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Pamela Danese, Pietro Romano

► **To cite this version:**

Pamela Danese, Pietro Romano. Relationship between Downstream Integration, Performance Measurement Systems and Supply Network Efficiency. *International Journal of Production Research*, 2011, pp.1. 10.1080/00207543.2011.575894 . hal-00719061

**HAL Id: hal-00719061**

**<https://hal.science/hal-00719061>**

Submitted on 19 Jul 2012

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Journal:	<i>International Journal of Production Research</i>
Manuscript ID:	TPRS-2010-IJPR-1103.R1
Manuscript Type:	Original Manuscript
Date Submitted by the Author:	15-Jan-2011
Complete List of Authors:	Danese, Pamela; University of Padova, Department of Management and Engineering Romano, Pietro; University of Udine, Department of Electrical Managerial and Mechanical Engineering
Keywords:	SUPPLY CHAIN MANAGEMENT, COLLABORATIVE MANUFACTURING
Keywords (user):	

SCHOLARONE™  
Manuscripts

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3 **Relationship between Downstream Integration, Performance Measurement Systems and**  
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5 **Supply Network Efficiency**  
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12 PAMELA DANESE (corresponding author)

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15 Department of Management and Engineering, University of Padova,  
16  
17 Stradella S. Nicola, 3, 36100 Vicenza, Italy, pamela.danese@unipd.it  
18  
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21  
22 PIETRO ROMANO

23  
24 Department of Electrical, Managerial and Mechanical Engineering, University of Udine,  
25  
26 Via delle Scienze, 208, 33100 Udine, Italy, pietro.romano@uniud.it  
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## Relationship between Downstream Integration, Performance Measurement Systems and Supply Network Efficiency

### Abstract

Downstream integration is a key managerial area to improve performance in supply networks. Though most studies agree that downstream integration positively influences performances, the literature also reports cases of failures in achieving significant improvements. This evidence suggests that some factors may act as moderators on the downstream integration-performance relationship. This paper analyzes the impact of downstream integration on supply network efficiency and the moderating effect on this relationship of supply network performance measurement systems. Data from a sample of 200 manufacturing plants settled in several countries around the world demonstrates that this moderating effect exists. Therefore, in order to strengthen the impact of downstream integration on supply network efficiency, managers should combine interventions on downstream integration and supply network performance measurement systems, rather than investing and focusing on downstream integration only.

**Keywords:** supply chain management; downstream integration; supply network efficiency; performance measurement systems; survey

### Introduction

Supply chain management (SCM) researchers emphasize the contribution of downstream integration to improve performance in supply networks (Romano 2009, Kannan and Tan 2010, Danese 2011). The term “downstream integration” - sometimes also referred in the literature as customer linkage (Lee *et al.* 2007) and external integration (Gimenez and Ventura 2005) – is used to identify the process of building intimacy and sharing information on manufacturing and demand plans between the logistics area of one company and the logistics area of its customer. The seminal study by Cooper *et al.* (1997) provided the basis for a rich stream of studies arguing that performance improvements in supply networks are not assured if supply chain integration practices are not accompanied by a coherent mix of complementary SCM initiatives encompassing, for instance, lead time reduction, supplier network rationalization, production network reconfiguration, development of partnerships, implementation of supply network performance measurement systems, etc. (Romano 2003, Danese *et al.* 2006, Li *et al.* 2009). According to this view, a myopic focus on a supply chain integration activity, without paving the way for its successful implementation by activating further supporting SCM initiatives, may lead the supply network to underperform both in terms of productivity and profitability. This poses a practical limitation because supply chain integration processes and complementary SCM activities are not cost free, and supply chain managers have limited resources and must deploy them in the most effective way. If

multiple initiatives need to be launched, it is vital for managers to understand how they mutually relate to determine their respective roles in contributing to performance. For instance, a supply chain integration practice may have no noticeable effect on performance in itself, but the way it “interacts” with another SCM practice may have an effect on the performance under consideration (Danese and Romano 2011). In other words, the presence of a certain SCM practice may mitigate or compensate for the limitations of a certain supply chain integration practice, thus determining a positive additional synergistic effect on performances.

In this paper we focus on the relationship between downstream integration and efficiency. Since downstream integration determines performance improvements that overcome the focal operation boundaries, in this paper we refer to efficiency using Bechtel and Jayaram’s (1997) perspective. As a consequence efficiency considers both single operation performance (e.g. the level of stocks, manufacturing costs) and supply network performance (e.g. in-process inventories and balancing of capacities between operations). In particular, we aim to investigate whether one complementary SCM initiative – i.e. the adoption of supply network performance measurement systems - can interact with downstream integration by positively moderating the relationship between this latter and supply network efficiency. Thus, this research intends to contribute to SCM literature by investigating whether any synergies between downstream integration and supply network performance measurement systems exist that a firm could or should exploit to achieve higher levels of efficiency. The aim is to open a debate on this issue, by providing empirical evidence on how efficiency improvements shouldn’t be pursued just by using downstream integration practices more extensively, but rather by modulating the implementation of supply network performance measurement systems and downstream integration more effectively. Such finding is useful also from the practitioner’s perspective, as it can give guidance on how to better combine downstream integration and supply network performance measurement systems to maximize the impact on efficiency performance.

The paper is organized as follows. First, it analyzes existing literature on the impact of downstream integration on efficiency and 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 results found. Finally, conclusions summarize the main theoretical and managerial contributions of this study and provide opportunities for future research.

### Literature review and hypotheses

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 (Handfield *et al.* 2009, Singh and Power 2009, Ou *et al.* 2010, Wiengarten *et al.* 2010). Being supply chain management a relatively young and multifaceted discipline, the basic definitions of supply chain integration used in SCM studies are heterogeneous.

As concerns research on the relationship between supply chain integration and performance, we distinguish between three points of view. Some researchers focused their analyses on integration with customers (Fynes *et al.* 2005, Gimenez and Ventura 2005, Sahin and Robinson 2005) in order to ascertain the distinct contribution of such practice to performance. For similar reasons some

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3 authors decided to concentrate on integration with suppliers (Jain *et al.* 2009, Lawson *et al.* 2009,  
4 Vachon *et al.* 2009, Wagner and Krause 2009). Instead, other authors took a broader perspective by  
5 considering integration with both customers and suppliers (Lee *et al.* 2007), or defining supply  
6 chain integration as a unique concept that includes both upstream and downstream integration  
7 (Vickery *et al.* 2003, Kim 2006).  
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11 Focusing our attention on the relationship between downstream integration and efficiency  
12 performance, several arguments can be found in the literature to support the existence of a positive  
13 link. A stream of research focuses on information sharing associated to customer integration and  
14 indicates in the reduction of demand variability, and hence of safety stock holding costs, the  
15 primary benefit of integration. For instance, several studies (Coppini *et al.* 2010, Wangphanich *et al.*  
16 2010) addressed the “bullwhip effect”, namely the natural tendency of decentralized decision  
17 making to amplify, delay and distort demand information moving upstream in a make-to-stock  
18 supply chain. Operational alignment to final demand of channel member activities is frequently  
19 identified among the recommend actions for counteracting the bullwhip effect (Chen *et al.* 2000,  
20 Lee *et al.* 2000). Sharing demand and/or inventory data with customers can improve the supplier’s  
21 order quantity decisions in multi-stage serial systems, because knowledge about the customer’s  
22 inventory levels reduces the demand uncertainty faced by the supplier. In particular, sharing point-  
23 of-sales demand enables the supplier to improve its forecast accuracy and lower total inventory  
24 costs. In addition, working in close contact with customers and sharing planning information make  
25 it possible for the supplier to know upcoming orders in advance and for the customer to be quickly  
26 acknowledged about possible delays. This in turn reduces system uncertainty and lowers costs  
27 (Bayraktar *et al.* 2009, Ryu *et al.* 2009). Lee *et al.* (2000) quantify cost reductions due to  
28 information sharing into 12-23%. Similarly, Gavirneni *et al.* (1999) report cost reductions of 1–  
29 35%, when sharing retailers’ demand data. Zhao *et al.* (2002) analyze the benefits of information  
30 sharing and ordering co-ordination in a supply network composed by a manufacturer that serves  
31 with a single product four retailers. They demonstrate that these practices significantly improve  
32 supply chain performance in terms of total costs.  
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41 According to several authors, information sharing is just one dimension of supply chain integration.  
42 Coordination is a further important aspect to achieve significant performance improvements. For  
43 instance, Sahin and Robinson (2005) argue that integration at different layers in the supply network  
44 contributes to performance in various ways: on the one hand it improves information sharing, on the  
45 other, it fosters coordination between supplier and customer in terms of joint improvement efforts,  
46 close contact and partnership. Similarly, Swink *et al.* (2007) maintain that supply chain integration  
47 entails both a better information sharing to align “operational activities” (e.g. ordering and payment  
48 systems, production and replenishment planning) between a supplier and a customer, and an  
49 improved coordination of “strategic activities” (e.g. relationship building, joint improvement  
50 activities) which creates customer-supplier intimacy. As reported in many studies (Flynn and Flynn  
51 1999, Frohlich and Westbrook 2001), coordination can promote an attitude of sharing problems,  
52 cooperation, openness of communication, and the creation of inter-company decision making  
53 routines that guarantees a more efficient problem solving. In case of unexpected problems,  
54 manufacturers working in close contact with customers can efficaciously support their partners in  
55 the search of solutions. Customers could provide the producer with feedbacks on quality and  
56 delivery performance, or involve the manufacturer in their quality improvement efforts.  
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3 From the above arguments it follows that there is a theoretical foundation as well as emerging  
4 evidence for a general positive relationship between downstream integration and efficiency  
5 performance. However, although the potential benefits of downstream integration, and in general  
6 supply chain integration, seem compelling, a recent academic debate has arisen on the actual  
7 positive impact of integration on company performance. In a literature review on SCM survey-  
8 based research, van der Vaart and van Donk (2008) argue that studies on the effect of supply chain  
9 integration on performance are not unanimous and that caution is advisable. In particular, some  
10 authors maintain that the nature of supply chain integration is complex and more knowledge is  
11 needed on its relation to performance. For instance, Stock *et al.* (2000) conclude that supply chain  
12 integration does not necessarily provide performance benefits in all cases. Sezen (2008) finds that  
13 integration with customers and suppliers is not significantly related to flexibility, efficiency,  
14 customer satisfaction and profit. Cousins and Menguc (2006) argue that whilst supply chain  
15 integration clearly has its benefits, it also has costs and may not enhance operational performance  
16 and “in some cases it has the reverse effect” (p. 616). Coherently, Das *et al.* (2006) report that  
17 collaborating with other partners can cause increased costs of coordination and inflexibility.

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25 With regard to the relationship between downstream integration and efficiency, Disney and Towill  
26 (2002) have investigated the issue of inventory nervousness in downstream integrated systems, and  
27 its negative effect on costs. They claim that, in integrated systems, continuously recalculating  
28 inventory control parameters according to demand signals causes fluctuations in target inventory  
29 levels or in production quantities. Therefore, a slow reaction to demand signals can result in a more  
30 stable inventory level and a reduction in production quantity fluctuations. In a further work, Disney  
31 *et al.* (2004) suggest that Vendor Managed Inventory (VMI) systems should not be too complex in  
32 order to improve the dynamics of supply chains. When testing different information sharing  
33 practices, they show that, although players have information available, very complex decision  
34 making can result in increased inventory costs.

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39 Therefore, while most studies agree on the positive effect of downstream integration on efficiency,  
40 this position is not unanimous, and further research and hypothesis testing is needed. Hence, we  
41 intend to analyze the following hypothesis:

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46 *Hypothesis 1: Downstream integration is positively related to efficiency performance.*

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50 We believe that an interesting opportunity to better understand the impact of downstream  
51 integration on efficiency performance lies in the examination of interactions between downstream  
52 integration and supply network performance measurement systems.

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55 The seminal study by Cooper *et al.* (1997) provides the basis for the assumption that performance  
56 improvements in supply networks are not assured if supply chain integration practices are not  
57 accompanied by a coherent mix of complementary SCM initiatives. Some authors identify in the  
58 use of supply network performance measurement systems a practice that can affect the impact of  
59 downstream integration on efficiency (Brewer and Speh 2001, Gunasekaran *et al.* 2004, Danese  
60 2006, Forslund and Jonsson 2009). Such systems require supply chain members to share common



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3 and agreed key indicators of supply network performance (Marchand and Raymond 2008).  
4 Companies should consider not only how a particular facility in the network performs (e.g. the level  
5 of stocks at the producer's warehouse), but also the performance of the whole supply chain or  
6 network (e.g. the total amount of stocks in the supply network) (Bechtel and Jayaram 1997).  
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10 According to Gunasekaran *et al.* (2004) supply network performance measurement systems are  
11 important to successfully implementing downstream integration practices. In general, such systems  
12 allow to drive decision making when deciding on improvement initiatives to be adopted. Thus,  
13 when supply network performance measurement systems are in place, downstream integration  
14 initiatives can be better directed to address specific problems. Instead, companies sometimes do not  
15 succeed in maximizing their supply chain's potential because they fail to develop the performance  
16 metrics and measures needed for identifying problems and crucial areas for improvements in their  
17 supply networks.  
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21 A further way supply network performance measurement systems can support the successful  
22 implementation of downstream integration concerns the reduction of the obstacles related to lack of  
23 trust in the customer-supplier relationship and the differences in goals and priorities between supply  
24 network partners. The studies by Brewer and Speh (2001) and Forslund and Jonsson (2009)  
25 recognize that downstream integration is considered one major factor in improving performance,  
26 but the successful realization of a collaborative attitude can be hindered by a poor trust and goal  
27 alignment. The use of supply network performance measurement systems can support trust and  
28 alignment by providing appropriate metrics to demonstrate that benefits are shared among the  
29 counterparts involved in collaborative initiatives.  
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34 Similarly, Danese (2006) demonstrates that if a company is integrated with its customers, but supply  
35 network performance measurement systems are scarcely adopted, supply network members can  
36 deviate from collaboration and adopt opportunistic behaviors. She reports evidences from the  
37 GlaxoSmithKline (GSK) case study. Production plants supply customer distribution centers using a  
38 Vendor Managed Inventory approach. The performance monitoring system adopted in GSK is  
39 considered one of the key factors in the successful implementation of VMI with distributors because  
40 it makes easy to identify and thus limit opportunistic behaviors. VMI requires that manufacturers  
41 monitor customers' inventory level and, according to sales forecasts, make periodic replenishments,  
42 deciding order quantities, shipping and timing. Customers usually pay just for the products they  
43 sell. Thus, when a performance monitoring systems is lacking, the customer uses to inflate its sales  
44 forecasts in order to be sure of product availability also in the event of an unexpected rise in  
45 demand. Only the wide adoption of supply network performance measurements systems can assure  
46 that downstream integration actions are aimed at the efficiency of the whole network, rather than at  
47 generating opportunistic behaviors and local optimization.  
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54 From the above, we can hypothesize that the use of supply network performance measurement  
55 systems can significantly affect the positive impact of downstream integration on efficiency and, as  
56 a consequence, that it operates as a moderator of the relationship between downstream integration  
57 and efficiency. A moderator variable affects the strength of a relation between an independent and  
58 dependent variable. Thus, this study intends to investigate, on the one hand, whether the adoption of  
59 a supply network performance measurement systems can amplify the effect of downstream  
60 integration on efficiency, on the other, whether the scarce use or absence of such systems can hinder



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3 downstream integration impact on efficiency. In other words, our research proposes to study the  
4 following hypothesis:  
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9 *Hypothesis 2: The use of supply network performance measurement systems positively moderates*  
10 *the relationship between downstream integration and efficiency performance.*  
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## 13 14 15 **Methodology**

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17 This study uses data from the third round of the High Performance Manufacturing (HPM) project  
18 data set (Schroeder and Flynn 2001). It includes responses from manufacturing plants operating in  
19 machinery, electronic and transportation components sectors (SIC codes: 35, 36 and 37,  
20 respectively) and located in different countries (i.e. Finland, US, Japan, Germany, Sweden, Korea,  
21 Italy, Austria and Spain). The plants in the HPM study were randomly selected from a master list of  
22 manufacturing plants in each of the countries. All plants represented different parent corporations,  
23 and had at least 100 employees.  
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28 Participating plants received a batch of questionnaires, targeted at the respondents who were the  
29 best informed about the topic of the specific questionnaire. In total 20 recipients were involved in  
30 each plant (plant manager, HR manager, process engineer, inventory manager etc). In order to raise  
31 measurement reliability each questionnaire was administered to more than one respondent within  
32 each plant. We asked the CEOs (or a coordinator within each plant) to provide us with the name and  
33 contact addresses of the respondents for each questionnaire, and to distribute the questionnaires we  
34 gave him/her by individual visits or by post to the respondents. Within the research team, a group of  
35 researchers and a person in charge of data collection were identified for each country. Each group  
36 had to provide assistance to the respondents, to ensure that the information gathered was both  
37 complete and correct.  
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42 The items used in the present research were targeted toward plant managers, inventory managers  
43 and plant superintendents, or their immediate subordinates working in direct contact with  
44 customers. Respondents were specifically asked to give answers on supply chain practices adopted,  
45 supply network performance measurement systems used and performances obtained. In particular,  
46 as in other survey-based SCM studies (see van der Vaart and van Donk 2008), we examined  
47 customer integration of focal operations in supply networks, by asking respondents from these  
48 operations about integration practices adopted with their customers. Since there were multiple  
49 respondents within plants for each item, an average was taken to obtain a single value for each item  
50 and plant.  
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55 Respondents from a total of 266 plants returned the questionnaires, but 66 plants were excluded  
56 from the analyses, since they provided incomplete responses about the items used in this study.  
57 Accordingly, the analysis that follows and all reported statistics were based on a sample of 200  
58 plants. As shown in Table 1, the sample is stratified to approximate equal distribution across all  
59 three sectors. Moreover, most plants in the responding sample were large-sized with 64% of the  
60 firms employing more than 250 people. The mean number of employees for the sample was about

639 (number of hourly and salaried personnel). We use size and industry as control variables later in the analysis to test whether these had any impact on efficiency performance.

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Insert here Table 1

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Three multi-item constructs were identified and considered in this paper, referred to as: Downstream Integration (DI), Supply Network Performance Measurement Systems (SNPM) and Efficiency (EFF). 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. Given the lack in SCM literature of a standard scale for measuring downstream integration, supply network performance measurement systems and efficiency (within and beyond focal operations' boundaries), we followed established guidelines for scale development and examined the measurement model through exploratory methods (Hair *et al.* 2006).

We ran a factor analysis with Varimax rotation on the complete set of items considered. As reported in Table 2, three 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.

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Insert here Table 2

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DI is operationalized as a five-item scale that measures the basic notions used to define supply chain integration considered by van der Vaart and van Donk (2008): supply chain practices - i.e. tangible activities that play an important role in the collaboration of a focal operation with its suppliers and/or customers (e.g. integrated production planning, synchronization, information sharing etc.) – and attitude/interactions – i.e. the relationships and attitude that a firm maintains with its suppliers or customers (e.g. closer relationships, relationship strength, long term orientation etc). Following these remarks, in this study we define DI as the process of building intimacy and sharing information on manufacturing and demand plans with customers. The items used refer to supply chain practices (i.e. considering of customer's forecasts in supply chain planning, customers' access

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3 to production plans, feedback on quality and delivery performance) and attitude/interactions (i.e.  
4 joint quality improvement efforts, close contact relationship). All five items load onto a single factor  
5 (Cronbach's alfa = 0.70).  
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8 The construct SNPM is composed of three items that consider whether the performance of the  
9 whole supply chain and of its members is monitored, and whether a shared system of performance  
10 indicators is used. The studies by Gunasekaran *et al.* (2004), Forslund (2007) and Forslund and  
11 Jonsson (2009) provided theoretical support for the use of such items. All three items load onto a  
12 single factor (Cronbach's alfa = 0.78).  
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15 Finally, we defined the efficiency (EFF) construct, by means of four items. On the one hand, they  
16 measure the efficiency performance of the focal operation - as do several survey-based papers on  
17 SCM (van der Vaart and van Donk, 2008). In particular, we asked respondents to provide their  
18 opinion about the plant performance compared with that of its competitors about: 1) unit cost of  
19 manufacturing and 2) inventory turnover. These two measures are often considered when evaluating  
20 the cost performance of a company (Bozarth *et al.* 2009, Kim *et al.* 2010).  
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25 On the other hand, since in this paper we consider the integration of the focal operation with  
26 customers, and this practice generates benefits beyond the focal operations' boundaries, we asked  
27 respondents to provide information on their perceptions of: 3) balancing of capacities, and 4) in-  
28 process inventories between operations. All four items load onto a single factor (Cronbach's alfa =  
29 0.70).  
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32 We think that the EFF construct proposed allows researchers to better evaluate the impact of DI on  
33 efficiency performance and interpret the interaction effect between DI and SNPM. For example, if  
34 the performance construct takes into consideration only the focal operation's efficiency, the local  
35 improvement due to downstream integration can be measured, but there is no chance of estimating  
36 the impact on the focal operation's network.  
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40 It is important to note that the items included in the three research scales mainly address the focal  
41 company perspective. Indeed, to guarantee the effective implementation of downstream integration  
42 practices, use of supply chain performance measurement systems and achievement of efficiency  
43 excellence, the point of views of other supply network members should be also considered (Jayaram  
44 *et al.* 2010). For instance, respondents from the focal operation may not have a precise idea of the  
45 situation of the inventories of their partners and capacity balancing between different plants in the  
46 network; or their perceptions on the use of supply chain performance measurement systems could  
47 differ from the perceptions of their partners. As a consequence, the risk is that the answers collected  
48 do not reflect the real situation. We tried to reduce these problems by relying on multiple  
49 respondents within each plant as well as on scales derived from previous studies. In particular, we  
50 selected those respondents who could be the best informed on the situation of the network and  
51 outbound processes, and usually worked in direct contact with customers.  
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57 All the items were measured using multi-item perceptual scales with values ranging from 1 to 7.

58 Table 3 shows basic statistics for the three constructs, each obtained by averaging the relevant  
59 items.  
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Insert here Table 3

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## Data analyses

To test the hypotheses we ran a hierarchical regression analysis. Firstly, control variables (i.e. firm size and sector) were considered in the regression model (model 0 in Table 4). 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. DI, SNPM - were introduced in the regression equation (model 1 in Table 4). Finally, in model 2 we included also the interaction term. If the coefficient of the interaction term is statistically significant, and  $R^2$  increases when this term is introduced in the model, the existence of a moderated effect is demonstrated.

To address the problem of multicollinearity, we followed the procedure recommended by Jaccard and Turrisi (2003), who suggest to mean-center the independent variables. Then we examined multicollinearity diagnostics by checking the variance inflation factor (VIF) and tolerance values. The values found (Table 4) are well within the recommended intervals.

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Insert here Table 4

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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 have been found. Hence, we can conclude that the control variables do not affect the results of the regression.

When the independent variables DI and SNPM are added to the regression model (model 1), we can note that SNPM is significantly related to efficiency performance, whereas DI is not. Thus, hypothesis H1 is not confirmed, namely it is not possible to conclude that DI always improves efficiency.

Models 2 reports changes occurring to the main variables when the interaction term is introduced. The significant and positive coefficient of  $DI \times SNPM$  suggests that it is possible to confirm the

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existence of a positive interaction effect between DI and SNPM. Additional support is the statistically significant change in  $R^2$  from model 1 to 2 (0.033). Therefore, hypothesis H2 is fully supported.

By deriving with respect to DI the regression equation of model 2 in Table 4 it is possible to calculate that the marginal effect of DI on EFF depends on SNPM, according to the following formula:

$$\frac{\partial \text{EFF}}{\partial \text{DI}} = 0.095 + 0.372 \cdot \text{SNPM} \quad (1)$$

where the variable SNPM is mean-centered. As Brambor *et al.* (2006) recommend, it is necessary to know the standard error for the coefficient represented by equation (1). The test of significance takes the form of a t test, where the standard error is a function of SNPM. We have verified that the t test is significant at a 0.05 level for the values of SNPM lower than  $-1.04$  and greater than  $0.26$ .

Figure 1 shows how the marginal effect of DI varies when SNPM increases. It is easy to see that DI has a stronger effect on efficiency performance when the level of SNPM is high. Further, we can note that for low levels of SNPM, the effect of DI could even be negative. This means that, when companies use no system to monitor supply network performance, not only are the benefits of DI lost, but also a contrasting effect emerges that risks the achievement of good levels of efficiency.

The research sample reveals that the centered variable SNPM varies from  $-2.23$  to  $1.50$ ; 34% of sample units falls below the SNPM critical value of  $-0.26$ , where the marginal effect is null. Below this value, DI seems to have a negative influence on efficiency performance (see Figure 1). However, since the SNPM critical value of  $-0.26$  falls within the not significance interval, empirical evidence provides support that the marginal effect is significantly negative for SNPM values below  $-1.04$  only. This situation is extreme because just the 8% of plants in our sample have so low levels of SNPM adoption.

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Insert here Figure 1

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To further gain an intuitive understanding of the interaction effect between DI and SNPM, we computed and graphed the relationship between efficiency performance and DI at a few different values of SNPM. As Cohen and Cohen (1983) suggest, a reasonable strategy is to evaluate the effects of DI on performance at “low”, and “high” values of SNPM, where “low” might be defined as one standard deviation below the mean SNPM score, and “high” as one standard deviation above the mean. Starting from the coefficients of model 2 in Table 4, and by using the two mentioned

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3 values of the variable SNPM, two linear equations of efficiency performance depending on DI were  
4 created. The visual patterns of Figure 2 confirms that the effect of DI on efficiency is greater when  
5 SNPM increases; while this effect can be negative when SNPM is at a low level.  
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8 Figure 2 highlights what Jaccard and Turrisi (2003) classify as ‘disordinal interaction’ or ‘crossover  
9 interaction’, namely an interaction in which the line that regresses y onto the focal independent  
10 variable (i.e. DI) for a given level of the moderator (e.g. low level of SNPM) intersects with the  
11 correspondent regression line for a different level of the moderator (e.g. high level of SNPM). This  
12 type of interaction is very useful for decision making in different situations. For instance, it suggests  
13 that a high level of DI (right side of Figure 2) should be accompanied by a high level of SNPM. On  
14 the other hand, below the intersection point ( $DI = -1.51$ ), a low level of SNPM seems convenient.  
15 However, the research sample reveals that this is a frontier situation. In fact, only one unit in sample  
16 units falls below the DI critical value of  $-1.51$ .  
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## 34 Discussion of results

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36 This study provides a number of original implications for the interpretation of the relationship  
37 between downstream integration and supply network efficiency. Our results are consistent with the  
38 stream of research which supports the adoption a coherent mix of complementary SCM initiatives  
39 (Romano 2003, Danese *et al.* 2006, Li *et al.* 2009). In fact we provide empirical evidence to  
40 demonstrate that investing in downstream integration activities without creating the conditions for  
41 their successful implementation through the activation of further supporting SCM initiatives may  
42 lead the supply network to underperform. In particular, our research contributes to the academic  
43 debate by providing new insights to better understand the controversial results found in some  
44 studies on the DI-efficiency relationship (Das *et al.* 2006, Cousins *et al.* 2008; Sezen 2008).  
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50 Interestingly enough, our data analysis does not confirm the existence of a positive direct effect of  
51 DI on efficiency in the “main effects only” model (see model 1). Instead, significant positive  
52 association of DI and efficiency is evident in bivariate correlation (0.233). This result indicates that  
53 the bivariate correlation may be spurious. When other aspects moderating the direct relationship  
54 between downstream integration and efficiency are accounted for, such as the adoption of supply  
55 network performance measurement systems, there is a significant impact on efficiency of the  
56 interaction between downstream integration and complementary SCM practices (see model 2).  
57 Therefore, significant efficiency improvements cannot be achieved by investing in downstream  
58 integration only. Our results indicate that improvements can occur only under certain conditions in  
59 terms of usage of supply network performance measurement systems.  
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3 In particular, the research findings confirm that the positive effect of downstream integration on  
4 supply network efficiency increases, when integration is accompanied by the implementation of  
5 supply network performance measurement systems. In this case, it is possible to better identify  
6 problems and criticalities in the supply network (e.g. facilities with large inventories or never on  
7 time, frequent stock outs of certain products/raw materials, low performing suppliers, etc.) and in  
8 turn to better direct adjustments and improvement efforts. On the contrary, the absence or a low  
9 usage of supply network performance measurement systems can act as a barrier that limits the  
10 efficacy of downstream integration practices, or even determines, in extreme cases, a negative  
11 impact of downstream integration on efficiency. In other words, if a company is integrated with its  
12 customers, but supply network performance measurement systems are scarcely adopted, supply  
13 network members can deviate from collaboration towards opportunistic behaviors. For instance,  
14 implementing a downstream integration practice such as the Vendor Managed Inventory without an  
15 adequate supply network performance measurement system can be counterproductive in terms of  
16 efficiency. Since customers usually pay just for the materials they take, they could swell their sales  
17 forecasts in order to force suppliers to increase stock, thus being sure of product availability also in  
18 the event of an unexpected rise in demand. Clearly this conduct privileges local optimization and  
19 has a negative impact on supply network efficiency. As reported by Danese (2006), only the  
20 adoption of supply network measurement systems can detect such behaviors and discourage  
21 opportunism both at customer and supplier side. In the same vein, Terwiesch *et al.* (2005) discuss  
22 how the use of a supply network performance measurement system reduces opportunistic behaviors  
23 that limit the efficacy of a downstream integration practice - the Collaborative Planning,  
24 Forecasting and Replenishment (CPFR) - in the semiconductor equipment industry. In this context  
25 sales forecasts are very volatile because they are continually updated as the customer receives fresh  
26 information about final demand. As a consequence, customers place soft orders with the suppliers,  
27 turning them into firm orders later. Suppliers are usually hesitant to plan in advance based on the  
28 shared forecast because of the risks of future adjustments and thus delay the allocation of capacity  
29 to future orders. This leads the customer to forecast inflation. In this particular scenario both  
30 suppliers and customers could take advantage of opportunistic conducts (i.e. the supplier does not  
31 allocate capacity in advance, the customer swells order forecast), thus eroding the values derived  
32 from CPFR implementation. A supply network performance measurement system that measures  
33 both customer forecast accuracy and supplier stock-outs and delays can discourage such  
34 opportunistic behaviors.  
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## 50 **Conclusions**

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52 This study demonstrates that the adoption of supply network performance measurement systems  
53 acts as moderator of the downstream integration-supply network efficiency relationship. The role of  
54 this moderator is twofold. On the one hand, the adoption of supply network performance  
55 measurement systems strengthens the positive impact of downstream integration on supply network  
56 efficiency, through a positive additional synergistic effect. The practical implication for managers is  
57 that performance optimization requires leveraging simultaneously on downstream integration and  
58 supply network performance measurement systems to foster interaction, rather than investing in  
59 downstream integration only.  
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3 On the other hand, the multivariate analysis provided evidence of the existence of disordinal  
4 interactions between downstream integration and the moderator considered. It follows that when  
5 downstream integration is not accompanied by an appropriate adoption of supply network  
6 performance measurement systems the positive impact of downstream integration on supply  
7 network efficiency can be hindered. Therefore managers should be aware of this effect, that could  
8 vanish their efforts of improving efficiency through downstream integration. Before deciding to  
9 invest in downstream integration, managers should ascertain the level of adoption of supply  
10 network performance measurement systems. In fact, they act as prerequisites for a successful  
11 implementation of downstream integration, because their adoption limits opportunistic behaviors  
12 that can offset downstream integration benefits.  
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18 Our findings extend studies on complementarities to the SCM context. The notion of  
19 complementarity between two or more activities derives from strategic management research and  
20 implies that “doing more of any one of them increases the returns to doing more of the others”  
21 (Siggelkow 2001). We found that the use of supply network performance measurement systems is  
22 complementary to the implementation of downstream integration because doing more of the  
23 moderator increases the marginal impact of downstream integration on efficiency. In particular, we  
24 demonstrate that for very low levels of the moderator, the marginal effect of downstream integration  
25 can be even negative. As the moderator adoption grows, this negative effect reduces; at a critical  
26 threshold it becomes positive; and, from this point, for increasing levels of the moderator this  
27 positive effect increases.  
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32 In conclusion, the limitations and future developments of this study should be considered along  
33 with the results. Firstly our research setting, firms operating in mechanical, electronic and  
34 transportation equipment industries, could limit the generalizability of our findings. It is likely that  
35 other sectors may show different patterns. Hence, future research should replicate and extend our  
36 model to samples drawn from other industries. A further opportunity for future research lies in the  
37 analysis of other moderating effects on downstream integration-efficiency relationship. We focused  
38 our analysis on the moderating role of supply network performance measurement systems. As  
39 argued before, SCM literature suggests that this is a particularly interesting research area. However,  
40 we think that it could be useful to extend the analyses to explore the possible moderating role of  
41 other SCM practices such as upstream integration, a fast supply network structure, lean supply,  
42 intra-company integration, etc. In line with this recommendation, it could be interesting studying  
43 the impact of the synergistic effects of SCM practices also on other performance dimensions (e.g.  
44 customer satisfaction and delivery performance). Extending this analysis would be really interesting  
45 because of its implications for management.  
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Table 1. The sample distribution according to sector

<b>Industry</b>	<b>Number of companies</b>	<b>Percentage</b>
Electronics	67	33.5
Machinery	68	34.0
Transportation components	65	32.5
<i>Total</i>	<i>200</i>	<i>100</i>

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Table 2. Rotated factor matrix

Item	Downstream Integration	Supply Network Performance Measurement Systems	Efficiency
We frequently are in close contact with our customers	<b>0.710</b>	0.372	-0.155
Our customers give us feedback on our quality and delivery performance	<b>0.792</b>	0.353	-0.046
We consider our customers' forecasts in our supply chain planning	<b>0.512</b>	0.306	0.344
Our customers do not have access to our production plans (reverse scored)	<b>0.613</b>	-0.260	0.241
Our customers involve us in their improvement efforts	<b>0.763</b>	0.080	0.041
We monitor our supply chain as a whole	0.139	<b>0.717</b>	0.299
We monitor the performance of supply chain members, in order to adjust supply chain plans	0.173	<b>0.782</b>	0.237
We use shared indicators of supply chain performance	0.088	<b>0.859</b>	0.175
Unit cost of manufacturing	0.043	0.021	<b>0.695</b>
Inventory turnover	-0.030	0.042	<b>0.716</b>
Capacities are balanced in our supply network	0.262	0.218	<b>0.638</b>
We have large in-process inventories between different operations (reverse scored)	-0.016	0.263	<b>0.676</b>

Note: Extraction method: principal factor analysis; rotation method: varimax with Kaiser normalization; rotation converged in five iterations.

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Table 3. Basic statistics, reliability and correlation analysis

Construct	Mean	S. D.	Range	Correlations	
				SNPM	EFF
Downstream Integration (DI)	5.00	0.56	3.13-6.27	0.416**	0.233**
Supply Network Performance Measurement Systems (SNPM)	5.06	0.71	2.83-6.56	-	0.432**
Efficiency (EFF)	4.54	0.80	2.25-6.64	-	-

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

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Table 4. Hierarchical regression analysis

	Control variables	Main effects	Interaction effects
	MODEL 0	MODEL 1	MODEL 2
Constant	4.390***	4.470***	4.386***
SIZE	1.838E-4	2.125E-4	2.183E-4
ELECTRONICS	-0.027	-0.200	-0.176
TRANSP. COM.	0.123	-0.008	0.025
DI		0.101	0.095*
SNPM		0.483***	0.553***
DIxSNPM			0.372**
R <sup>2</sup>	0.053	0.247	0.280
$\Delta R^2$	0.053	0.195	0.033
F of R <sup>2</sup> change	3.203*	22.118***	7.815**
R <sup>2</sup> Adjusted	0.036	0.225	0.255
$\Delta R^2$ adjusted	0.036	0.125	0.030

Note: The values reported are unstandardized regression coefficients:

\* p-value < 0.05 level

\*\* p-value < 0.01 level

\*\*\* p-value < 0.001 level

Multicollinearity diagnostics: VIF < 1.473 and tolerance > 0.679

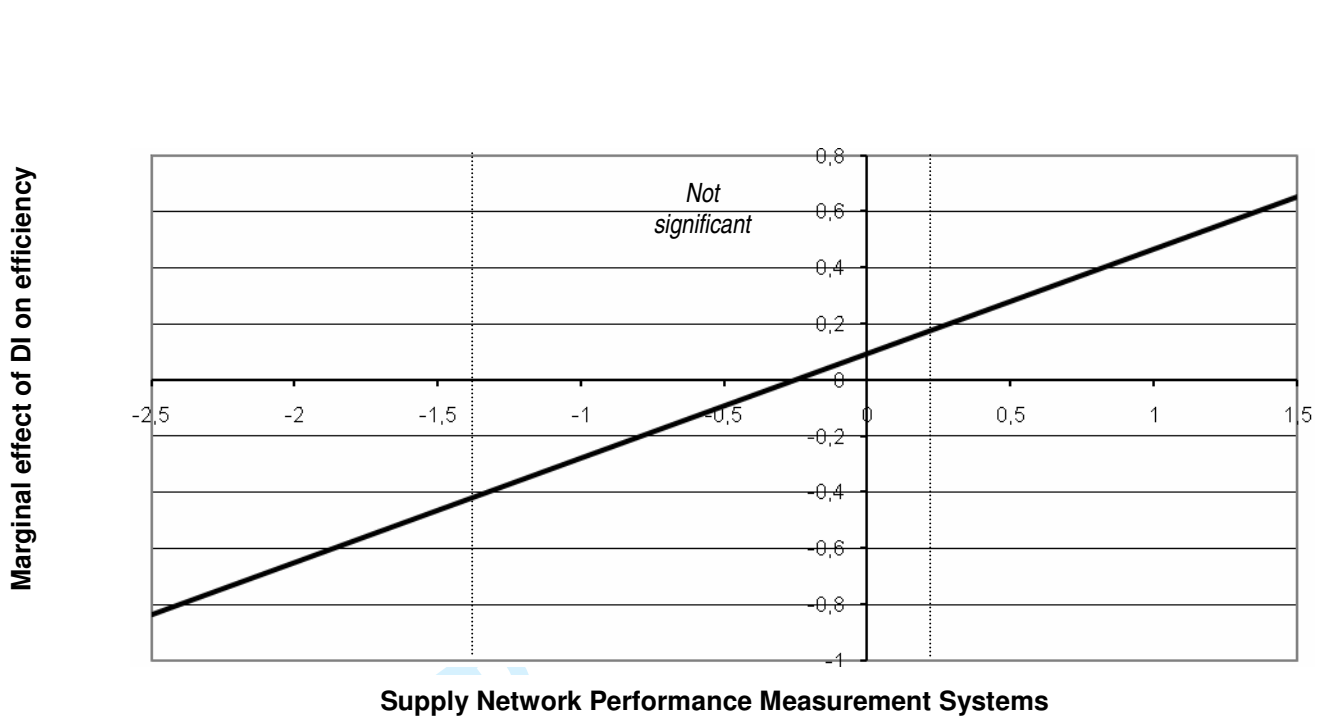


Figure 1. The impact of the adoption of Supply Network Performance Measurement Systems on the marginal effect of Downstream Integration on Efficiency

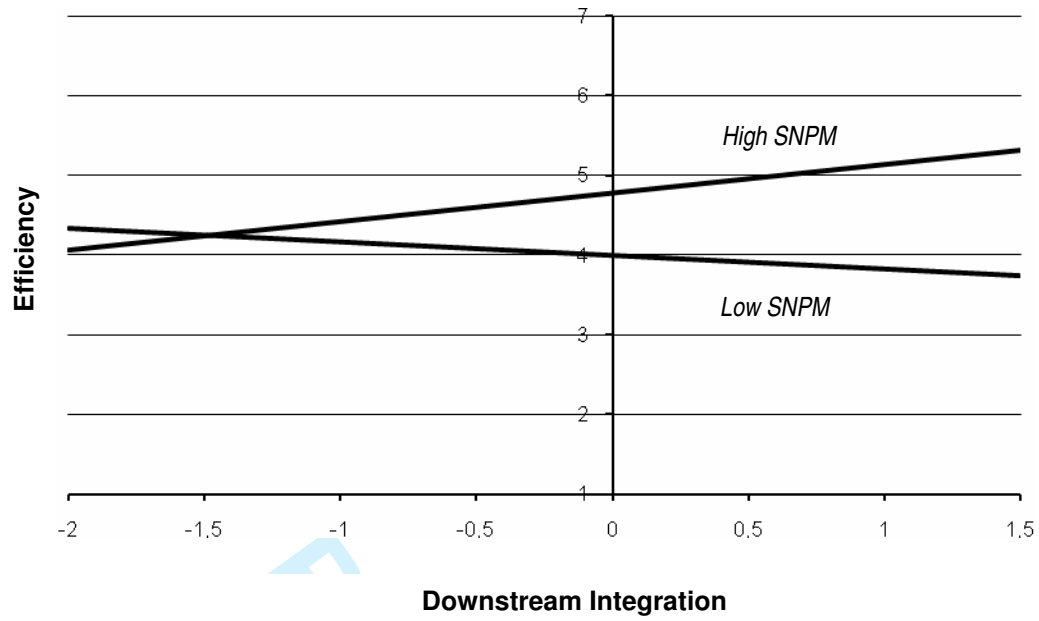


Figure 2. Efficiency slope at low and high levels of adoption of Supply Network Performance Measurement Systems