has to be noted though that this list may not be representative sample of manufacturers in the UK or abroad. However this is partially mitigated by the breath of manufacturing sectors covered in this study. Future research could seek to validate the findings of this study using random sampling or targeting specific sub-sectors within manufacturing.

Take in Table 2

We acknowledge that the responses to several questions may be open to bias and manipulation. A potential source of bias is the motivation of completing the questionnaires. As respondents aim for an award, it is not inconceivable that they provide dishonest or "polished" answers to increase their chances of success. Although this is a potential limitation of the data, steps have been taken by both the Institution and the authors to minimise its impact on the findings. First, the assessment process includes several steps aimed at eliminating dishonest behaviour or deliberate exaggeration. The questionnaire requires the provision of explicit evidence of the claims respondents make. Such evidence has been varied but has included copies of policy documents, examples of key performance indicators, and copies of internal communications. When such evidence was not provided, the answers were not included in the analysis (there were very few instances when this was necessary). In addition, a group of assessors selected by the IMechE visited the shortlisted companies and then made any necessary changes on an answer's content. Although only a few such changes have been made, they have been taken into account in this study. Third, through the coding process, we cross-checked the sections answered and no inconsistencies were found. The above actions do not completely eliminate bias, but we believe that they significantly reduce it and as a result we believe its impact on the analysis is negligible.

Following several iterations, we identified two contextual dimensions that determined the configurations of the supply chain integration practices that were reported. Using these two dimensions as axes, it was possible to group the approaches described by the informants into four categories that represent the supply chain configuration strategies. In the following section we describe the two contextual dimensions and the four supply chain configuration strategies that emerged from the data and discuss how they relate to each other.

Results and Discussion

The two contextual dimensions affecting supply chain integration decisions that emerged from the data analysis are process structure and its relationship to customer demand, and a product's newness to the manufacturer. Process structure is driven by uncertainty in customer demand (Childerhouse *et al.* 2002; van Donk and van der Vaart 2004; Koufteros *et al.* 2005), as manufacturers organise their processes according to variability in customers' orders. Product newness, on the other hand, is associated with product lifecycle (Childerhouse *et al.* 2002; Narasimhan *et al.* 2010), and also to industry clockspeed (Fine 1998; Childerhouse *et al.* 2002; van Donk and van der Vaart 2004; Fynes *et al.* 2005; Koufteros *et al.* 2005), as this relates to the pace at which new products are introduced.

Combining the two contextual dimensions and using examples from our data, we identified four supply chain integration configurations, which we have labelled customised, ramp-up, recurring, and coordinated. The four categories differ in the processes used to integrate customers and suppliers in product development, and production planning. Figure 1 summarises the integration characteristics and management practices which are associated with each quadrant. The four subsections that follow describe each of the four configuration categories. We discuss each in turn and explain how integration approaches differ between the configurations we have identified in product development and production planning.

Take in Figure 1

Customised Integration

This category includes integration mechanisms that focus on the production of new-to-the-firm products produced in very low volumes. Approaches to integration in this configuration are in our sample adopted by build-to-order manufacturers, e.g. engineering companies that supply components and sub-assemblies to the aerospace, electrical machines and equipment, marine, and medical equipment sectors. The main difference between the integration mechanisms used in this category and those in other configurations is the closeness of collaboration with the customer and supplier and the combination of new product development with production planning.

Product development

Formally, the integration process starts with the signing of a contract and is followed by a discussion about detailed specifications. Informally, customers and manufacturers have frequent discussions which aim at understanding each other's requirements and capabilities. Contrary to recurring and coordinated integration, where product specifications are set, customers describe their need but not the solution. As the manufacturer develops the product and solution, technical specifications are discussed in detail with customers and are then communicated to suppliers using mechanisms that are supported by the development of close relationships, such as frequent discussions, visits, and exchange of emails.

Innovation takes place by addressing customers' expressed needs rather than through the development of an entirely new product, i.e. product innovation is pulled rather than pushed (Blindenbach-Driessen and Van Den Ende 2010) which is more the case in the other configurations. As shown in the following extract, the accuracy of expression of the technical requirements depends on the customer's experience with the product. Some of the best performing companies explained that they will make the process of integration as structured as possible by using formal methodologies to capture customer requirements. This was so, regardless of the degree of trust and prior experience that may exist in the relationship with the customer (Smets *et al.* 2013b):

> *"At the start of a contract we (...) discuss the technical specification required (...) especially if the customer has developed the product before they have a good understanding of their own requirements" (respondent from aerospace sector).*

At the front end of development, frequent meetings and communication are taking place to enable customers and manufacturers to learn from each other (Cousins *et al.* 2011). During the middle and later stages, customer interaction focuses on project managing the development and delivery of the product. Despite earlier evidence, which argued for increased customer participation when control mechanisms are formal (Smets *et al.* 2013a), our respondents suggested that during the later stages there was little collaboration with customers in the management of specific processes. Manufacturers provide updates on the progress of the project, but they do not work closely on managing intra-organisational processes.

On the suppliers' side, integration mechanisms are supporting close relationships during the front end of development, by facilitating meetings and regular communication. This is similar to product development of ramp-up integration mechanisms where suppliers are encouraged to evaluate ideas and may be given full responsibility for the development of certain components. This approach, which has been previously labelled the *black box* (Petersen *et al.* 2005), reduces the risk of knowledge-sharing with competitors, as it gives key suppliers the technical autonomy to invest in and develop subsystems. Achieving this requires the exchange of a combination of technical capabilities and market knowledge (Cousins *et al.* 2011), and is therefore less appropriate for coordinated and recurring where the focus is more on meeting daily demand. Manufacturers collaboratively manage processes that define the new product's design by sharing assets with key suppliers, e.g. specialised equipment. Given the uncertainty often associated with entirely new products (Menguc *et al.* 2013) there is close monitoring of the development of these components:

> *"...suppliers have a clear understanding of what is required, (...). Close relationships and monitoring are key..." (marine sector)*

Customised integration in product development is close on both sides of the supply network, with the focal company often acting as a broker:

> *"(...) we try to bring together all parties concerned. This includes customers, designers, toolmakers and material suppliers. All of these are experts in their own area but often do not consider the requirements of the others. By facilitating discussions, all parties gain a greater understanding of the requirements but may also bring a different perspective to resolving a particular issue that may not have otherwise been considered. Early involvement by key players promotes project ownership by those suppliers." (aerospace sector)*

Production planning

In production planning, the mechanisms of integration are less formal than in the other configurations. Although production plans exist, these are associated with the control of product development and no model was reported for the integration of the supply chain in a manner similar to that found in the ramp-up and coordinated configurations (Gunasekaran and Ngai 2005). The volume of products is low and customers visit the manufacturer to receive one-to-one updates on the progress of the new product. Such visits may result in change requests, which are carefully managed to avoid scope creep and misinterpretations of the design requirements.

Customised integration mechanisms do not rely extensively on ICT systems for integrating with suppliers and customers as is the case in ramp-up and coordinated configurations. Since the take-up of integration technologies by engineer-to-order organisations is relatively low (Tsinopoulos and Bell 2010), information sharing, both on the suppliers' and customers' side, takes place using ad hoc processes such as emails and phone calls. Such processes advance the design, communicate progress and clarify requests as illustrated in the following quote:

> *"The main [ICT] integration is the use of CAD. We have product ranges available on CAD for our customers to incorporate in their designs (..)" (electric supplier)*

Previous work on integration that has argued for the development of trust in such organisational contexts, claims that it depends on the interaction of buyers' and suppliers' beliefs and actions which in turn leads to commitment of resources (Johnston *et al.* 2004). The development of high value, customised products, which require the implementation of sophisticated engineering knowledge and skill, requires the sharing of information between the various stakeholders (Blindenbach-Driessen and Van Den Ende 2010). Such information, however, may be sensitive as it is often perceived as a source of competitive advantage

(Tsinopoulos and Bell 2010). Customised integrations are largely based on trust and the resultant relationships are likely to be long lasting, depending often on individuals within two or more organisations.

Customized Configurations involve intense integrative mechanisms, requiring high levels of trust and information sharing and processes which are often informal and customized according to the context.

Recurring Integration

This configuration includes supply chain integrations that aim at delivering familiar products in low volumes that are only manufactured following customers' recurring orders. Approaches to integration in this configuration are adopted by manufacturers of relatively mature products where a customer base already exists, e.g. engineering companies in the aerospace, railways and off-road equipment, and oil and gas sectors. The main difference between this and the integration mechanisms in the other configurations is the familiarity of the product specification by the customer and supplier, and the greater focus on production planning.

Product development

Integration mechanisms in product development on the customer side focus on the sharing of detailed technical modifications to existing products. Similar to customised configurations, knowledge, manifested as technical specifications, is shared between the various parties using informal communication channels with relative "ease" (Un *et al.* 2010). However, unlike customised integration, customers are familiar with the manufacturer's products and are requesting incremental improvements (Athaide and Klink 2009).

Customers' requests are more specific than those in customised integration and are managed through a process of continuous, often formal communication interaction.

The mechanism of intra-organisational integration focuses on the management of processes related to the later stages of the development process. As with customised configurations, project management practices support timely completion and the development of trust (Smets *et al.* 2013b). Innovation takes place from within customers' systems (Blindenbach-Driessen and Van Den Ende 2010) as product development processes focus more on the incremental improvement and customisation of existing products rather than the introduction of entirely new products. As explained by Menguc *et al.* (2013), the customers' impact on radical innovation projects is minimal, but they could actually benefit incremental innovation projects as indicated in the following quote:

> *"Customer visits lead to an enhanced understanding (...). This frequently leads to informed enquiries along the lines of "could you modify product X by…?" These have […] led to new product ideas which has helped us maintain high levels of innovation" (nuclear energy sector)*

Supplier integration in product development consists of a technical exchange of ideas for the modification of existing products which works in two different ways. One is to make use of the supply chain relationships established during customised integration, i.e. when the product was new and there was scope for radical innovation (Menguc *et al.* 2013). As was explained by one of the low volume manufacturers in our sample, *"early involvement by key players promotes project ownership by those suppliers."* The benefit of this approach is that the prospect of future continued business incentivises the supplier to provide cost savings and development of ideas (Gassenheimer *et al.* 1995). A second way is to use a tendering process for achieving higher cost savings. During this process, detailed information is sought on performance metrics, such as lead times and quality, and the interaction is taking place with both the procurement department and R&D functions. The relationship here lasts for as long as the project and, despite the findings of Brattström and Richtnér (2014), there were examples of close integration between the two functions and suppliers. Put differently, in recurring configurations, procurement and R&D functions present a united front when integrating with a supplier for the development of specifications.

Production planning

Integration mechanisms in production planning aim at communicating progress, and at managing the project's phases of the development of the agreed modifications and is more tightly controlled (Lau *et al.* 2010b). On the customer side, progress is reported using standard communication methods (email, phone calls, etc.). Portals are mainly used to provide access to relevant product documentation. Similarly, communication with suppliers is conducted using emails and phone calls with few making use of supplier portals aimed at providing quick updates on the progress of the project and on supplier requirements. As many of the companies in our data were relatively small, such initiatives were either driven by their larger customers or were ad hoc.

Recurring configurations are characterised by a technical exchange of ideas for the modification of an existing product, where production planning is aligned with the project phases and information is shared through generic communication tools such as email and telephone. This type of integration configuration is appropriate in situations where familiar products (i.e. mature) are being produced in low volumes and where the products are manufactured following customers' recurring orders (i.e. stable demand). Manufacturers of relatively mature products such as gas turbines often use these configurations.

Ramp-up integration

This configuration includes supply chain integrations that focus on the production of new and relatively standardised products in high volumes. Approaches to integration in this configuration are adopted in our sample by manufacturers in the automotive and electronics sectors. Customers and suppliers are integrated for testing newly developed products and for setting future production schedules. The main difference between this and the previous two configurations, where integration was carried out with other businesses, is that it encourages the participation of end users for the collection and testing of new ideas.

Product development

Integration mechanisms in product development on the customer side focus on product testing and marketing. Although systematic collaboration with customers is often advocated as good practice (Cooper and Kleinschmidt 1987) and has been present in customised configurations, in ramp-up the views of only a few customers are sought during the early phases of the product development process (Griffin and Hauser 1996). In line with the findings of Menguc *et al.* (2013), who argue that customers' integration in radically new products is minimal, customers are invited to sales visits after the products have been launched. Feedback is collected to address any initial technical problems, incrementally improve their performance, and develop marketing strategies.

Communication with customers is administered through marketing or sales departments. These departments are often closely integrated with R&D and engineering, bringing the "voice of the customer" to the product development process and consequently translating it into product specifications (Lamore *et al.* 2013).

Integration mechanisms with suppliers during product development focus on the development of process technology. Similar to customised configurations, suppliers provide the technical ability to test the feasibility of new ideas which in turn improve product development performance (Petersen *et al.* 2005; Koufteros *et al.* 2007). As also explained by one respondent:

> *"We use the knowledge of our tooling suppliers to help develop new technologies. Here, for example, we are using the skills of [a supplier] to assist in the development of a one-hit tightening process to achieve yielded fasteners on the frame" (automotive sector).*

Production planning

In production planning, integration mechanisms make use of established information systems. Similar to coordinated configurations, but unlike customised and recurring, visibility is increased by quickly communicating new orders, forecasts, and any changes in trends as production is ramping up (Barratt and Oke 2007). Changes in customer demand patterns are frequent as the take-up of the new products is uncertain, and suppliers and customers aim to quickly resolve technical problems associated with the newness of the products. Consequently, flexibility and problem solving ability become key criteria for establishing relationships with and selecting suppliers as indicated in the quote below:

> *"…[We invite] on site assistance with problem solving for quality issues, also support and co-ordination for production and planning issues" (automotive sector).*

Ramp-up configurations involve structured and systematic integration mechanisms where information is shared extensively using already established processes and IT systems. Integration configurations of this type are most suitable in high clockspeed situations where the aim is to develop new products to be ramped up for high volumes. Such configurations are often adapted by manufacturing organisations that belong to high volume industries, such as FMCG, where the introduction of new products is relatively frequent and the volume of products is high.

Coordinated Integration

This configuration includes supply chain integrations that focus on the production of mature and relatively standardised products in high volumes. Although different from Lejeune and Yakova's (2005) *coordinated supply chain,* the integration mechanisms in this configuration also aim at sharing information on a supply-chain-wide basis. Examples of companies in our sample included high volume manufacturers in the automotive, electronics, and process sectors. Similar to ramp-up, integration mechanisms in coordinated configurations differ according to how close the organisation is to the end user. In contrast to the other configurations, however, integration mechanisms here aim mainly to incrementally improve the product and improve operational efficiencies.

Product development

In product development, integration mechanisms modify and improve existing products. Integration with customers involves the collection of feedback on technical problems and the collection of ideas for modifications and improvements to existing products. Customers, who are already familiar with the products, request specific and detailed modifications, which lead mainly to incremental improvements (Menguc *et al.* 2013). Large scale feedback techniques, such as focus groups and surveys, are used to systematically collect and analyse customers' views. Similar to *ramp-up* integration, several of these activities are administered by the marketing and sales departments.

On the suppliers' side, integration in product development is relatively limited. As with recurring but unlike customised configurations, supplier efforts focus on incremental improvements of existing products. Yet, there is a significant focus on integration for process innovation for reducing costs and defects through the elimination of wastefulness across the supply chain activities by using established methodologies, such as lean manufacturing and Six Sigma.

Production planning

During production planning, integration mechanisms of coordinated configurations use information systems to link customer demand with supplier orders and aim at increasing the speed of delivery and minimising transaction costs. The development of the production plan is integrated both on the supplier and customer sides using linked information systems. On the customer side, orders are collected and forecasts are developed. Manufacturers provide information on the distribution channels and use it to develop an understanding of customer behaviour and trends.

Communication in itself is not a sufficient integration mechanism to improve suppliers' performance, although collaboration has been shown to do so (Prahinski and Benton 2004). When available, and unlike the integration in the other configuration types, point of sales data are collected and shared across the supply chain which improves the accuracy and timeliness of market data (Bowersox and Calantone 1998). In highly integrated cases in our sample, production schedules are shared with key suppliers who then use them to develop their own plans. As with the other integration configurations, sharing planning processes increases the level of trust between the two parties and subsequently improves performance (Johnston *et al.* 2004). Effective information sharing enhances supply chain management practice as it improves performance metrics such as delivery time (Zhou and Benton 2007), customer service and financial performance (Vickery *et al.* 2003).

Coordinated Configurations are characterised by established, well-developed and tested processes, and information systems intended to reduce transaction costs. Such configurations of integration are aimed at delivering high volumes of products that the manufacturer is familiar with, such as manufacturing plants in industrial sectors where cost and speed are the key purchase criteria.

Conclusions

In this paper we set out to answer the following two research questions:

- What are the dimensions that determine the configurations of supply chain integration?
- How do integration mechanisms differ between configurations?

The first dimension we identified is the way a manufacturer organises its process in order to fulfil customer demand. The second involves the product's newness to the customer and supplier. Using the two dimensions, we defined four supply chain integration configurations which we labelled as customised, ramp-up, recurring, and coordinated (Figure 1).

The different configurations require different integration mechanisms which change as products mature. For each configuration we have identified and discussed several such mechanisms. When volumes are low, e.g. in engineering to order manufacturers, the likely configurations are customised and recurring. In customised, integration mechanisms will be based on frequent and often less formal communication processes, aimed at addressing the customer's expressed needs. The focus will be more on the front end of product development. In recurring, integration mechanisms become more formal, extending the relationships developed when the products were new, aiming at addressing technical modifications, and the focus will be more on the later stages of development.

When volumes are high and products standardised, e.g. in FMCG and automotive manufacturers, the likely configurations are ramp-up and coordinated. In both cases, integration mechanisms encourage input from the end user, and make use of information systems to process ordering information. In ramp-up, integration mechanisms focus on product testing and marketing, aiming at bringing the voice of the customer to the product development process. In coordinated, the focus is on cost reduction through the elimination of waste.

Implications for research

Our results have implications for researchers investigating supply chain integration. Process structure and product newness and the four configurations we have identified could explain the diversity and dynamism of supply chain integration practices and efforts. Theoretical efforts to explain the mechanisms employed to integrate with customers and suppliers would need to account for the diversity our dimensions propose. For instance, customised integration will require a different approach to developing a relationship with suppliers and understanding customer needs, to that needed in coordinated integration. As a result the explanation of the mechanisms through which integration leads to improved performance would be different, depending on the interaction of product newness and process structure. This argument could add a new insight to the findings of recent studies, who argue for a nonlinear relationship between integration and performance (Das *et al.* 2006; Villena *et al.* 2011). Level of integration and performance are likely to be moderated by product newness and process structure – a proposition which could be tested in a future study.

A final implication for researchers relates to the methods used to measure integration. As the configuration of integration depends on the type of operation and product newness, studies examining the extent of integration could focus more explicitly on the different groupings according to the four categories we offer here. Therefore, we would recommend that scales used within surveys are customised to capture the type as well the extent of integration between customers and suppliers.

Implications for Practice

Our results have implications for supply chain and procurement managers. Efforts to integrate with customers and suppliers are likely to vary depending on to which quadrant an operation belongs. The configuration of integration will change as a product matures. Different suppliers may provide better support at different stages of a product's lifecycle. During the development of new products, those suppliers with more robust product development processes would better support the launch of new products, whereas at a later stage those with more streamlined manufacturing operations and better integration of ICT systems could provide a better fit.

When swapping between suppliers is not feasible, we recommend that different relational governance mechanisms are set out from the start. Given that the nature of the relationship between a manufacturer and its suppliers will change as the products for which they engage mature, the way a relationship is defined and governed would also be expected to change. Procurement managers could therefore ensure that this change is reflected in the formalised agreement between the two.

Both of these suggestions would have implications for the type of contracts that would be developed and administered between the two parties. Again, the impact of the product lifecycle could be reflected in the contractual agreement to ensure that appropriate emphasis is given at the relevant stages.

Our final advice to practitioners is that although the configuration of supplier integration changes across quadrants, there will almost always be a way of integrating with customers and suppliers. As was also evident in a minority of our sample cases, lack of integration efforts is attributed to the uniqueness of the operation. Our study confirms that such variations do exist, yet supply chain integration would take different forms. Consequently, efforts to integrate with the suppliers should not be avoided as, when certain conditions are met, it could lead to improved performance.

Limitations

Our study has some limitations which may affect the generalizability of our findings. Two limitations relate to the source of our data. The companies included in this study are those that have applied for an award in the UK and as such the sample is not necessarily representative of manufacturers in the UK or abroad. This could create bias for either the completion of the application or nature of the sample. In relation to the former, and as explained in the methodology section, several measures have been taken both by the organisers of the awards and by the authors of this study to eliminate any dishonest responses aimed at improving the respondents' chances of success. However, we cannot argue that we have completely eliminated this possibility. In relation to the latter, the data provided us with several relevant examples, which although insightful, there were not always fully representative of industry practice.

A third and linked limitation relates to the process of the identification of the two dimensions: process structure and product newness. During our analysis we followed a rigorous process to ensure that the two dimensions and resulting classifications are the ones that best fit our data. Although our analysis is in line with literature on process structure and product newness, we accept the fact that other dimensions might be relevant.

Further Research

Directions for future research stem first from our limitations. Given our findings we would encourage future researchers to strengthen the conceptualisation of the dimensions of integration of production planning and product development. This could be conducted by adding some additional ones or by further exploring the theoretical contexts within which the ones we identified apply. Following this, we would encourage future researcher to conduct a wider survey which confirms our findings and future conceptualisation and improves their validity. Such a study, however, should take into account the variations in the approach to integration reported here. For instance, a wider survey could help to statistically confirm our results using cluster analysis, and provide insights into contextual differences across manufacturing sub-sectors.

A second avenue for future research is to explore the link between integration and performance. Previous studies have widely supported the argument that closer integration with customers and suppliers leads to improved performance. Although our findings do not contradict this assertion, they shed new light onto the way integration could lead to performance improvement. As the configuration of integration varies significantly across the quadrants of Figure 1, the process through which performance is improved should also vary. Future studies could therefore explore this link by developing measurement scales specific to each quadrant and then examine how variations in integration can affect plant performance.

A final avenue for future research relates to the second limitation of this study. To identify any additional dimensions we could examine the evolution of supply chain integration over time. The most likely change would be around product newness; as manufacturing plants become more familiar with the products they produce, the focus on integration is likely to change. Our data focused on the manufacturers' practices during a short period of time (three years). A future study could examine how supply chain integration changes over time by tracking the development of a new product over its life cycle.

References

Athaide, G. A. and R. R. Klink (2009). "Managing Seller–Buyer Relationships during New Product Development." Journal of Product Innovation Management **26**(5): 566-577.

Barratt, M. and A. Oke (2007). "Antecedents of supply chain visibility in retail supply chains: A resource based theory perspective." Journal of Operations Management **25**(6): 1217-1233.

Blindenbach-Driessen, F. and J. Van Den Ende (2010). "Innovation Management Practices Compared: The Example of Project-Based Firms*." Journal of Product Innovation Management **27**(5): 705-724.

Bowersox, D. J. and R. J. Calantone (1998). "Executive Insights: Global Logistics." Journal of International Marketing **6**(4): 83-93.

Brattström, A. and A. Richtnér (2014). "Good Cop–Bad Cop: Trust, Control, and the Lure of Integration." Journal of Product Innovation Management **31**(3): 584-598.

Carbonell, P., A. I. Rodríguez-Escudero and D. Pujari (2009). "Customer Involvement in New Service Development: An Examination of Antecedents and Outcomes*." Journal of Product Innovation Management **26**(5): 536-550.

Childerhouse, P., J. Aitken and D. R. Towill (2002). "Analysis and design of focused demand chains." Journal of Operations Management **20**(6): 675-689.

Choi, T. Y. and D. R. Krause (2006). "The supply base and its complexity: Implications for transaction costs, risks, responsiveness, and innovation." Journal of Operations Management **24**(5): 637-652.

Cooper, R. G. and E. J. Kleinschmidt (1987). "New Products: What Separates Winners from Losers?" Journal of Product Innovation Management **4**(3): 169-184.

Cousineau, M., T. W. Lauer and E. Peacock (2004). "Supplier source integration in a large manufacturing company." Supply Chain Management: An International Journal **9**(1): 110-117.

Cousins, P. D., B. Lawson, K. J. Petersen and R. B. Handfield (2011). "Breakthrough Scanning, Supplier Knowledge Exchange, and New Product Development Performance." Journal of Product Innovation Management **28**(6): 930-942.

Cousins, P. D. and B. Menguc (2006). "The implications of socialization and integration in supply chain management." Journal of Operations Management **24**(5): 604-620.

Das, A., R. Narasimhan and S. Talluri (2006). "Supplier integration--Finding an optimal configuration." Journal of Operations Management **24**(5): 563-582.

Droge, C., J. Jayaram and S. K. Vickery (2000). "The Ability of Minimize the Timing of New Product Development and Introduction: An Examination of Antecedent Factors in the North American Automobile Supplier Industry." Journal of Product Innovation Management **17**(1): 24-40.

Droge, C., J. Jayaram and S. K. Vickery (2004). "The effects of internal versus external integration practices on time-based performance and overall firm performance." Journal of Operations Management **22**(6): 557-573.

Fine, C. H. (1998). Clockspeed: Winning industry control in the age of temporary advantage, Basic Books.

Fisher, M. L. (1997). "What is the right supply chain for your product?" Harvard Business Review **75**(2): 105-116.

Flynn, B. B., B. Huo and X. Zhao (2010). "The impact of supply chain integration on performance: A contingency and configuration approach." Journal of Operations Management **28**(1): 58-71.

Frohlich, M. T. and R. Westbrook (2001). "Arcs of integration: an international study of supply chain strategies." Journal of Operations Management **19**(2): 185-200.

Fynes, B., C. Voss and S. de Bu´rca (2005). "The impact of supply chain relationship dynamics on manufacturing performance." International Journal of Operations & Production Management Decision **25**(1): 6-19.

Garside, J. and C. Tsinopoulos (2004). Guide to Manufacturing Excellence, PE Publishing.

Gassenheimer, J. B., R. J. Calantone and J. I. Scully (1995). "Supplier involvement and dealer satisfaction: implications for enhancing channel relationships." Journal of Business & Industrial Marketing **10**(2): 7-19.

Gimenez, C., T. v. d. Vaart and D. P. v. Donk (2012). "Supply chain integration and performance: the moderating effect of supply complexity." International Journal of Operations & Production Management **32**(5): 583-610.

Griffin, A. and J. R. Hauser (1996). "Integrating R&D and Marketing: A Review and Analysis of the Literature." Journal of Product Innovation Management **13**(3): 191-215.

Guba, E. G. and Y. S. Lincoln (1989). Fourth Generation Evaluation. Newbury Park, CA, Sage.

Gunasekaran, A. and E. W. T. Ngai (2005). "Build-to-order supply chain management: a literature review and framework for development." Journal of Operations Management **23**(5): 423-451.

Hill, A. and T. Hill (2009). Manufacturing Operations Strategy. London, Palgrave MacMillan.

Huang, M.-C., G.-F. Yen and T.-C. Liu (2014). "Reexamining supply chain integration and the supplier's performance relationships under uncertainty." Supply Chain Management: An International Journal **19**(1): 64-78.

Humphries, A. S. and R. Wilding (2001). "Partnerships in UK Defense Procurement." The International Journal of Logistics Management **12**(1): 83-96.

Ireland, R. D. and J. W. Webb (2007). "A multi-theoretic perspective on trust and power in strategic supply chains." Journal of Operations Management **25**(2): 482-497.

Jean, R.-J. B., R. R. Sinkovics and T. P. Hiebaum (2014). "The Effects of Supplier Involvement and Knowledge Protection on Product Innovation in Customer–Supplier

Relationships: A Study of Global Automotive Suppliers in China." Journal of Product Innovation Management **31**(1): 98-113.

Johnston, D. A., D. M. McCutcheon, F. I. Stuart and H. Kerwood (2004). "Effects of supplier trust on performance of cooperative supplier relationships." Journal of Operations Management **22**(1): 23-38.

Koufteros, X., M. Vonderembse and J. Jayaram (2005). "Internal and External Integration for Product Development: The Contingency Effects of Uncertainty, Equivocality, and Platform Strategy." Decision Sciences **36**(1): 97-133.

Koufteros, X. A., T. C. E. Cheng and K. H. Lai (2007). ""Black-box" and "gray-box" supplier integration in product development: Antecedents, consequences and the moderating role of firm size." Journal of Operations Management **25**(4): 847-870.

Lambert, D. M., M. A. Emmelhainz and J. T. Gardner (1996). "Developing and Implementing Supply Chain Partnerships." International Journal of Logistics Management **9**(2): 1-19.

Lamore, P. R., D. Berkowitz and P. A. Farrington (2013). "Proactive/Responsive Market Orientation and Marketing—Research and Development Integration." Journal of Product Innovation Management **30**(4): 695-711.

Lau, A. K. W., R. C. M. Yam, E. P. Y. Tang and H. Y. Sun (2010b). "Factors influencing the relationship between product modularity and supply chain integration." International Journal of Operations & Production Management **30**(9): 951-977.

Lee, H. L., V. Padmanabhan and S. Whang (1997). "Information distortion in a supply chain: the bullwhip effect." Management Science **43**(4): 546-558.

Lejeune, M. A. and N. Yakova (2005). "On characterizing the 4 C's in supply chain management." Journal of Operations Management **23**(1): 81-100.

Lockstrom, M., J. Schadel, N. Harrison, R. Moser and M. K. Malhotra (2010). "Antecedents to supplier integration in the automotive industry: A multiple-case study of foreign subsidiaries in China." Journal of Operations Management **28**(3): 240-256.

Mena, C., A. Humphries and R. Wilding (2009). "A Comparison of Inter- and Intra-Organisational Relationships: Two Case Studies from UK Food and Drink Industry." International Journal of Physical Distribution and Logistics Management **39**(9): 762-778.

Menguc, B., A. Seigyoung and P. Yannnopoulos (2013). "Customer and Supplier Involvement in Design: The Moderating Role of Incremental and Radical Innovation Capability." Journal of Product Innovation Management **31**(2): 313-328.

Michelfelder, I. and J. Kratzer (2013). "Why and How Combining Strong and Weak Ties within a Single Interorganizational R&D Collaboration Outperforms Other Collaboration Structures." Journal of Product Innovation Management **30**(6): 1159-1177.

Miles, M. B. and A. M. Huberman (1994). Qualitative Data Analysis: An Expanded Sourcebook USA, SAGE Publications.

Miller, D. (1986). "Configurations of Strategy and Structure: Towards a Synthesis." Strategic Management Journal **7**(3): 233-249.

Mitra, S. and V. Singhal (2008). "Supply chain integration and shareholder value: Evidence from consortium based industry exchanges." Journal of Operations Management **26**(1): 96-114.

Narasimhan, R., M. Swink and S. Viswanathan (2010). "On Decisions for Integration Implementation: An Examination of Complementarities Between Product-Process Technology Integration and Supply Chain Integration." Decision Sciences **41**(2): 355-372.

Neuendorf, K. (2002). The content analysis guidebook, Sage Publications.

Pagell, M. (2004). "Understanding the factors that enable and inhibit the integration of operations, purchasing and logistics." Journal of Operations Management **22**(5): 459-487.

Petersen, K. J., R. B. Handfield and G. L. Ragatz (2005). "Supplier integration into new product development: coordinating product, process and supply chain design." Journal of Operations Management **23**(3-4): 371-388.

Power, D. (2005). "Supply chain management integration and implementation: a literature review." Supply Chain Management: An International Journal **10**(4): 252-263.

Prahinski, C. and W. C. Benton (2004). "Supplier evaluations: communication strategies to improve supplier performance." Journal of Operations Management **22**(1): 39-62.

Rosenzweig, E. D., A. V. Roth and J. W. Dean (2003). "The influence of an integration strategy on competitive capabilities and business performance: An exploratory study of consumer products manufacturers." Journal of Operations Management **21**(4): 437-456.

Silvestro, R. and P. Lustrato (2014). "Integrating financial and physical supply chains: the role of banks in enabling supply chain integration." International Journal of Operations & Production Management **34**(3): 298-324.

Smets, L. P. M., F. Langerak and S. A. Rijsdijk (2013a). "Shouldn't Customers Control Customized Product Development?" Journal of Product Innovation Management **30**(6): 1242-1253.

Smets, L. P. M., K. E. van Oorschot and F. Langerak (2013b). "Don't Trust Trust: A Dynamic Approach to Controlling Supplier Involvement in New Product Development." Journal of Product Innovation Management **30**(6): 1145-1158.

Soltani, E., P. K. Ahmed, Y. Ying Liao and P. U. Anosike (2014). "Qualitative middle-range research in operations management." International Journal of Operations & Production Management **34**(8): 1003-1027.

Song, M. and C. A. Di Benedetto (2008). "Supplier's involvement and success of radical new product development in new ventures." Journal of Operations Management **26**(1): 1-22.

Stevens, G. C. (1989). "Integrating the Supply Chain." International Journal of Physical Distribution & Logistics Management **19**(8): 3-8.

Swink, M., R. Narasimhan and C. Wang (2007). "Managing beyond the factory walls: Effects of four types of strategic integration on manufacturing plant performance." Journal of Operations Management **25**(1): 148-164.

Symon, G. and C. Cassell (2012). Assessing Qualitative Research. Qualitative Organizational Research: Core Methods and Current Challenges. G. Symon and C. Cassell. London, Sage**:** 204-223.

Tsinopoulos, C. and Z. b. M. F. Al Zu'bi (2012). "Clockspeed Effectiveness of Lead Users and Product Experts." International Journal of Operations & Production Management **32**(9): 1097-1118.

Tsinopoulos, C. D. and K. Bell (2010). "Supply chain integration systems by small engineering to order companies: the challenge of implementation." Journal of Manufacturing Technology Management **21**(1): 50-62.

Un, C. A., A. Cuervo-Cazurra and K. Asakawa (2010). "R&D Collaborations and Product Innovation." Journal of Product Innovation Management **27**(5): 673-689.

Vaart, T. v. d., D. P. v. Donk, C. Gimenez and V. Sierra (2012). "Modelling the integration-performance relationship: Collaborative practices, enablers and contextual factors." International Journal of Operations & Production Management **32**(9): 1043-1074.

van Beers, C. and F. Zand (2014). "R&D Cooperation, Partner Diversity, and Innovation Performance: An Empirical Analysis." Journal of Product Innovation Management **31**(2): 292-312.

van der Vaart, J. T. and D. O. van Donk (2008). "A critical review of survey based research in supply chain integration." International Journal of Production Economics **111**(1): 42-55.

van Donk, D. P. and J. T. van der Vaart (2004). "Business conditions, shared resources and integrative practices in the supply chain." Journal of Purchasing & Supply Management **10**(3): 107-116.

Vanpoucke, E., K. K. Boyer and A. Vereecke (2009). "Supply chain information flow strategies: an empirical taxonomy." International Journal of Operations & Production Management **29**(11-12): 1213-1241.

Vickery, S. K., J. Jayaram, C. Droge and R. Calantone (2003). "The effects of an integrative supply chain strategy on customer service and financial performance: an analysis of direct versus indirect relationships." Journal of Operations Management **21**(5): 523-539.

Villena, V. H., E. Revilla and T. Y. Choi (2011). "The dark side of buyer-supplier relationships: A social capital perspective." Journal of Operations Management **29**(6): 561-576.

Zhou, H. and W. C. Benton (2007). "Supply chain practice and information sharing." Journal of Operations Management **25**: 1348-1365.

Table 1 Contextual variables affecting integration

Contextual dimensions	Argument	Authors
Product lifecycle	Short lifecycles require faster time to market and shorter end-to-end pipelines.	Fine (1998); Childerhouse *et al.* (2002); Das *et al.* (2006); Narasimhan *et al.* (2010)
Industry clockspeed	The speed of change in products, processes and organisations affects the structure of supply chains and hence the level of integration.	Fine (1998); Childerhouse *et al.* (2002); van Donk and van der Vaart (2004); Fynes *et al.* (2005); Koufteros *et al.* (2005)
Firm size	Larger firms have more skills and resources, hold more leverage in relationships.	Koufteros *et al.* (2007)
Product type	Differences in demand for functional and innovative products call for differences in efficiency and responsiveness of the supply chain and the approach to integration.	Fisher (1997); Childerhouse *et al.* (2002)
Time window for delivery	Rapid response required for some products needs different supply chain structure	Childerhouse *et al.* (2002); van Donk and van der Vaart (2004)
Volume	Products with larger volumes allow for lean and efficient chains and more agile chains are appropriate in cases of lower volumes.	van Donk and van der Vaart (2004)
Variety	Variety affects order decoupling points and hence relationships with supply chain partners.	Childerhouse *et al.* (2002); van Donk and van der Vaart (2004); Fynes *et al.* (2005)
Customer Demand Variability / Uncertainty	Variability of demand affects planning, inventory, capacity and supply chain structure.	Childerhouse *et al.* (2002); van Donk and van der Vaart (2004); Fynes *et al.* (2005); Koufteros *et al.* (2005)

Table 2 Sample characteristics of respondents

Industry Sector	Percentage in Sample	Type of Business	Percentage in Sample
Aerospace	13%	Original Equipment Manufacturer	40%
Automotive	10%	Primary Manufacturer	14%
Building Products	2%	First Tier System and Component Manufacturer	9%
Communications	4%	Parts Manufacturer	18%
Electrical machines and equipment	8%	Supplier of Services	14%
Electronics	2%	Sub-contractor	5%
Fast Moving Consumer Goods	9%		
Food	4%		
General Manufacturing	15%		
Marine	7%		
Medical Equipment	2%		
Pharmaceuticals	2%		
Railways and off Road Equipment	7%		
White Goods	1%		
Energy (including oil and gas and nuclear)	10%		
Manufacturing Services	4%		

Note: For confidentiality reasons the names of the participating companies or information that can help identify them cannot be revealed.

Product Newness		
Familiar	**2. <u>Recurring</u>** Integration configurations that aim at delivering familiar products in low volumes that are only manufactured following customers' recurring orders. *<u>New Product Development</u>* Integration activities focus mainly on improvements of existing products. • The customer is integrated at the later stages of the process, mainly focusing on the modification of existing products to meet own needs using detailed technical requirements. • The supplier provides cost improvement ideas. *<u>Production planning</u>* Integration activities on both the customer and supplier side focus on the controlling of the development project. Project management metrics such as cost, time, and quality are used. *<u>Examples</u>: aerospace, railways and off road equipment, and oil and gas*	**4. <u>Synchronised</u>** Integration configurations that aim at delivering high volumes of products that the manufacturer is familiar with. *<u>New Product Development</u>* Integration activities focus on the collection of ideas for new products. • The customer is integrated at the later stages of the process focusing on the collection of feedback on existing products. • The supplier's integration is limited and focused more on cost reduction through process improvements *<u>Production Planning</u>* Integration activities focus on cost reduction and increasing speed of delivery. In OEMs distributors, dealerships, or other distribution channels provide forecasts which are then communicated across the supply chain. *<u>Examples</u>: automotive, electronics and process sectors*
New to the Firm	**1. <u>Cutomised</u>** Integration configurations that focus on the production of new-to-the-firm products produced in very low volumes. *<u>New Product Development</u>* Integration activities focus on the understanding of customer requirements and supplier capabilities. • The customer is integrated during the early stages. Technical requirements are not detailed until later in the development cycle. • The supplier provides detailed information of their capabilities early in the new development cycle. *<u>Production planning</u>* Integration activities on both the customer and supplier side focus on the controlling of the development project. Project management metrics such as cost, time, and quality are used. ICT systems are not essential to integrate. *<u>Examples</u>: engineering companies that supply components and sub assemblies to the aerospace, electrical machines and equipment, marine and medical equipment sectors*	**3. <u>Ramp-up</u>** Integration configurations that aim at developing new-to-the-firm products to be ramped up for high volumes *<u>New Product Development</u>* Integration activities focus on the development of new to the firm products and the processes that will deliver them to customers. • The customer is integrated during product testing. • The supplier is integrated across the new product development process, *<u>Production Planning</u>* Integration activities focus on the development of the systems and processes that will enable the prompt delivery of the new products to the customers. *<u>Examples</u>: high volume manufacturers in the automotive and electronics sectors*
	Low Volume High Customisation *Engineer to order, Make to order*	High Volume High Standardisation *Assemble to order, Build to stock*

Process Structure

Figure 1 Dimensions of the configuration of external integration