Improving supply chain responsiveness through Advanced Manufacturing Technology. The mediating role of internal and external integration

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Abstract:

Responsiveness is one of the key performance factors that firms need to face up to the challenges posed by today's markets. Many manufacturing firms are investing in Advanced Manufacturing Technology (AMT) with a view to improving competitiveness. However, empirical evidence shows that investments in AMT alone do not lead to improvements in performance. In this study, a model that links AMT implementation and responsiveness through internal and external integration is proposed. A sample of 441 Spanish industrial companies was used to test the model through structural equation modelling. The findings highlight that internal integration needs to be supplemented with external integration in order to ensure that the implementation of AMT will result in improved responsiveness. Supply chain managers should focus on integration within the supply chain -firstly internal and later external- to obtain returns on investments in AMT in the form of improved flexibility and more reliable and faster deliveries.

Keywords: AMT; Internal Integration; External Integration; Responsiveness; Supply Chain Integration.

Introduction

Responsiveness to customer requests is a key competitive factor in the current business environment of today's global and volatile marketplace, with increasing product varieties, shortening life cycles and more demanding competition (Danese, Romano, and Formentini 2013). Providing the right product, at the right time to the costumer is the main objective of any supply chain. In order to become more responsive, firms require more speed and more flexibility in their supply chains, i.e., an agile supply chain (Christopher 2000) or a responsive supply chain (Gunasekaran, Lai, and Cheng 2008), making the supply chain play a key role in organisational performance.

To achieve these competitive capabilities, many manufacturing firms rely on investments in Advanced Manufacturing Technology (AMT). Farooq and O´Brien (2015) state that manufacturing firms, when making decisions regarding technology selection, should consider direct and indirect consequences on their supply chain. The association between AMT and performance has been studied by many over the years. However, as Das and Jayaram (2003), several years ago, and Heim and Peng (2010), more recently, show, the empirical evidence as to that relationship is not conclusive, possibly because of the very different dimensions of performance that can be measured, among other reasons.

Kim, Cavusgil, and Cavusgil (2013) highlight that, in today's hypercompetitive market, a firm's individual efforts, by themselves, are not sufficient, but rather the firm must rely on its supply chain partners to create responsiveness to customers and generate added value for them. As a result, one important finding is that information technology (IT) in general, and AMT in particular, are valuable but, as Melville, Kraemer, and Gorbaxani *(*2004) point out, dependent upon internal and external factors related to chain partners. Nevertheless, alignment between the information model and the supply chain model, and the way that this affects performance, need to be investigated further. Indeed, technology, internal integration and external collaboration are among the five major areas or pillars of future research in supply chain management (Stank, Dittmann, and Autry 2011).

Taking into account that there is a clear relationship between integration and performance, according to many (Frohlich and Westbrook 2001; Stank, Keller, and Closs 2001; Rosenzweig, Roth, and Dean 2003; Yu 2015), integration emerges as a key factor that connects AMT with performance. However, others such as Fabbe-Costes and Jahre (2008) think that this positive relationship has generally been assumed to be true rather than based on empirical support. Existing empirical research is not conclusive either, finding no positive association between Supply Chain Integration (SCI) and performance as single constructs (Sofyalıoğlu and Öztürk 2012) or any overall positive and significant relationship between SCI and firm performance (Leuschner, Rogers, and Charvet 2013). Therefore, the relationship between SCI and performance remains elusive and requires more empirical evidence.

Some studies, such as those by Rosenzweig, Roth, and Dean (2003) and Flynn, Huo, and Zhao (2010), show that internal integration is the foundation upon which customer and supplier integration is built. With regard to the relationship between AMT and the integration of internal business processes, there are pioneering theoretical studies, such as those by Nemetz and Fry (1988) and Parthasarthy and Sethi (1992) that, from a conceptual perspective, argue that integration at least partially results from using AMT, and empirical evidence also exists that supports this hypothesis (Cagliano and Spina 2000; Jonsson 2000; Sacristán-Díaz, Machuca, and Álvarez-Gil 2003).

This paper focuses on responsiveness, as this seems to be (along with cost) the most significant competitive capability in today's evolving markets. In spite of this, and despite the fact that some studies exist that support the connection between SCI and responsiveness (Danese, Romano, and Formentini 2013; Kim, Cavusgil, and Cavusgil 2013), responsiveness as a specific outcome of supply chain integration has been explored much less than other performance dimensions.

Other more recent studies qualify this connection with the nuance that it is internal integration that has a mediating effect on responsiveness (Williams et al. 2013). However, to achieve responsiveness it is necessary to reduce uncertainty and equivocality, and to enhance the capability to resolve potential conflicts with external trading partners, and so it is necessary to investigate the impact of internal integration on external integration. Indeed, internal integration provides important information that is necessary to reduce uncertainty and equivocality (Koufteros, Vonderembse and Jayaram 2005, Huo 2012) and enhances a company's capability to communicate and solve problems with external partners (Zhao et al. 2011). Therefore, companies must first develop internal integration capabilities before they can engage in meaningful external integration (Zhao et al. 2011) and provide flexibility and delivery performance.

This article uses these ideas and the arguments of the Resource Based View and the Dynamic Capabilities Theory as the basis for testing four hypotheses with a model that analyses internal and external integration's mediating role in the influence that AMT has on responsiveness in industrial markets. It must be highlighted that although the relationship between IT and SCI has been the subject of much research in the past, there are no studies on the specific role of AMT in SCI (Kamal and Irani 2014). By introducing the concepts of AMT and responsiveness, our model constitutes a research novelty, since it focuses on the relationship between AMT implementation and responsiveness, as well as on the mediating role of supply chain integration.

The paper has been structured in five sections. After the present introduction, section 2 introduces the theoretical background to this research and formulates the hypotheses; section 3 describes the methodology; in section 4, the results are shown and discussed. Section 5 ends with the conclusions drawn, managerial implications, limitations and further research.

Theoretical background and hypotheses

The link between AMT implementation and internal integration

The most usual way that literature has distinguished between existing types of AMT since the 1980's, has been through three broad categories related to three basic functions or types of activity performed: design, manufacturing and planning (Adler 1988; Boyer and Pagell 2000; Sacristán-Díaz, Machuca, and Álvarez-Gil 2003; Swamidass and Kotha 1998; Swink and Nair 2007; Chung and Swink 2009). Design AMT is a set of technologies, such as CAD, CAE and CAPP, that reduce time to market through the reduction of design cycle times. Manufacturing AMT refers to programmable production technologies, such as CNC and FMS, which allow scope and scale economies to be obtained simultaneously. Planning or administrative AMT enables faster and cheaper communication, both within an organisation and across a supply chain, with the ERP system being its quintessential exponent. Thus, AMT is a set of mostly programmable technologies which, together with high levels of efficiency, can provide great flexibility to the activities involved in the design, planning, execution and control of operations. All these technologies together can provide manufacturing companies with the flexibility and speed that they need to be more responsive to customer needs.

Companies increasingly rely on IT to improve supply chain practices, but past evidence suggests that implementing IT does not guarantee enhanced business performance (Yu 2015). Major changes in the way that a business operates internally are required for strategic information systems to be implemented successfully, especially, as to the extent that their internal functions are linked or, in other words, as to their degree of internal integration. Internal integration is the degree to which manufacturers structure their own organisational strategies, practices and processes into collaborative, synchronised processes, in order to fulfil their customers' requirements and efficiently interact with their suppliers (Flynn, Huo, and Zhao 2010). From a conceptual perspective, Nemetz and Fry (1988) and Parthasarthy and Sethi (1992) argue that integration results, at least partially, from using AMT. Adler (1988) and Cohen and Apte (1997) also point to the plant-wide integration to which such technologies often lead.

In more recent times there have been other studies that empirically support the relationship between AMT and the integration of internal business processes, indicating integration requirements for some types of AMT (Swink and Nair 2007; Chung and Swink 2009) and that companies with larger investments in AMT are more integrated technically (Jonsson 2000; Sacristán-Díaz, Machuca, and Álvarez-Gil 2003).

On the other hand, AMT implementation provides benefits to the firm at the organisational level through improvements in areas such as work flows and communication (Zairi 1992). In this sense, AMT has a vast potential to facilitate internal collaboration by improving coordination between internal functions and departments; in other words, it can facilitate the development of internal integration.

In line with previous research, our first hypothesis, which is confirmatory in nature, is as follows:

H1: AMT implementation favours internal integration.

Internal and external integration

Firms' value creation depends not only on the integration and alignment of their internal processes, but also on the integration and alignment of processes between different firms. In this respect, Troyer and Cooper (1995) argued that to realise the full potential of supply chain management (SCM) it is necessary to integrate companies on the various levels of the supply chain. In fact, Pagell (2004) states that the concept of managing the supply chain is actually based on integration and most SCM definitions relate to integration (Näslund and Hulthen 2012).

That said, for supply chain integration (SCI) to succeed, both internal processes within the company, and external processes involving suppliers and customers (Frohlich and Westbrook 2001; Schoenherr and Swink 2012) have to be integrated. The supply chain operations reference model (SCOR, Supply-Chain Council 2012) supports this idea; the need to align the plan, source, make, deliver, return and enable processes of each firm in the chain with both customers and suppliers. Just one of the reasons behind the failure of external integration programs has been the lack of internal integration within the firm (Rosenzweig, Roth, and Dean 2003). In fact, Williams et al. (2013) suggest that a high level of internal integration may be required for buyers and suppliers to achieve the desired benefits of collaborative information sharing activities. Dey and Cheffi (2013) point out that coordination among functions is a crucial antecedent to effective supply chain interaction.

Indeed, both internal and external integration are closely related and both are essential in order for an improvement in results to be achieved (Stank, Keller, and Daugherty 2001; Flynn, Huo, and Zhao 2010). While internal integration recognises that the departments and functions within a manufacturer should function as part of an integrated process, external integration recognises the importance of establishing close, interactive relationships with customers and suppliers. Both perspectives are important for enabling supply chain members to act in a concerted way and to maximise the value of the supply chain (Flynn, Huo, and Zhao 2010).

According to Flynn, Huo, and Zhao (2010) internal integration forms the foundation upon which customer and supplier integration builds, and Horn, Scheffler, and Schiele (2014) found that internal integration is a precondition for external integration with suppliers. Zhao et al. (2011) find that internal integration impacts on both the relationship commitment to customers and on the relationship commitment to suppliers. The logic that drives internal integration is equally relevant for the integrating activities of external organisations, so internal integrative capabilities are the basis of external integrative capabilities (Koufteros, Vonderembse, and Jayaram 2005; Huo 2012). In this sense, using a Resource Based View framework, Koufteros, Vickery, and Dröge (2012) found that buyers acquire supplier capabilities for the purpose of converting them into competitive advantages through integrative mechanisms. Thus, Wong, Wong, and Boon-itt (2013) indicate that internal integration and external integration can complement each other to allow focal firms to capture external knowledge and information to enhance product innovation, for example. As a result, the positive impact that generates internal integration can be used to enhance integration with suppliers and customers.

Drawing upon the aforementioned arguments, the following hypothesis is put forward:

H2: Internal integration leads to a higher level of external integration

External integration and performance

The existence of a positive relationship between the integration of the supply chain and performance has generally been assumed to be true rather than based on empirical support (Fabbe-Costes and Jahre 2008). Contrary to this, some authors have questioned the usefulness of the concept of integration, suggesting that it may be more difficult in practice than in theory and, therefore, that it is more rhetoric than reality (Fawcett and Magnum 2002; Bagchi et al. 2005). The issue has continued to arouse much interest in recent years and has sparked several attempts to integrate empirical evidence in the form of literature reviews or meta-analyses. Thus, e.g., Fabbe-Costes and Jahre (2008) found 19 papers in favour and 12 with mixed results, and concluded that better SCI does not always improve performance. In a meta-analysis of 22 articles published between 2000 and 2012, Sofyalıoğlu and Öztürk (2012) found no positive association between SCI and performance as single constructs.

The difficulties in establishing a clear link between SCI and performance come from unclear definitions and 'weak' measures relating to SCI, performance or both (Fabbe-Costes and Jahre 2008). On the one hand, definitions and measures of SCI are diverse (Näslund and Hulthen 2012). Despite the numerous conceptual and empirical papers within the field of SCM, there are neither well-established definitions nor constructs and scales that unambiguously measure SCI (Gimenez, Van der Vaart, and Van Donk 2012). To begin with, as we have seen, the concept of integration includes both an internal and an external component. If we focus on the external component, integration can be analysed towards suppliers, towards customers or in both directions. The scope of integration may also be different, only extending to a nearby dealer (dyadic integration) or spreading to other levels of the supply chain. Furthermore, the concept of integration is broad and sometimes vague, and may include a variety of dimensions or areas. For example, Danese, Romano, and Formentini (2013) define it as the degree to which a manufacturer develops collaborative relationships and intimacy, exchanges information and jointly plans and coordinates supply chain activities with both suppliers and customers. In the same line of these three dimensions are Alfalla-Luque, Medina-López, and Dey (2012) (information integration, coordination and resource sharing and organisational relationship linkage) and Power (2005) (information systems, inventory and supply chain relationships). For their part, Fabbe-Costes and Jahre (2008) propose four intertwined layers of integration: (1) flows (physical, information and financial); (2) processes and activities; (3) technologies and systems; and (4) actors (structure and organisations).

Defining and measuring the other part of the relationship, performance, is an even more complex issue. Fabbe-Costes and Jahre (2008) found many different ways to measure this, ranging from pure operational logistics performance (such as inventory level, response time, service quality and logistics cost) to broad strategic performance (e.g., improved competitive position, profitability and growth, often including customer value and satisfaction). In an analysis of previous literature, Flynn, Huo, and Zhao (2010) find, *inter alia*: operational performance, financial performance, logistics service performance, competitive capabilities, business performance, marketplace performance, productivity performance, etc. Furthermore, performance consideration can refer to different units of analysis, such as the whole supply chain, a company, a business unit or a plant. Performance is typically measured through perceptual scales, and here we find many different items used, and many different constructs. Some researchers use a single construct when assessing the impact of SCI on performance while others use various dimensions of SCI (Sofyalıoğlu and Öztürk 2012). Thus, there is no consensus as to how to measure performance, which suggests differences in strategic visions of the potential of SCI and SCM (Fabbe-Costes and Jahre 2008).

Given the inconsistent empirical results that have been obtained as to the relationship between SCI and performance, the factors that might influence this relationship are beginning to be investigated. Among the factors that have been found so far are organisational culture (Cao et al. 2015), demand and technology uncertainty (Huang, Yen, and Liu 2014) and the company's competitive strategy (Huo et al. 2014).

Dey and Cheffi (2013) state that in spite of a number of articles having been published recently on SCI in leading journals, they give rise to more questions than answers. Therefore, SCI and its relation to performance is an interesting research topic with important managerial implications (Fabbe-Costes and Jahre 2008). So, when companies invest to reduce lead times and integrate with suppliers, the positive impact on performance is enhanced (Danese 2013). Of all the performance measures, responsiveness (along with cost) seems to be the most significant competitive capability in today's evolving markets and some studies exist that support the connection between SCI and responsiveness (Danese, Romano, and Formentini 2013; Kim, Cavusgil, and Cavusgil 2013). Boon-itt and Wong (2011) found that internal integration and supplier integration were positively associated with customer delivery performance, but customer integration was not. On the basis of this evidence, the following hypothesis is proposed:

H3: Greater external integration results in better responsiveness.

The mediating role of integration in the AMT-responsiveness relationship

According to the review of previous research, AMT implementation does not have a clear effect on performance. Some authors have previously pointed to the need to incorporate other variables in order to be able to understand the relationship between AMT and performance. Thus, Powell and Dent-Micallef (1997) indicate that IT needs other resources and complementary skills to achieve a significant impact on competitive advantage. In the same line, Melville, Kraemer, and Gorbaxani (2004) point out that IT in general, and AMT in particularly, are valuable but dependent upon internal and external factors related to chain partners. However, although IT and technological factors are included among the many driving factors that have been discussed in the SCI literature, AMT, as such, have been the subject of very little analysis (Kamal and Irani 2014).

Basing themselves on the Resource Based View of the firm, Miles and Snow (2007) recognised the gains in capability that occurred when firms created trusting, cross-firm relationships that they then used to share knowledge and expertise. As we have seen previously, AMT implementation provides improvements in work flows and communication at an organisational level (Zairi 1992), so it also has great potential to facilitate collaborative planning among supply chain partners by sharing information on demand forecasts and production schedules (Chen and Paulraj 2004). Thus, by implementing AMT in its supply chain system a firm is able to enhance channel specific assets through effective information exchange and better coordination with supply chain partners. As integration is positively related to performance, a tentative additional hypothesis could be formulated as to the existence of a mediating effect of internal and external integration in the relationship between AMT and responsiveness. As some authors state that one variable can have a mediating effect between two other variables, even in cases where no empirical evidence exists as to a direct effect between them (Hayes 2009; Zhao, Lynch, and Chen 2010), the following hypothesis is proposed:

H4: Internal and external integration has a mediating effect between AMT and responsiveness

Figure 1 shows the hypothesised model based on the theoretical background and discussion.

Insert Figure 1 about here

From a theoretical point-of-view, our model is built on the Resource-Based View (RBV) (Barney 1991) and the Dynamic Capabilities Theory (Teece, Pisano, and Shuen 1997). From the RBV perspective, AMT is considered here as bundle of resources, i.e., a "stock of available factors that are owned or controlled by firm", whereas internal and external integration are capabilities, i.e., "a firm's capacity to deploy resources, usually in combination, using organizational processes, to effect a desired end" (Amit and Schoemaker 1993: 35). Our model analyses how these firms' bundles of resources and capabilities provide competitive advantage in the form of responsiveness. This theoretical support is also complemented by the dynamic capabilities theory, which defines dynamic capabilities as "the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments" (Teece, Pisano, and Shuen 1997: 516). In fact, our model assumes rapidly changing environments and focuses on responsiveness, analysing the firm's ability of supply chain integration based on AMT resources.

Methodology

Population and sample

To test the hypotheses a population of 2036 Spanish companies was used, with a staff at least 50 employees taken from the DUNS 50000 Database in all industrial sectors except those exclusively associated with extraction activities, refining, editing and recycling, which therefore do not occupy intermediate positions in the supply chain (approach taken by Van der Vaart et al. (2012)). Fieldwork was conducted May-September 2012. The sample was finally made up of 441 companies (21.7% response rate) which provided the same number of valid questionnaires.

The questionnaire was pretested by five internationally recognised researchers in the areas specifically related to this study. As a result of the pre-test, several items were recorded, some formal aspects of the questionnaire were modified and the wording was simplified and modified according the experts' suggestions.

The data gathering method consisted of a telephone survey using a computerised system (Computer Aided Telephone Interviewing, CATI).

The questionnaire was divided into two different areas depending on who the key informant was. The first section was directed at the head of supply chain management, logistics or operations management. This section included the questions relating to internal and external integration and to operational firm performance. The second section was directed at the head of information systems (IS) or IT, and was related to the use and implementation of Information and Communication Technologies.

Since there were two different informants in each organisation, it was necessary to make two different calls at different times to fill out both of the questionnaire sections for each company. In cases where firms had completed only one section by the midpoint of the expected fieldwork period, a web-based questionnaire was designed to make it easier for the remaining interviewees to answer the questions (some stated that they could answer the questions outside their usual work schedule).

No evidence of response bias when comparing respondents with non-respondents was found. Thus, there is no significant difference in firm sales between the value in the population and in the sample. Finally, the responses of early respondents were compared with those provided by late respondents (Armstrong and Overton 1977) and statistically significant differences (α=.05) were only found for two variables (29 variables included in the study). In sum, taking together all of the above we can be confident that the sample to be used in the study is random and representative of the population.

Variables

Advanced Manufacturing Technology (AMT) implementation was measured using a recent parsimonious scale from Moyano-Fuentes et al. (2012) that includes the most representative items of each automated technology. The heads of IS or IT were asked to rate the extent to which each technology had been implemented on a scale of 1-7 (1=not implemented; 7=fully implemented). Specifically, respondents had to assess the following items:

- Using computer aided design (CAD) for parts and items design in the manufacturing process.
- Using computer aided manufacturing (CAM) to plan and control the manufacturing process.
- Using computer aided engineering (CAE), which includes software to support engineers in tasks such as analysis, simulation, design, diagnosis and repair.
- Using computer aided process planning (CAPP) to transform design specifications into manufacturing instructions.
- Using flexible manufacturing systems (FMS), which is a combination of software and hardware elements that enable the manufacturing system to react to changes.
- Using enterprise resource planning (ERP) to integrate manufacturing with all the other functions.

Internal integration was measured following the construct proposed and tested by Flynn, Huo, and Zhao (2010). The informants were asked to indicate the degree of integration in two areas relating to internal integration on a scale of 1-7 (1=not at all; 7=extensive).

External integration or *supply chain integration* was measured following the construct proposed and tested by Rai, Patnayakuni, and Seth (2006). External integration was a second order factor made up of two constructs: Financial flow integration and Physical and information flow integration. Financial flow integration is defined as the degree to which financial flows between a focal firm and its supply chain partners are driven by workflow events. Physical and information flow integration is defined as the degree to which a focal firm uses global optimisation with its supply chain partners to manage the stocking and flow of material and finished goods and the extent of operational, tactical and strategic information sharing that occurs between a focal firm and its supply chain partners (Rai, Patnayakuni, and Seth 2006). The informants were asked about the degree to which they agreed with a series of statements relating to external integration on a scale of 1-7 (1=totally disagree; 4=neither agree nor disagree and 7=totally agree).

Responsiveness was measured following Hallgren and Olhager (2009) who consider it as the simultaneous achievement of flexibility and delivery performance. Thus, responsiveness was a second order factor made up of two constructs: flexibility and deliveries. The original scales proposed and tested by Flynn, Huo, and Zhao (2010) were slightly adapted. The informants were asked to indicate the degree to which they agreed with a series of statements relating to responsiveness on a scale of 1-7 (1=totally disagree; 4=neither agree nor disagree and 7=totally agree).

Methods of analysis

A structural equation model was developed to test the hypotheses. EQS 6.1 and the Robust Maximum Likelihood method were used, which has been considered the most accurate for non-normal settings (e.g., Bentler 2006).

The Mulaik and Millsap (2000) four-step approach was followed for modelling:

1. Common factor analysis to establish the number of latent variables.
2. Confirmatory factor analysis to confirm the measurement model.
3. Test the structural model.
4. Test nested models to obtain the most parsimonious.

The Rungtusanatham, Miller, and Boyer (2014) guidelines to analyse these relationships were followed to test the mediating effects. Specifically, the bootstrapping procedure was chosen, which has more advantages for our case, including (Rungtusanatham, Miller, and Boyer 2014):

- Being able to accommodate multiple mediators in parallel or in series.
- Correcting for the non-normality of the sampling distribution of a specific indirect effect.
- Offering a greater degree of flexibility to test for contrasts.

The aim was to overcome the limitations of the Baron and Kenny (1986) method, which requires including the direct effect between the independent and dependent variables.

These limitations have been stated elsewhere in several studies (Hayes 2009; Zhao, Lynch, and Chen 2010).

Analysis and results

Measurement model

Content validity was ensured through the pre-test of the questionnaire carried out by 5 internationally recognised researchers in the areas included in this research. Scale unidimensionality was assessed though an exploratory factor analysis, providing eigenvalues higher than the unit, standardised factorial loads higher than 0.4 and a significant explained variance for each extracted factor and high values for Chi-Squared/degrees of freedom in Barlett's sphericity test ($p<.05$). Two second order factors were used to measure external chain integration and responsiveness. Reliability was tested using Cronbach's alpha with scores higher than 0.7 (Bagozzi and Yi 1988). Results for the exploratory factor analysis are shown in Table 1. Items indicated by an asterisk (*) were dropped after a reliability analysis.

Divergent validity or the ability of the scales to discriminate between the different constructs being measured was confirmed using two tests. Firstly, referring to Tables 1 and 2 the Cronbach's alpha coefficients for the scales were greater than their correlations with other scales. Secondly, the average item-to-total correlations with items not in the scales were substantially lower than the average item to total correlations with items within the respective scales.

Insert Table 1 about here

Insert Table 2 about here

Finally, a confirmatory factor analysis (CFA) was performed using EQS 6.1 to confirm the scales' dimensionality and test convergent validity. As a prior step, data exploration was carried out through the normalised estimation of Mardia's test, which confirmed multivariate non-normality of data. In a situation like this, the Robust Maximum Likelihood method is more appropriate. The Robust Maximum Likelihood method improves standard error estimates and scales the model test statistics according to the Satorra and Bentler theory, which takes into account the degree of non-normality (Bentler, 2006; Satorra, 1993). The final fit of the CFA was highly satisfactory. Standardised factorial loads and R2 are shown for each variable in Table 3.

Insert Table 3 about here

Hypotheses testing

As stated above, a structural equation model was developed to test the hypotheses and EQS was used (with the Robust Maximum Likelihood estimation method). First the baseline model (Figure 2) was run which included the mediating effects of internal and external integration in the relationship between AMT implementation and responsiveness. This model yielded an overall good fit (Scaled, Satorra-Bentler, χ^2=656.3, with 362 degrees of freedom, χ^2/df=1.81; RMSEA=.043; CFI=.92; BFI=.92) and an analysis of the model's diagnostic tools (standardised residuals matrix and modification indices) showed no need for re-specification. All three hypotheses receive sufficient support as all the relationships are significant (p<.05).

Insert Figure 2 about here

In order to test H4 (internal and external integration mediate the effect between AMT implementation and responsiveness) resampling was performed on 2000 samples with bootstrapping in Amos v.22 (Amos was used instead of EQS as it provides information on indirect effects and confidence intervals). Table 4 shows the original estimates and the resulting resampling estimates and confidence intervals. As shown in the last row, the mediating effect is significant, since there is no zero in the confidence intervals.

Insert Table 4 about here

Additionally, the baseline model was then modified to test for mediating effects by creating a direct path between AMT implementation and responsiveness (Model 1). This model (χ^2=674.17; df=361; χ^2/df=1.86, RMSEA=.045; CFI=.92; BFI=.85) provided a poorer fit to the data than the baseline model. The significant path coefficients remained the same as in the baseline model with no significant path coefficient for the relationship between AMT and responsiveness (Figure 3). The Chi-squared difference test was not significant for Model 1 versus the baseline model (ΔX^2 (1 *df*) =17.87, p>.05). Therefore, the baseline model appears to be a more parsimonious explanation of the data.

Insert Figure 3 about here

Finally, several partial models were run to test the robustness of mediating effects from joint internal and external integration. These models show the direct effect of AMT on responsiveness and distinguish between the roles of internal and external integration in the AMT-responsiveness relationship (Table 5).

Insert Table 5 about here

No significant coefficient for the relationship between AMT and external integration was found. The Chi-squared difference test was not significant for any partial model, indicating that the baseline model would be a better explanation for the data. These results allow hypothesis 4 to be accepted and indicate the significant role that internal and external integration play jointly in the relationship that links AMT implementation and responsiveness.

Conclusions

Theoretical implications

This paper provides an empirical contribution to the knowledge of the complexities and interrelationships between three of the five pillars for supply chain excellence (Stank, Dittmann, and Autry 2011): technology, internal integration, and external collaboration. It also helps understand how supply chain integration is created and how to provide responsiveness to customers. Moreover, by focusing on responsiveness it contributes to knowledge of the AMT-performance relationship, which is not sufficiently clear.

The findings show the importance of company integration-related aspects for a better understanding of the relationship between implementation of AMT and responsiveness. These results confirm the findings of Powell and Dent-Micallef (1997) who conclude that IT does not provide a competitive advantage in isolation, but needs to be supplemented with other resources and entrepreneurial skills. At the same time, our findings extend said authors' conclusions since they show that any capabilities that complement IT must extend outside the boundaries of the company and include the supply chain.

The importance of achieving a balance between efficiency and flexibility in today's competitive environment is also emphasised. Production costs can be kept under control with AMT, whereas responsiveness is enhanced through SCI. If this is so, the combination of AMT and SCI would be a powerful source of competitive advantage which would provide efficiency and responsiveness at the same time.

Moreover, our research can also be viewed as a complement and extension of recent supply chain integration research. Recent studies suggest that external and internal integrative activities create greater responsiveness in supply chains. Schoenherr and Swink (2012) show that external integration activities are positively related to flexibility performance outcomes and Williams et al. (2013) show that internal integration provides complementary information by processing capabilities required to yield responsiveness. Our findings show the need to supplement internal integration with external integration to ensure that the implementation of AMT will result in improved responsiveness. In other words, the connection between internal and external integration is necessary for AMT to affect responsiveness.

Our results also highlight the importance of analysing the impact of supply chain integration on responsiveness in greater detail by first analysing the impact of internal integration on external integration. Our findings suggest that in order to achieve good performance in terms of flexibility and delivery, firms must first focus on improving the integration of internal functions and departments so that integration with external actors can be sufficiently guaranteed. These findings complement the results found by Koufteros, Vonderembse and Jayaram (2005) and Zhao et al. (2011) by providing new empirical evidence of the impact of internal integration on external integration in the context of responsiveness. However they contradict those of Sanders (2007), who found that inter-organisational collaboration only impacts the results indirectly through its influence on intra-organisational cooperation.

Managerial implications, limitations and future research

From a practical perspective, it appears that managers should focus on integration within the supply chain -firstly internal and later external- to obtain returns on investments in AMT in the form of improved flexibility and more reliable and faster deliveries. Our findings also indicate that inter-functional and inter-departmental integration is an incentive for advancing supply chain integration. While this is in line with previous results found in the literature (Flynn, Huo, and Zhao 2010; Zhao et al. 2011; Schoenherr and Swink 2012; Yu 2015) they contradict the findings of Braunscheidel and Suresh (2009).

The results of this study have been obtained in industrial markets that occupy intermediate positions in the supply chains of final products, and consequently from companies that interact frequently with both upstream and downstream companies in their supply chains. As a result, our findings should have major and robust implications.

The implications of our results must be considered in the light of the possible limitations of our research. One important limitation relates to the cross-sectional nature of our study, meaning that the analysis was conducted at a particular moment in time. Further research as well as longitudinal analyses should be carried out in a wide range of industrial and geographical settings to confirm these findings.

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Figure 1. Theoretical hypothesised model

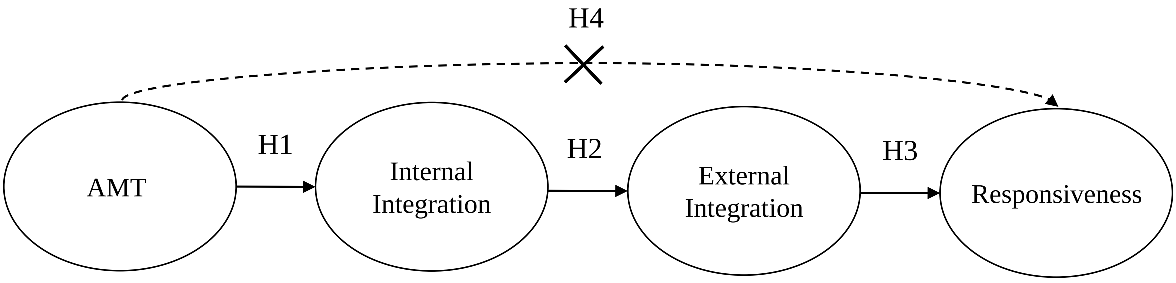
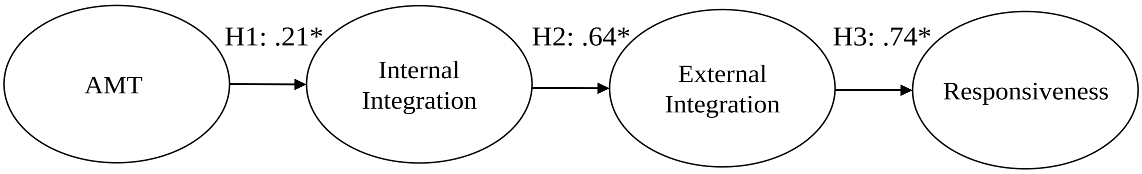
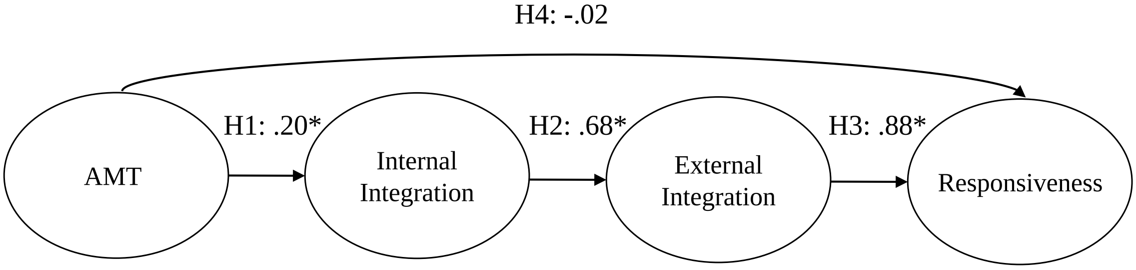


Figure 2. Structural baseline equation model



* *p<.05*

Figure 3. Structural model with directs links versus mediating effects (Model 1)



* *p<.05*

Table 1. Exploratory Factor Analysis

Factor	Variable	Standardised Factor Loading	Cronbach's α	% Explained Variance
AMT	Using computer aided design (CAD)	.57	.75	45.8
	Using computer aided manufacturing (CAM)	.73		
	Using computer aided engineering (CAE)	.75		
	Using computer aided process planning (CAPP)	.79		
	Using flexible manufacturing systems (FMS)	.69		
	Using enterprise resource planning (ERP)	.46		
Internal integration	Data integration between internal functions	.80	.84	56.1
	Enterprise application integration between internal functions	.76		
	Integrative inventory management	.78		
	Real time searching of the level of inventory	.70		
	Real time searching of logistics-related operating data	.74		
	Utilisation of periodic inter-departmental meetings among internal functions.*			
	Use of cross functional teams in process improvement. *			
	Use of cross functional teams in new product development. *			
	Real time integration and connection among all internal functions from raw materials management through production, shipping and sales	.71		
Financial flow integration	Account receivables processes are automatically triggered when we ship to our customers	.90	.77	81.3
	Account payable processes are automatically triggered when we receive supplies from our suppliers	.90		
Physical and information flow integration	*Physical flow integration*		.78	44.3
	Inventory holdings are minimised across the supply chain *			
	Supply chain-wide inventory is jointly managed with suppliers and logistics partners	.55		
	Suppliers and logistics partners deliver products and material just in time	.54		
	Distribution networks are configured to minimise total chain-wide supply chain inventory costs	.67		
	Information flow integration			
	Production and delivery schedules are shared across the supply chain	.72		
	Performance metrics are shared across the supply chain	.78		
	Supply chain members collaborate in arriving at demand forecasts	.69		
	Our downstream partners (e.g., distributors, wholesalers, retailers) share their real sales data with us *			
	Inventory data are visible at all steps across the supply chain	.67		
Flexibility	Our company can quickly modify products to meet our major customer's requirements	.82	.90	71.6
	Our company can quickly modify products as response to innovations from our major competitors	.87		
	Our company can quickly introduce new products into the market	.82		
	Our company can quickly respond to changes in market demand	.84		
	Our company can quickly respond to changes in competitors	.86		
Deliveries	Our company has an outstanding on-time delivery record to our major customer	.82	.75	68.2
	The lead time for fulfilling customers' orders is short	.83		
	Our company provides a high level of customer service to our major customer	.82		

Note: One EFA was carried out for each construct independently.

Table 2. Correlations between scale items

	AMT1	AMT2	AMT3	AMT4	AMT5	AMT6	ININ1	ININ2	ININ3	ININ4	ININ5	ININ6	INFI1	INFI2	INPI1	INPI2	INPI3	INPI4	INPI5	INPI6	INPI7	FLEX1	FLEX2	FLEX3	FLEX4	FLEX5	DEL1	DEL2
AMT1																												
AMT2	.27**																											
AMT3	.49**	.43**																										
AMT4	.31**	.48**	.45**																									
AMT5	.14**	.47**	.37**	.49**																								
AMT6	.14**	.18**	.21**	.33**	23**																							
ININ1	.02	.09*	.04	.13**	.10*	.11*																						
ININ2	.14	.10*	.03	.12**	.13**	.14**	.73**																					
ININ3	.00	.10*	-.00	.13**	.06	.12*	.51**	.44**																				
ININ4	.05	.12*	.07	.19**	.08	.15**	.37**	.29**	.65**																			
ININ5	.01	.08	.06	.13**	.09*	.13**	.43**	.44**	.47**	.46**																		
ININ6	.06	.09	.08	.15**	.10*	.14**	.46**	.46**	.40**	.38**	.49**																	
INFI1	.07	.07	.06	.08	.04	.08	.19**	.17**	.20**	.24**	.20**	.15**																
INFI2	.07	.08	.04	.12*	.07	.12*	.18**	.12**	.20**	.22**	.16**	.20**	.62**															
INPI1	.06	.01	.07	.04	.03	.05	.03	.07	.12*	.13**	.10*	.21**	.17**	.14**														
INPI2	-.08	.03	.08	.06	.07	.06	.13**	.11*	.10*	.08	.17**	.19**	.11*	.14**	.29**													
INPI3	-.05	.04	.02	.09*	.00	.04	.20**	.21**	.27**	.22**	.26**	.29**	.19**	.12*	.28**	.37**												
INPI4	.05	.03	.03	.08	.08	.05	.26**	.25**	.19**	.23**	.27**	.38**	.18**	.16**	.25**	.27**	.33**											
INPI5	-.03	.00	-.00	-.00	.04	.02	.23**	.25**	.25**	.21**	.27**	.36**	.16**	.15**	.26**	.29**	.46**	.56**										
INPI6	-.01	.00	-.01	-.00	-.02	.02	.22**	.26**	.20**	.19**	.30**	.29**	.13**	.11*	.33**	.21**	.34**	.36**	.50**									
INPI7	.00	.00	-.00	.04	-.04	.21**	.24**	.23**	.29**	.34**	.25**	.29**	.17**	.09	.29**	.22**	.33**	.46**	.39**	37**								
FLEX1	-.00	.09*	.03	.03	.12**	.06	.10*	.11*	.02	.03	.09	.16**	.05	.09	.17**	.11*	.14**	.22**	.23**	.11*	.14**							
FLEX2	-.00	.09*	.01	.02	.11*	.06	.08	.09	.06	.06	.12*	.15**	.05	.13**	.18**	.14*	.20**	.19**	.26**	.12**	.14**	.69**						
FLEX3	-.03	.07	.04	.08	.12**	.12**	.08	.10*	.05	.07	.07	.17**	.05	.18**	.13**	.20**	.16**	.19**	.25**	.14**	.11*	.55**	.67**					
FLEX4	-.01	.07	.04	.05	.12**	.12**	.18**	.18**	.08	.13**	.15**	.23**	.12**	.18**	.19**	.17**	.22**	.28**	.28**	.16**	.17**	.63**	.59**	.61**				
FLEX5	.00	.05	.02	.03	.10*	.10*	.10*	.13**	.07	.08	.11*	.18**	.10*	.20**	.17**	.22**	.24**	.20**	.26**	.15**	.18**	.57**	.71**	.62**	.70**			
DEL1	-.00	-.04	-.07	-.04	.05	.05	.19**	.21**	.18**	.18**	.21**	.21**	.17**	.18**	.16**	.25**	.18**	.28**	.30**	.16**	.23**	.22**	.22**	.22**	.27**	.25**		
DEL2	-.00	-.01	-.06	-.05	.00	.00	.10*	.14**	.08	.06	.11*	.07	.15**	.12**	.04	.18**	.13**	.17**	.19**	.09*	.10*	.20**	.16**	.21**	.23**	.21**	.52**	
DEL3	-.08	.27**	.49**	.31**	.14**	.14**	.22**	.22**	.17**	.19**	.23**	.18**	.11*	.07	.07	.22**	.19**	.28**	.31**	.18**	.19**	.26**	.27**	.28**	.33**	.30**	.50**	.53**

***p<.01, *p<.05*

Table 3. Confirmatory factor analysis

Factor	Variable	Standardised Factor Loading	R^2
External integration	Financial flow integration	.41	.17
	Physical and information flow integration	.84	.71
Responsiveness	Flexibility	.58	.33
	Deliveries	.74	.54
AMT	Using computer aided design (CAD)	.45	.20
	Using computer aided manufacturing (CAM)	.66	.44
	Using computer aided engineering (CAE)	.65	.42
	Using computer aided process planning (CAPP)	.75	.57
	Using flexible manufacturing systems (FMS)	.63	.39
	Using enterprise resource planning (ERP)	.37	.14
Internal integration	Data integration among internal functions	.77	.59
	Enterprise application integration among internal functions	.73	.54
	Integrative inventory management	.70	.49
	Real time searching of the level of inventory	.61	.37
	Real-time searching of logistics-related operating data	.66	.44
	Real-time integration and connection among all internal functions from raw material management through production, shipping and sales	.65	.42
Financial flow integration	Account receivables processes are automatically triggered when we ship to our customers	.82	.68
	Account payable process are automatically triggered when we receive supplies from our suppliers	.76	.58
Physical and information flow integration	*Physical flow integration*		
	Supply chain-wide inventory is jointly managed with suppliers are logistics partners	.42	.18
	Suppliers and logistics partners deliver products and material just in time	.44	.19
	Distribution networks are configured to minimise total supply chain chain-wide inventory costs	.59	.34
	Information flow integration		
	Production and delivery schedules are shared across the supply chain	.69	.48
	Performance metrics are shared across the supply chain		
	Supply chain members collaborate in arriving at demand forecasts	.76	.58
	Inventory data are visible at all steps across the supply chain	.61	.37
		.59	.35
Flexibility	Our company can quickly modify products to meet our major customer's requirements	.76	.58
	Our company can quickly modify products as response to innovations from our major competitors	.84	.71
	Or company can quickly introduce new products into the market	.77	.60
	Our company can quickly respond to changes in market demand	.79	.63
	Our company can quickly respond to changes in competitors	.83	.69
Deliveries	Our company has an outstanding on-time delivery record to our major customer	.73	.53
	The lead time for fulfilling customers' orders is short	.70	.49
	Our company provides a high level of customer service to our major customer	.74	.55

Table 4. Results of bootstrapping on the baseline model

	Original Sample			Bootstrapping (means)		Bootstrapping 95% Confidence Intervals	
Parameter	**Estimate**	**Robust SE**	**t-Student**	**Estimate**	**Robust SE**	**Percentile**	**Bias Corrected**
AMT → Internal Integration (II)	.175***	.051	3.463	.177	.058	[.077, .298]	[.085, .309]
II → External Integration (EI)	.372***	.070	5.311	.376	.103	[.192, .595]	[.192, .596]
EI→ Responsiveness	.969***	.206	4.715	1.007	.315	[.510, 1.73]	[.509, 1.732]
AMT → II → EI →Responsiveness	-	-	-	.063	-	[.025, .114]	[.024, .117]

Note: Estimates are unstandardised.
*** p < .001

Table 5. Comparison of the partial structural models with the baseline model

Partial Model	RMSEA	X^2/df	ΔX^2/df over the baseline model	Standardised coefficient of focal relationship
AMT → Responsiveness	.05	2.17	+.36	.11*
AMT → Internal Integration→Responsiveness	.06	2.47	+.66	.48* (AMT→Internal Integration)
AMT→External Integration→Responsiveness	.046	1.89	+.08	.13 (AMT→External Integration)

* *p<.05*