Research paper

Supply chain integration and efficiency performance: a study on the interactions between customer and supplier integration

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Abstract

Purpose – This research intends to investigate whether there are synergies that a firm could or should exploit by simultaneously implementing customer and supplier integration. In particular, the aim is to analyze the impact of customer integration on efficiency, and the moderating role of supplier integration.

Design/methodology/approach – This study analyzes data from a sample of 200 manufacturing plants. Two hypotheses are tested through a hierarchical regression analysis. Customer and supplier integration constructs consider items related to different aspects of the integration (e.g. sharing of production plans and customers' forecasts, feedback on performance, communication on quality considerations and design changes, joint quality improvement efforts, close contact, partnerships). The focus of the integration clearly extends beyond the dyad, as it includes the integration of focal operations upstream and downstream, with both suppliers and customers.

Findings – Supplier integration positively moderates the relationship between customer integration and efficiency, whereas the analyses do not support the hypothesis that in general customer integration positively impacts on efficiency. They also reveal that, when supplier integration is at a low level, customer integration can even produce a reduction in efficiency.

Practical implications – Efficiency performance optimization requires levering simultaneously on customer and supplier integration to foster their interaction, rather than investing and acting on customer integration only. In addition, before deciding whether to invest in customer integration, managers should ascertain the level of supplier integration, since it acts as a prerequisite for the successful implementation of customer integration.

Originality/value – Compared with previous studies investigating the main impact of customer and supplier integration on a company's performance, this research analyzes a model that considers the interaction effect between these integration strategies. This provides a number of original implications for the interpretation of the relationship between customer and supplier integration and efficiency.

Keywords Supplier relations, Supply chain management, Performance measures, Customer relationship management

Paper type Research paper

1. Introduction

Over the years the attention of practitioners and academic literature on integration practices between supply chain partners has significantly grown (van der Vaart and van Donk, 2008). The intensification of global competition and the demand for better customer service have considerably increased the need for integration between companies. Consequently, supply chain (SC) integration, aimed at coordinating processes along the supply chain seamlessly, nowadays is considered an important determinant to maintain a competitive advantage over competitors.

Numerous studies have explored the concept of SC integration in different research areas such as information processing (Lee *et al.*, 1997; Lee *et al.*, 2000; Zhao *et al.*, 2002), inventory planning and logistics (Ganeshan *et al.*, 2001; Disney and Towill, 2002; Romano, 2009; Danese, 2011), or partnership/relationships (Carter *et al.*, 2000; Fynes *et al.*, 2005). The dominant belief is that SC integration is a useful approach to improve various measures of firm performance (Fabbe-Costes and Jahre, 2008; van der Vaart and van Donk, 2008; Singh and Power, 2009; Ou *et al.*, 2010; Wiengarten *et al.*, 2010). However, some authors argue that performance improvements are not assured if SC integration

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programs are not accompanied by the implementation of a coherent mix of supply chain management (SCM) initiatives encompassing, for instance, lead time reduction, supplier network rationalization, production network reconfiguration, development of partnerships, etc (de Treville *et al.*, 2004; Danese *et al.*, 2006; Kim, 2006). In particular, it has been proposed that implementing integration both upstream and downstream is better than concentrating the firm's efforts on integrating customers or suppliers only (Frohlich and Westbrook, 2001; Rosenzweig *et al.*, 2003).

Despite this recognition, SCM literature does not empirically examine the way these integration practices "interact" and whether their simultaneous presence can determine a positive additional synergistic effect on companies' performance. Several authors distinguish between integration with customers and suppliers and investigate the main impact of each integration activity on companies' performance (Lee *et al.*, 2007). A key question however is: are there synergies that a firm could or should exploit by simultaneously implementing customer and supplier integration?

This paper intends to contribute to filling this gap by focusing on efficiency performance. In particular, the aim is to analyze the impact of customer integration on efficiency, and the moderating role of supplier integration. In fact, SCM literature suggests that customer integration, as well as reducing inventory and manufacturing costs, usually determines other additional costs, due to the frequent plan modifications required to follow customer needs (Disney and Towill, 2002). Supplier integration could be a useful tool to limit the negative implications of customer integration on costs, thus amplifying its positive effect on efficiency. Our intent is to open an interesting debate on this issue, by introducing explanations on how efficiency is not improved by using just customer integration practices more extensively, but by simultaneously integrating upstream.

The paper is organized as follows. First, it analyzes existing literature on the impact of customer integration on efficiency and the moderating role of supplier integration, and then discusses the research hypotheses this study intends to examine. The following section introduces the sampling frame, measures and data collection. This is followed by analyses and discussion of the theoretical and managerial implications of this study. Finally, conclusions are drawn which summarize the results found.

2. Literature review and research hypotheses

2.1 Relationship between customer integration and efficiency

In a recent literature review on survey-based SCM studies, Fabbe-Costes and Jahre (2008) argue that authors generally agree that stronger linkages and a higher degree of integration across organizational boundaries lead to better performance for the focal organization and its supply network. Some researchers have limited their analyses to integration with customers (Closs and Savitskie, 2003; Fynes *et al.*, 2005; Sahin and Robinson, 2005) or suppliers (Das *et al.*, 2006; Handfield *et al.*, 2009; Jain *et al.* 2009; Lawson *et al.*, 2009; Vachon *et al.*, 2009; Wagner and Krause, 2009) in order to ascertain their distinct contribution to performance. Instead, in other studies, authors take a broader perspective by considering integration with both customers and suppliers (Lee *et al.*, 2007), or by defining SC integration as a unique concept that includes both upstream and downstream integration (Vickery *et al.*, 2003; Kim, 2006).

Focusing our attention on the relationship between customer integration and efficiency performance, several arguments can be found in the literature to support the existence of a positive link. For instance, Lee *et al.* (1997) identify the potential causes of the "bullwhip effect" (i.e. the natural tendency of decentralized decision-making to amplify, delay and distort demand information moving upstream in a make-to-stock supply chain) and recommend strategies for counteracting its effect. Suggested remedies include sharing point-of-sales data and operational alignment to final demand of channel member activities. These practices reduce system uncertainty and, in turn, costs (Chen *et al.*, 2000; Bayraktar *et al.*, 2009; Ryu *et al.*, 2009; Coppini *et al.*, 2010; Wangphanich *et al.*, 2010). Lee *et al.* (2000) demonstrated that information sharing lowers costs from 12-23 percent, while Gavirneni *et al.* (1999) reported cost reductions of 1-35 percent, when sharing retailers' demand data. Zhao *et al.* (2002) found that information sharing and order co-ordination significantly impact on supply chain performance in terms of total costs; while Lin *et al.* (2002) demonstrated that sharing demand information allows greater inventory cost savings to be achieved.

A further important aspect of customer integration is the development of partnership relationships with customers (Power, 2005). These can promote cooperation, openness of communication and a problem-sharing attitude. Companies working in close contact can share information on unexpected problems that can occur locally and, on the basis of these, activities are adjusted accordingly. Customers could provide the producer with feedbacks on quality and delivery performance, or involve the manufacturer in their quality improvement efforts. Thus, partnership relationships guarantee more efficient problem solving and the creation of inter-company decision-making routines (Flynn and Flynn, 1999; Frohlich and Westbrook, 2001).

From the above arguments, it follows that there is a theoretical foundation as well as emerging evidence for a general positive relationship between customer integration and efficiency performance.

However, although the potential benefits of customer integration, and in general SC integration, seem compelling, a recent academic debate has arisen on the actual positive impact of integration on company performance. A couple of literature reviews on SCM survey-based research have argued that studies on the effect of SC integration on performance are not unanimous and that caution is advisable (Fabbe-Costes and Jahre, 2008; van der Vaart and van Donk, 2008). In particular, some authors maintain that the nature of SC integration is complex and more knowledge is needed on its relation to performance. For instance, Stock *et al.* (2000) conclude that external integration does not necessarily provide performance benefits in all cases. Sezen (2008) found that information sharing and SC integration were not significantly related to flexibility, efficiency and output performance (i.e. customer satisfaction and profit). Cousins and Menguc (2006) argue that whilst SC integration clearly has its benefits, it also has costs and "in some cases it has the reverse effect" (p. 616). Coherently, Das *et al.* (2006) report that collaborating with other partners can cause increased costs of coordination and inflexibility.

With regard to the relationship between customer integration and efficiency, Disney and Towill (2002) have investigated the issue of inventory nervousness in downstream integrated systems, and its negative effect on costs. They claim that, in integrated systems, continuously recalculating inventory control parameters according to demand signals causes fluctuations in target inventory levels or in production quantities. Therefore, a slow reaction to demand signals can result in a more stable inventory level and a reduction in production quantity fluctuations. In a further work, Disney *et al.* (2004) suggest that Vendor Managed Inventory (VMI) systems should not be too complex in order to improve the dynamics of supply chains. When testing different information sharing practices, they show that, although players have information available, very complex decision making can result in increased inventory costs.

Therefore, while the general link between customer integration and efficiency is widely acknowledged, inconsistencies across previous studies suggest the need for further research and hypothesis testing. Hence, we intend to analyze the following hypothesis:

H1. Customer integration is positively related to efficiency performance.

2.2 The interaction effect of customer and supplier integration

Both van der Vaart and van Donk (2008) and Fabbe-Costes and Jahre (2008) conclude that a possible explanation for the mixed results emerging from SCM studies on the relationship between SC integration and performance can be that studies use different definitions of SC integration and levels of analysis.

In particular, studies do not only differ with regard to the items applied to measure integration practices, but also for the direction and span of the integration. As explained above, several SCM studies focus on supplier or customer integration. Instead, by recognizing the importance for companies to integrate upstream and downstream simultaneously, some authors include in their studies both these dimensions. In particular, Fabbe-Costes and Jahre (2008) distinguish between:

- studies that test the relationship between customer and supplier integration and performance separately; and
- studies that consider integration of suppliers – focal company – customers without differentiating between upstream and downstream integration.

For instance, Lee *et al.* (2007) investigate the distinct contribution of integrating internally with customers and suppliers to improve different dimensions of performance, such as cost containment and reliability.

Instead, Kim (2006) builds an aggregate construct of SC integration and, by analyzing a sample of 623 manufacturing Korean and Japanese organizations, demonstrates that the level of SC integration positively impacts on firm performance, in terms of market and financial performance, and customer satisfaction.

Also the seminal work of Frohlich and Westbrook (2001) on "arcs of integration" is classified by Fabbe-Costes and Jahre (2008) among those SCM studies that do not differentiate between customer and supplier integration. In fact, this study defines five distinct classes of supply chain strategies based upon what they call an "arc of integration" (representing the relative direction – toward suppliers and/or customers – and degree of integration activity), and demonstrates that the strategy based on the greatest arc of integration guarantees the best performance. However, they do not distinguish between the contribution of customer and supplier integration. Starting from this research, over the years, several studies have been developed. By extending Frohlich and Westbrook's (2001) research, Rosenzweig *et al.* (2003) studied the relationship between SC integration and multiple measures of business performance and the mediating effect of competitive capabilities. Zailani and Rajagopal (2005) analyzed the concept of arcs of integration in the US and the East Asian context. Based on an extensive literature review of multiple aspects of SC integration and performance, they conclude that most companies integrate their organization with suppliers and customers by pursuing a strategy with a broad arc of integration, and that companies with the greatest arcs of supplier and customer integration have the highest rate of performance improvement. Kannan and Tan (2010) do not only recognize the need to integrate both suppliers and customers, but also analyze the positive impact of a broad span of integration (i.e. beyond the immediate network) on several performance dimensions.

The abovementioned studies reveal that, even though customer and supplier integration can be considered as two distinct concepts that differ with regard to the direction of integration, they are in fact strictly related, since SC integration requires that companies be simultaneously integrated upstream and downstream, and significant benefits can be achieved when a firm is integrated with both customers and suppliers.

Starting from these considerations, we believe that an interesting opportunity to better understand the impact of SC integration on companies' performance lies in the examination of possible interaction effects between customer and supplier integration. As demonstrated by Lee *et al.* (2007), each of these integration strategies could directly influence the level of performance achieved. However, when implemented together, they could also interact by determining an additional positive effect on performance. Although the literature does not explicitly test the existence of this interaction effect on performance, the abovementioned studies illustrate the importance of integrating downstream and upstream simultaneously.

In particular, what has not been tested in the extant literature and is plausible is that absence of supplier integration is likely to significantly weaken the effect of customer integration on efficiency performance. For instance, it is well known that the benefits due to bullwhip-effect reduction are maximized when an high level of customer integration is accompanied by a high level of supplier integration, as suppliers can align their production plans with those of final customers (Lee *et al.*, 1997). In addition, supplier integration can help to limit the negative impact of the nervousness effect caused by customer integration, as the upstream network is able to efficaciously react in the event of demand changes without creating significant inefficiencies (e.g. rush orders), or the manufacturer and suppliers can rapidly reach an agreement on how to modify production and purchasing plans to satisfy the demand, when it suddenly changes (Danese *et al.*, 2009). However, the role of supplier integration as moderator of the customer integration-efficiency relationship has not been empirically proved. In other words, there is a lack of empirical evidence proving that the presence of supplier integration enhances the impact of customer integration on efficiency, whereas the absence of supplier integration weakens it. We feel that shedding light on this point would provide sturdy arguments to explain the inconsistencies across previous studies on the relationship between customer integration and efficiency. For these reasons, this research intends to study the following hypothesis:

H2. Supplier integration positively moderates the relationship between customer integration and efficiency performance.

Table I summarizes the main issues discussed in the literature review, that inspired the two hypotheses underlying this research.

3. Methods

3.1 Data collection and sample

This study uses data from the third round of the High Performance Manufacturing (HPM) project data set. Data were collected in 2007 by an international team of researchers working in different universities all over the world. During the 2005-2007 timeframe they collaborated to update the HPM questionnaire and decide how to organize data collection (e.g. how to contact plants and respondents). Data include responses from manufacturing plants operating in machinery, electronic and transportation components sectors (SIC codes: 35, 36 and 37, respectively) and located in different countries (i.e. Finland, US, Japan, Germany, Sweden, Korea, Italy, Austria and Spain). The plants in the HPM study were randomly selected from a master list of manufacturing plants in each of the countries. All plants represented different parent corporations, and had at least 100 employees.

Participating plants received a batch of questionnaires, targeted at the respondents who were the best informed about the topic of the specific questionnaire. In total 20 recipients were involved in each plant (plant manager, HR manager, process engineer, new product development manager etc). In order to raise measurement reliability, each questionnaire was administered to different respondents within each plant. Researchers involved in HPM project asked the CEOs (or a coordinator within each plant) to provide the name and contact addresses of the respondents for each questionnaire, and to distribute the questionnaires received by individual visits or by post to the respondents. Within the research group, for each country, a group of researchers and a person in charge of data collection were identified. Each group had to provide assistance to the respondents, to ensure that the information gathered was both complete and correct. We were responsible for collecting data from plants located in Italy.

The items used in the present research were targeted toward plant managers, inventory managers and plant superintendents, or their immediate subordinates working in direct contact with customers and suppliers. Respondents were specifically asked to give answers on SCM practices adopted and performances obtained. In particular, as in other survey-based SCM studies (see van der Vaart and van Donk, 2008), both supplier and customer integration of focal firms were examined, by asking respondents from these firms about integration practices adopted with suppliers and customers respectively. Since there were multiple respondents within each plant for each item, an average was taken to obtain a single value per item per plant.

Respondents from a total of 266 plants returned the questionnaires, but 66 plants were excluded from the analyses because they provided incomplete responses about the items used in this study. Accordingly, the analysis that follows and all reported statistics were based on a sample of 200 plants. As shown in Table II, the sample is stratified to approximate equal distribution across all three sectors. We use industry (as well as size) as a control variable later in the analysis to test whether this had any impact on efficiency performance.

3.2 Research variables and measures

The items used in the present research are a subset of the whole HPM survey. In the HPM questionnaire, multiple measurement items for each latent construct are used because they provide a greater degree of reliability than single items.

Table I Main issues discussed in the literature review

	Main issues	Studies
CI positively affects efficiency performance	Information sharing and alignment to final demand reduce the bullwhip effect	Lee *et al.* (1997); Gavirneni *et al.* (1999); Lee *et al.* (2000); Lin *et al.* (2002); Zhao *et al.* (2002); Coppini *et al.* (2010)
	Partnership relationships guarantee more efficient problem solving	Flynn and Flynn (1999); Frohlich and Westbrook (2001); Power (2005)
The positive impact of CI on efficiency is questionable	SCM survey-based studies are not unanimous	Fabbe-Costes and Jahre (2008); van der Vaart and van Donk (2008)
	SC integration does not have a significant or even a negative impact on performance	Stock *et al.* (2000); Cousins and Menguc (2006); Das *et al.* (2006); Sezen (2008)
	CI amplifies the nervousness effect	Disney and Towill (2002); Disney *et al.* (2004)
SI can strengthen the effect of CI on efficiency performance	Integration with both customers and suppliers is important to maximize performance	Frohlich and Westbrook (2001); Rosenzweig *et al.* (2003); Zailani and Rajagopal (2005); Kim (2006); Kannan and Tan (2010)
	Bullwhip-effect reduction is maximized when a high level of CI is accompanied by a high level of SI	Lee *et al.* (1997)
	SI can help to mitigate the negative effect of nervousness	Danese *et al.* (2009)

Table II Sample characteristics

	n	%
Total number of plants	200	
Electronics	67	33.5
Machinery	68	34
Transportation components	65	32.5
Mean number of hourly and salaried personnel	639	
Percentage of large-size plants (more than 250 employees)		64

Given the lack in the SCM literature of a standard scale for measuring supplier and customer integration, and efficiency performance (within and beyond focal firms' boundaries), firstly we identified the central dimensions of integration and efficiency usually mentioned in the literature. Then, we followed established guidelines for scale development and examined the measurement model through exploratory methods (Hair *et al.*, 2006).

Each construct with its block of items was first factor analyzed. This was done to assure the internal rule of unidimensionality. Table III reports the items comprising each construct, and the outputs of SPSS 17.0 obtained by factor analyzing the items of each construct separately, along with reliability test results using Cronbach's α. Convergent validity is demonstrated since, for each construct only one component with an eigenvalue above 1 is identified, the variance explained is above 50 percent, and factor loadings are all above 0.50 (Hair *et al.*, 2006).

Then, as suggested by Hair *et al.* (2006), we ran a principal component analysis with Varimax rotation on the complete set of items that compose the two independent variables: supplier and customer integration. Two factors with eigenvalues above 1 were extracted and there was comforting evidence for both convergent and discriminant validity. All the items load onto their intended constructs and have high factor loadings (i.e. more than 0.50), thus reflecting high construct validity. Further, there are no cross-loadings greater than 0.40, providing evidence of discriminant validity.

Finally, Cronbach α-values for the three constructs exceed 0.70, indicating high reliability (Nunnally, 1994).

Thus, three multi-item constructs were identified:

1. customer integration (CI);
2. supplier integration (SI); and
3. efficiency (EFF).

As to the efficiency (EFF) construct, it should be noted that the items considered measure the efficiency performance of the focal firm – as do several survey-based papers on SCM (van der Vaart and van Donk, 2008) – but also the benefits beyond focal firms' boundaries (see Zhao *et al.*, 2002; Kim *et al.*, 2010).

All the items were measured using multi-item perceptual scales with values ranging from 1 to 7.

Table IV shows basic statistics for the three constructs, each obtained by averaging the relevant items.

4. Data analysis and results

4.1 Hierarchical regression

The central issue this research intends to investigate is not only whether customer integration positively affects efficiency, but also whether customer and supplier integration interact by determining a positive significant effect on efficiency performance. In particular, this research intends to investigate whether supplier integration can act as moderator in the customer integration-efficiency relationship.

Table III Validity test of measures

Factor	Item	Factor loading	Variance explained (%)	Cronbach α
Customer integration (CI)	We frequently are in close contact with our customers	0.80	50.60	0.72
	Our customers give us feedback on our quality and delivery performance	0.81		
	We consider our customers' forecasts in our supply chain planning	0.61		
	Our customers do not have access to our production plans (reverse scored)	0.72		
	We work as a partner with our customers	0.62		
	Our customers involve us in their quality improvement efforts	0.70		
	KMO = 0.719 (Bartlett's test of sphericity, $p < 0.001$)			
Supplier integration (SI)	We share our production plans with our suppliers	0.53	53.66	0.73
	We emphasize openness of communications in collaborating with our suppliers	0.66		
	We maintain cooperative relationships with our suppliers	0.80		
	We maintain close communications with suppliers about quality considerations and design changes	0.81		
	We actively engage suppliers in our quality improvement efforts	0.81		
	KMO = 0.759 (Bartlett's test of sphericity, $p < 0.001$)			
Efficiency (EFF)	Indicate your opinion about how your plant compares with its competitors in your industry with regard to: unit cost of manufacturing	0.69	52.17	0.70
	Indicate your opinion about how your plant compares with its competitors in your industry with regard to: inventory turnover	0.75		
	Capacities are balanced in our supply network	0.71		
	We have large in-process inventories between different operations (reverse scored)	0.74		
	KMO = 0.737 (Bartlett's test of sphericity, $p < 0.001$)			

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Table IV Basic statistics and correlation analysis

Variables	Mean	S.D.	Range	Correlations SI	EFF
1 Customer integration (CI)	5.09	0.52	3.39-6.28	0.437*	0.244*
2 Supplier integration (SI)	5.31	0.50	3.75-6.70	–	0.455*
3 Efficiency (EFF)	4.54	0.80	2.25-6.64	–	–

Note: *Significant at the 0.01 level (Pearson probabilities)

We employed a hierarchical regression procedure, by using SPSS 17.0 (linear regression module; entering method: by blocks). Firstly, control variables (i.e. firm size and sector) were considered in the regression model. The firm size (SIZE) was measured by the number of employees (hourly and salaried personnel). The sector was inserted in the regression model by creating dummy variables. The form of dummy variable coding used was "indicator coding", which means that the regression coefficients for the dummy variables represent the deviation from the comparison group. The machinery sector was arbitrarily taken as the baseline/ comparison group.

Then, the main independent variables – i.e. CI, SI – were introduced as a block, followed by the interaction term. The following equation describes the moderated regression tested in this study:

$$EFF = \beta_0 + \beta_1 \cdot CI + \beta_2 \cdot SI + \beta_3 \cdot CI \cdot SI + \varepsilon \qquad (1)$$

As suggested by Jaccard and Turrisi (2003) and Brambor *et al.* (2006), when the β_3-coefficient of the product term $CI \cdot SI$ is statistically significant, and R^2 increases when this term is introduced in the model, the existence of a moderated effect on the CI-EFF relationship is demonstrated. As recommended by several authors, to address the problem of multicollinearity, we mean-centered the independent variables (Jaccard and Turrisi, 2003). Then, we examined multicollinearity diagnostics, by checking the variance inflation factor (VIF) and tolerance values.

Table V reports the results of the hierarchical regression analysis.

Model 0 represents the first step of the hierarchical regression. The control variables industry and size do not result as significantly related to efficiency performance. Also in the models 1 and 2 similar results on the effect of control variables on the response variable are found. Thus, we can conclude that when introducing the additional variables in models 1 and 2, the effect of the control variables appears stable. More interestingly, when the independent variables: CI and SI are added to the regression model (model 1), we can note that SI is significantly related to efficiency performance, whereas CI is not. Thus, we found that hypothesis *H1* is not confirmed, and thus in general it is not possible to conclude that CI always improves efficiency.

Model 2 reports the interaction result, along with changes occurring to the main variables when the product term was introduced. The significant and positive β_3 coefficient suggests that it is possible to confirm the existence of a positive interaction effect between CI and SI. Additional support is the significant change in R^2 from model 1 to 2 (0.028). Therefore, *H2* is fully supported.

Table V Hierarchical regression analysis

	Control variables Model 0	Main effects Model 1	Interaction effect Model 2
Constant	4.390***	4.459***	4.386***
Size	1.83E-4	1.10E-4	1.13E-4
Electronics	−0.027	−0.113	−0.106
Transp. com.	0.123	0.104	0.116
CI		0.090	0.060*
SI		0.657***	0.696***
SIXCI			0.565**
R^2	0.053	0.222	0.250
R^2 adjusted	0.036	0.199	0.224
ΔR^2	0.053	0.169	0.028
F value of ΔR^2	3.203*	18.613***	6.352**

Notes: The values reported are unstandardized regression coefficients; * p-value < 0.05 level; ** p-value < 0.01 level; *** p-value < 0.001 level; VIF (variance inflation factor) below 1.501; Tolerance above 0.666

In all the models, for all the independent variables the VIF is lower than 1.501 and tolerance is greater than 0.666, which are coherent with the recommended threshold values (Hair *et al.*, 2006). Also the bivariate correlation of CI and SI with the interaction term confirms that multicollinearity is not a problem in model 2 (correlation between CI*SI and CI is 0.036 (p-value: 0.617), and between CI*SI and SI is −0.042 (p-value: 0.552)).

4.2 Additional analyses for interpreting moderated regression

By considering the coefficients of Table V (model 2), we can calculate that the marginal effect of CI on EFF depends on SI, according to the following formula:

$$\frac{\partial \mathrm{EFF}}{\partial \mathrm{CI}} = 0.060 + 0.565 \cdot \mathrm{SI} \qquad (2)$$

where the variable SI is centered. The test of significance of the coefficient in equation (2) takes the form of a *t* test, where the standard error is a function of SI (Brambor *et al.*, 2006). We have verified that the t test is significant at a 0.05 level for the values of SI lower than −0.74, and greater than 0.28 (see the Appendix for further details).

Figure 1 shows how the marginal effect of CI varies when SI increases. It is easy to see that CI has a stronger effect on efficiency performance when the level of SI is high. Further, we can note that for low levels of SI, the effect of CI could even be negative. This means that, when companies are not integrated upstream, not only are the benefits of CI lost, but also a contrasting effect emerges that risks the achievement of good levels of efficiency. Between the values of −0.74 and 0.28, the marginal effect of CI is not significant.

The research sample reveals that the centered variable SI varies from −1.56 to 1.39; 39 percent of sample units falls below the SI critical value of −0.1. Below this value, CI seems to have a negative influence on efficiency performance (see Figure 1). However, this situation is extreme (i.e. companies with very low level of SI), since most units in the sample are above the critical value of −0.1, and the remaining units show a SI mean value of −0.50.

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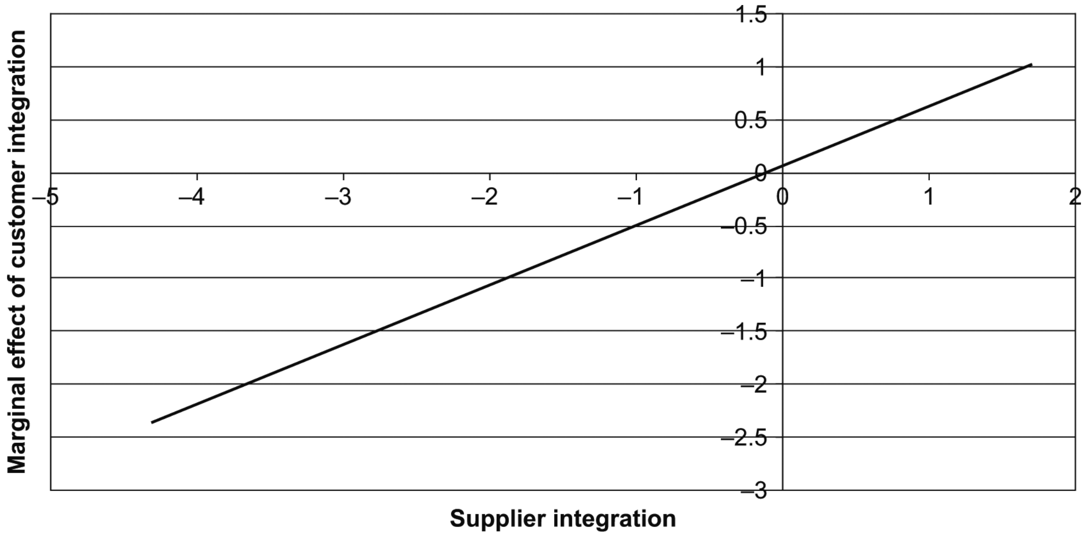
Figure 1 The influence of supplier integration on the marginal effect of customer integration



To further gain an intuitive understanding of the interaction effect between CI and SI, we computed and graphed through MS-Excel the slope of efficiency performance on CI at a few different values of SI. A suggested strategy is to evaluate the effects of CI on performance at "low", "medium", and "high" values of SI, where "low" might be defined as one standard deviation below the mean SI score, "medium" as the mean value, and "high" as one standard deviation above the mean (Cohen and Cohen, 1983). Starting from the coefficients of model 2 in Table V, and by using the three mentioned values of the variable SI, three linear equations of efficiency performance, depending on CI, were created. The visual patterns of Figure 2 confirms that the effect of CI on efficiency is greater when SI increases; while its effect is negative when SI is at a low level.

Figure 2 highlights what Jaccard and Turrisi (2003) classify as "disordinal interaction" or "crossover interaction", namely an interaction in which the regression line that regresses y onto the focal independent variable (i.e. CI) for a given level of the moderator (e.g. low level of SI) intersects with the correspondent regression line for a different level of the moderator (e.g. high level of SI). This type of interaction is very useful for decision making in different situations. For instance, it suggests that a high level of CI (right side of Figure 2) should be accompanied by a high level of SI. On the other hand a low level of CI (left side of Figure 2) should be accompanied by a low level of SI. However, the research sample reveals that this is a rare situation. In fact, only one unit in the sample falls below the CI critical value of -1.23 (i.e. intersection point). Below the intersection point, a low level of SI appears to be more convenient (see Figure 2).

5. Discussion

Our analyses empirically demonstrate that SI positively moderates the relationship between CI and efficiency (*H2*), whereas they do not support that in general CI significantly and positively impacts efficiency (*H1*). These results have both theoretical and managerial implications.

First, these findings provide new insights to better understand the controversial opinions and results found on the CI-efficiency link. Differently from those studies demonstrating that CI significantly improves efficiency (Gavirneni *et al.*, 1999; Lee *et al.*, 2000; Lin *et al.*, 2002; Zhao *et al.*, 2002), this research suggests that efficiency improvements cannot be achieved merely by improving CI. There is a significant impact on efficiency through CI only under certain conditions in terms of supplier integration.

In particular, Figures 1 and 2 reveal that the positive impact of CI on efficiency increases with rising levels of integration between the company and its suppliers. A possible explanation of this positive synergistic effect of SI and CI can be found in studies on bullwhip effect and systems dynamics (Towill *et al.*, 1992; Lee *et al.*, 1997; Mason-Jones and Towill, 1999). When the company is closely coupled with customers, it can transfer to integrated suppliers all the information they need to align their production and shipping plans to the final market demand. Thus, the co-presence of SI and CI makes it possible to reduce inventories not only at the customer-producer interface, but also in the supplier network.

On the contrary, when SI is low, CI can even penalize efficiency performance. In fact, as explained above, CI can cause a "nervousness" effect, arising when companies seek to follow market signals and demand changes, that can negatively affect cost performance (Disney and Towill, 2002). As illustrated in some case studies on SC integration (Danese *et al.*, 2009), SI can help to mitigate the negative impact of the nervousness effect, thus making CI beneficial in terms of cost improvements. Supplier integration can facilitate coping with this effect as it allows the manufacturer to be rapidly updated on the progress of its orders at the supplier's plant and to decide jointly with the supplier the most appropriate plan modifications in order to accommodate final customer requests. Instead, when SI is low, lack of collaboration with suppliers and uncertainty about order progress at the supplier's plant force the manufacturer to inefficiently resort to rush deliveries from suppliers and large amounts of safety stocks to anticipate customer requests and chase demand.

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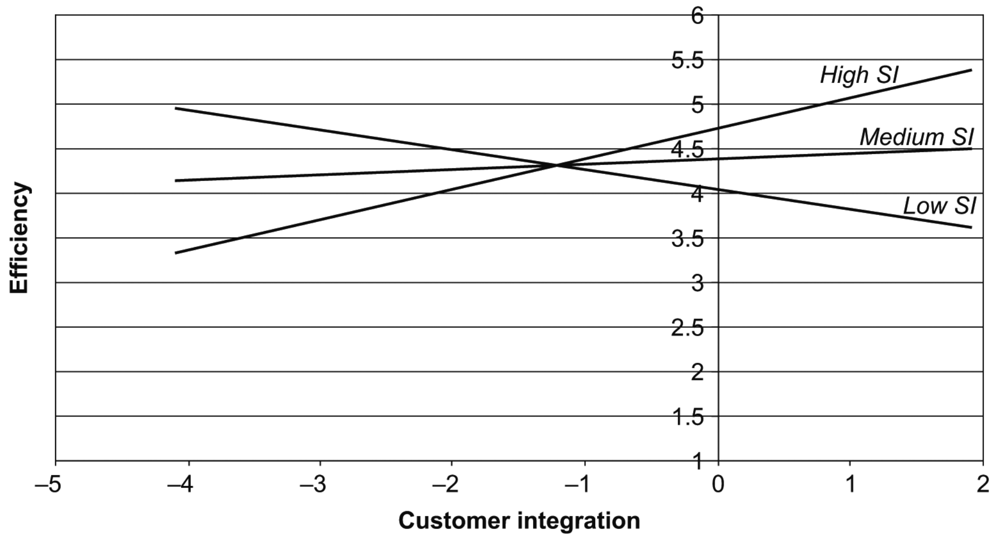
Figure 2 Efficiency slope at low, medium and high levels of supplier integration



Results found on the CI-efficiency link and the moderating effect of SI can have interesting managerial implications. An important hint for managers is that efficiency performance optimization requires levering simultaneously on CI and SI to foster their interaction, rather than investing and acting on CI only. In fact, when CI is not accompanied by a high level of SI, this latter can act as a barrier that hinders the positive impact of CI on efficiency. This is because the absence of integration with suppliers does not allow the company to efficaciously manage the nervousness effect caused by CI. Therefore managers should be aware of this effect, that could offset their efforts to improve efficiency through CI.

Finally, by clarifying what should be the impact of CI on efficiency and the role of SI, this study offers guidance for managers facing the selection of the most appropriate mix and sequence of SC integration initiatives, in order to maximize efficiency improvements. After having achieved good levels of CI, companies should direct their efforts towards SI, by extending the integration upstream, rather than continuing investing on CI. For instance, from model 2 it is easy to calculate that starting from a situation with a 6-level of both CI and SI, a one-point increment in CI increases efficiency performance by 8.6 percent; whereas a one-point increment in SI increases performance by 22.8 percent. Moreover, before deciding to invest on CI, managers should ascertain what the level of SI is. In fact, SI paves the way for the successful implementation of CI, because it can help to limit a series of problems (e.g. nervousness of plans) that can offset CI benefits.

5.1 Limitations of this study and future research

This research also exhibits a series of limitations to be taken into consideration that suggest some proposals for future research.

First, as in several other surveys on SCM (Frohlich and Westbrook, 2001; Kim, 2006; Lee *et al.*, 2007), in this study we collected information on the level of integration of the focal firm with its suppliers and customers. This limits the focus of this research to the immediate network of the focal company. Instead, as suggested by Kannan and Tan (2010) and Jayaram *et al.* (2010), SC integration could go beyond the immediate network, by involving second/third tier customers/suppliers. However, we think that it could be difficult to evaluate the involvement of these actors or the integration between second and first (or third and second) tier suppliers/customers by collecting information from respondents within the focal firms. An *ad hoc* survey-based research should be designed to evaluate the integration of the total supply network that should collect information from different respondents within plants positioned in different tiers of the same supply network. In line with Seuring's (2008) suggestions, we think that collecting data from supply chains (i.e. at least two, or three or more stages of the supply chains) could be very useful.

A further opportunity for future research lies in the analysis of possible additional moderating effects on the CI-efficiency relationship, in order to increase the understanding of how to optimize cost reduction. In SCM literature, it is widely recognized that performance can be significantly improved when SCM implementation encompasses an appropriate bundle of initiatives ranging from physical and relational supply network reconfiguration to inter-organizational process re-engineering (de Treville *et al.*, 2004; Danese *et al.*, 2006; Kim, 2006; Li *et al.*, 2009). Extending the analysis of moderated effects would be very interesting because of its implications for management.

Finally, future studies could further investigate some interesting indications which emerged in this research. For instance, a remarkable and counterintuitive hint resulting from this study concerns the role of SI when CI is low. As highlighted in the left side of Figure 2, companies characterized by extremely low degrees of integration with their customers seem to be more efficient when integration with suppliers is also low. It could be argued that integration with suppliers in absence of integration with customers is not likely to guarantee low stock and efficiency. In fact, suppliers' plans are aligned with those of the manufacturer, but not with final demand; and at the same time integrating suppliers brings with it significant coordination costs. However, this situation (i.e. CI extremely low and SI at a high level) is

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particularly rare and extreme (i.e. only one plant in our sample), and thus further research is necessary to corroborate this finding.

6. Conclusion

This study intends to contribute to existing literature on SC integration by investigating the impact of customer integration on efficiency performance and the moderating role of supplier integration. Results found highlight the need for firms to simultaneously pursue integration with customers and suppliers to improve efficiency performance. In fact, CI alone is not enough to guarantee cost reductions; and if SI is low, CI can even make efficiency worse. This provides a number of original implications for the interpretation of the relationship between CI and efficiency. In particular, we can infer that CI can cause additional costs and problems that SI can help to mitigate. Schedule nervousness is a typical effect linked to customer integration, that can be efficaciously faced through the integration of suppliers.

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Appendix. Significance of the marginal effect of CI on EFF

With reference to the following equation describing moderated regression:

$$y = \beta_0 + \beta_1 x + \beta_2 z + \beta_3 xz + \varepsilon$$

the test of significance of the marginal effect $\partial y/\partial x = \beta_1 + \beta_3 z$, takes the form of a *t* test, where the standard error is a function of z and can be calculated such that:

$$\text{standard error} = \left[\left(\text{var}(\beta_1) + z^2 \cdot \text{var}(\beta_3) + 2 \cdot z \cdot \text{cov}(\beta_1 \beta_3) \right) \right]^{1/2}$$

where $\text{var}(\beta_1)$, $\text{var}(\beta_3)$ and $\text{cov}(\beta_1\ \beta_3)$ are the variances of β_1, and β_3 and the covariance of β_1, and β_3, respectively. Following these formulas, we have created and applied an MS-Excel sheet, that automatically calculates the range of z values, where this t test results significant at 0.05 level. The input data of this MS-Excel sheet are: β_1, β_3, $\text{var}(\beta_1)$, $\text{var}(\beta_3)$, and $\text{cov}(\beta_1\ \beta_3)$. All these input data can be obtained from linear regression module of SPSS 17.0. In particular, they can be extracted by selecting "covariance matrix" in the regression coefficient menu of the "statistics" option.

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