*2010 International Conference on E-business, Management and Economics*
*IPEDR vol.3 (2011) © (2011) IACSIT Press, Hong Kong*

# Performance Measurement Systems and Downstream Integration

A study on their combined impact on supply network efficiency

Pietro Romano
Department of Electrical, Managerial and Mechanical Engineering
University of Udine
Udine, Italy
pietro.romano@uniud.it

Pamela Danese
Department of Management and Engineering
University of Padova
Padova, Italy
pamela.danese@unipd.it

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

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

## I. INTRODUCTION AND THEORETICAL BACKGROUND

Authors generally agree that stronger linkages and higher degree of integration across organizational boundaries lead to better performance for the focal organization and its supply network [1]. A number of research studies tried to better define the concept of supply chain integration, by discriminating between the efforts to integrate either customer or supplier information and inputs into internal planning [2], [3]. Though the majority of papers consider an extended scope of supply chain integration (i.e. both upstream and downstream), some researchers have focused their analysis on customers or suppliers in order to ascertain their distinct contribute to performance. For instance, [4] 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. Sharing demand and/or inventory data with customer can improve the supplier’s order quantity decisions in multi-stage serial systems, because knowledge about the customer’s inventory levels reduces the demand uncertainty faced by the supplier [5]. In particular, sharing point-of-sales demand enables the supplier to improve its forecast accuracy and lower total inventory costs. Working in close contact with customers and sharing planning information make it possible for the supplier to know in advance upcoming orders and for the customer to be quickly acknowledged about possible delays. This in turn reduces system uncertainty and lower costs [6].

To sum up, current research assumes that the primary benefit of integration with customers is a reduction in demand variability and hence in safety stock holding costs. [7] argue that integration at different layers in supply network contributes to performance in various ways: on the one hand it improves coordination (e.g. joint improvement efforts, close contact, partnership), on the other, it fosters information sharing. Similarly, [8] maintain that supply chain integration pertains both better information sharing to align “operational activities” (e.g. ordering and payment systems, material movements, production and replenishment planning) between a supplier and a customer, and improved coordination of “strategic activities” (e.g. relationship building, joint development activities, sharing of costs and capability information) which creates customer-supplier intimacy.

Accordingly, we define downstream integration (DI) as the process of building intimacy and sharing information on manufacturing and demand plans with customers. Activities commonly associated with building greater DI include frequent customer contacts, supplier’s involvement in customer’s improvement efforts, attention to customer’s feedback/satisfaction on supplier’s performance, consideration of customer’s forecast in supplier’s plans, and customer’s open access to supplier’s plans.

An information processing perspective [9] offers an interpretation of the effects of DI activities. Rich communication with external sources of information related to market needs, to delivery performance, to work progress at supplier’s plant leads to greater opportunities for waste reduction, since upstream members in supply networks are enabled to anticipate and more fully respond to changes in customers’ specific needs. Therefore, manufacturing and delivery activities can be better planned to match demand without building excess inventory and improve capacity utilization [3], [8]. DI leads also to more efficient problem solving, as it promotes cooperation, joint work, and the creation of inter-company decision making routines [2]. It follows that there is a theoretical foundation and an emerging evidence for a general positive relationship between DI and efficiency performance. Hence, we can posit that:

- Hypothesis 1: Downstream integration is positively related to supply network efficiency.

Even though most of the literature believes that DI, in general, is beneficial to efficiency, and more DI is assumed to be better than less DI, the variety of the empirical bases and research design of the studies suggest that caution is advisable [1]. Nascent empirical evidence reports ambivalent or inconsistent results. We identified two main streams of research in the literature. Some authors have argued that DI has the potential to generate opportunistic behaviors. Others maintain that DI is a very complex activity whose overall impact on supply network performance is really hard to capture.

As to the first stream, agency theory suggests that firms who integrate too closely with suppliers open themselves up to risks including adverse selection, moral hazard, and opportunity costs [10]. For example, suppliers may be less motivated to provide high levels of performance if they feel that their business interest are secured. Therefore, on the long term, DI could lead the supply-side of the dyadic relationship to underperform. But even customers can adopt opportunistic conducts, especially when reliable supply network inventory measurement systems are absent [11].

As to the second stream, [12] suggested that DI is more difficult in practice that in theory. Sometimes suppliers are not ready (equipped) to handle a close way of working or customers are not actually prepared to part with the requisite information (technologies, etc.) to allow them to work in an integrated manner. [13] argue that whilst integration clearly has its benefits, it also has costs and may not enhance operational performance and, "in some cases it has the reverse effect" (p. 616). [14] have investigated inventory nervousness in downstream integrated systems. They claim that, in integrated systems, continuously recalculating inventory control parameters according to the demand signal causes fluctuation in target inventory levels or in production quantities. Therefore, a slow reaction to demand signal can result in a more stable inventory level and in a reduction in production quantity fluctuations. In a further work, [15] suggest that Vendor Managed Inventory (VMI) systems should not be too complex to improve the dynamics of supply chains. When testing different information sharing practices, they show that, although players have information available, a very complex decision making can result in increased inventory costs.

In the same vein, some authors agree that DI does not always lead to better outcomes, because other dimensions need to be considered to fully understand the relationship [13]. Therefore, while the general linkage between DI and efficiency is well acknowledged, inconsistencies across previous studies suggest the need for further research and hypothesis testing.

A deeper specification of the interaction between DI and efficiency involves the examination of likely moderating effects. A moderating hypothesis would suggest that the nature of the relationship between DI and efficiency varies, depending on the value of other variables (i.e. moderators). For instance, a fundamental SCM practice that is usually associated with DI is the adoption of a supply network performance measurement (SNPM) systems. Such systems require supply chain members to share common and agreed key indicators of supply network performance [16]. Companies can decide to evaluate several measures: on-time delivery, order lead time, level of stocks, distribution costs, etc. and should consider not only how a particular facility in the network performs (e.g. the level of stocks at the producer's warehouse), but also the performance of the whole supply chain or network (e.g. the total amount of stocks in the supply network) [17]. Lastly, it should be note that, a SNPM systems should consist, not only in defining a common metrics and measuring adequate indicators, but also in monitoring and analysing them for driving future actions and decisions [18].

SNPM systems are important to successfully implementing DI practices. In general, they allow to drive decision making when deciding on improvement initiatives to be adopted. Thus DI initiatives can be better directed [16]. Companies sometimes do not succeed in maximizing their supply chain's potential because they often fail to develop the performance metrics and measures needed for identifying problems and criticalities in the supply network, and thus crucial areas for improvements. Instead, when advanced SNPM systems are adopted, companies can accurately plan ad hoc DI interventions designed to address specific problems in the supply networks. For this reason, we can argue that SNPM systems are likely to act as moderators in DI-supply network efficiency relationship, since it is plausible that the impact of DI on supply network performance efficiency increases, when SNPM systems are adopted. However, quantitative research on this issue lacks. Therefore, we advance the following hyphotesis.

- Hypothesis 2: Supply network performance measurement systems positively moderate the relationship between DI and supply network efficiency.

## II. Research Methodology

Manufacturing firms operating in mechanical, electronic and transportation equipment sectors formed the sampling universe (SIC codes: 35, 36 and 37, respectively). During the identification stage of the reference population, we selected for medium (i.e. from 51 to 250 employees) and large (i.e. more than 250 employees) enterprises. Starting from this population, companies from different countries (i.e. Finland, US, Japan, Germany, Sweden, Korea, Italy, Austria and Spain) were randomly selected. A total of 266 responses were returned, and of these 66 incomplete responses were discarded. Accordingly, the analysis that follows and all reported statistics were based on a sample of 200 firms. The sample is stratified to approximate equal distribution across all three sectors. Moreover, most firms in the responding sample were large-sized with 64% of the firms employing more than 250 people. The mean number of employees for the sample was about 639. We use size (as well as industry) as a control variable later in the analysis to test whether this mattered to the supply network efficiency performance. Finally, mean sales were 162.29 million dollars.

Three multi-item constructs were identified and considered in this paper referred to as (see Table I): Downstream Integration (DI), Fast Supply Network Structure (FSNS) and Supply Network Performance Measurement systems (SNPM).

TABLE I. CONSTRUCTS AND ITEMS

| Construct | Item |
|---|---|
| Downstream Integration (DI) | We frequently are in close contact with our customers |
| | Our customers give us feedback on our quality and delivery performance |
| | We consider our customers' forecasts in our supply chain planning |
| | Our customers do not have access to our production plans |
| | We work as a partner with our customers |
| | Our customers involve us in their (quality) improvement efforts |
| | Our company strives to shorten supplier lead time, in order to avoid inventory and stockouts |
| Supply Network Performance Measurement systems (SNPM) | We monitor each of the supply chains as a whole |
| | We monitor the performance of supply chain members, in order to adjust supply chain plans |
| | We use of shared indicators of supply chain performance |
| Supply network efficiency (EFF) | We outperform our competitors for the unit cost of manufacturing |
| | We outperform our competitors for inventory turnover |
| | Capacities are balanced in our supply network. |
| | We have large in-process inventories between different operations |

The items comprising each construct were factor analyzed using varimax rotation with Kaiser normalization and extracting all the eigenvalues that are above 1. Convergent validity is demonstrated since, for each construct, factor loadings are all above 0.50 and only one component was identified (total variance explained above 50%). We tested also that off-factor loadings of the items were smaller than 0.4. Finally, Cronbach α-values for the five constructs exceed 0.70, indicating high reliability.

(1) Downstream Integration: This is a six-item scale that measures to the two basic notions usually used to define integration: coordination (e.g. joint improvement efforts, close contact, partnership), and information sharing (e.g. customers' feedback on quality and delivery performance, sharing of customers' forecasts, customers' access to manufacturer's production plans) [7], [8].

(2) Supply Network Performance Measurement (SNPM) systems: this construct is composed by three items, that consider whether performances of the whole supply chain or of its members are monitored, and whether a shared system of performance indicators is used [16], [18].

(3) Supply network efficiency (EFF). This construct includes four items. On the one hand, they measure efficiency performances of the focal firm - as several survey-based papers on SCM do [19]. In particular, we asked respondents from focal firm about: 1) unit cost of manufacturing and 2) inventory turnover.

On the other hand, since in this paper we consider focal firm's integration with customers, we asked respondents to provide information on the overall performance of focal firms' supply network, in terms of: 3) balancing of capacities in the supply network, and 4) in-process inventories between operations. We think that this choice allows researchers to better evaluate the overall impact of DI on efficiency performances and to better interpret interaction effects that can exist.

## III. DATA ANALYSIS

Moderated relationships are reflected in the concept of statistical interaction, and the following equation describes the logic of moderated regression [20]:

$$y = \beta_0 + \beta_1 x + \beta_2 z + \beta_3 xz + \varepsilon \quad (1)$$

where x is DI, z is SNPM and y the efficiency performance. The 'xz' term in the equation is called interaction term. DI variable is the focal independent variable in this study.

We employed a hierarchical regression procedure. 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 company's employees. The sector was insert 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 deviation from the comparison group. The mechanical sector was arbitrarily taken as the baseline/comparison group.

Then, independent variables - i.e. DI and SNPM - were introduced as a block, followed by the interaction term. As suggested by [20], when the $\beta_3$-coefficient of the product term xz is statistically significant, and $R^2$ increases when this term is introduced in the model, the existence of a moderated effect on x-y relationship is demonstrated.

Table 2 reports the result of the hierarchical regression analysis. To address the problem of multicollinearity, we mean-centered the independent variables and checked whether the VIF falls within the recommended interval.

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. More interestingly, when the independent variable SNPM is added in the regression model (model 1), we can note that DI is not significantly related to efficiency performance. Thus, results found do not confirm and support hypothesis H1, namely that in general a positive relationship exists between DI and supply network efficiency. Models 2 reports the interaction results, along with changes occurring to main variables when the product term was introduced. The significant and positive β of the interaction terms suggests that it is possible to confirm the existence of positive interaction effects between DI and SNPM. Additional support is the significant change in $R^2$ from model 1 to 2 (0.033). In the end, hypotheses 2 is fully supported.

TABLE II. HIERARCHICAL REGRESSON 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** |
| $R^2$ | 0.053 | 0.247 | 0.280 |
| $\Delta R^2$ | 0.053 | 0.195 | 0.033 |
| F of $R^2$ change | 3.203* | 22.118*** | 7.815** |

The value reported are unstandardized regression coefficients:
* p-value <.05 level
** p-value <.01 level
*** p-value <.001 level
Multicollinearity diagnostics: VIF < 1.473

## IV. Discussion of Results

This study provides a number of original implications for the interpretation of the relationship between DI and supply network efficiency. Our results are consistent with the stream of research which supports the adoption of multiple SCM practices (see [21] and [22]) as we provide empirical evidence to demonstrate that DI does not lead directly to better outcomes, because other SCM actions need to be considered to fully exploit the relationship. In particular, our research contributes to the academic debate by providing new insights to better understand the controversial results found in some studies on the DI-efficiency relationship [10], [13]. A difference of our findings with those of prior studies is the absence of a positive direct effect of DI on efficiency in the "main effects only" model. Significant positive association of DI and efficiency is evident in bivariate correlation (0.233). However, this association disappears in multiple regression analysis (see model 1). This result indicates that the bivariate correlation may be spurious. When other aspects moderating the direct relationship between DI and efficiency are accounted for, there is a significant impact on efficiency of the interaction between DI and SNPM (see model 2). Therefore significant efficiency improvements cannot be achieved only by improving DI. Our results indicate that this can happen only under certain conditions in terms of usage of supply network performance measurement systems.

In particular our results confirm that the positive effect of DI on supply network efficiency increases, when integration is accompanied by the implementation of supply network performance measurement systems. In this case, it is possible to better identify problems and criticalities in the supply network (e.g. facilities with huge inventories or never on time, frequent stock outs of certain products/raw materials, low performing suppliers, etc.) and in turn to better direct adjustments and improvement efforts. However, SNPM systems can act also as a barrier to the efficacy of DI practices, determining a negative impact of DI on efficiency. In fact, the marginal effect of the variable DI on efficiency can be expressed such that:

$$\frac{\partial EFF}{\partial DI} = \beta_1 + \beta_3 \cdot SNPM = 0.095 + 0.372 \cdot SNPM \qquad (2)$$

Therefore for values of SNPM centered lower than -0.26 the marginal effect of DI on EFF is negative. In other words, if a company is integrated with its customers, but SNPM systems are scarcely adopted, supply network members can deviate from cooperative, towards opportunistic behaviors. To give an example, GlaxoSmithKline's production plants supply distribution centers using a Vendor Managed Inventory approach [11]. The performance monitoring system adopted in GSK is considered one of the key factors in the successful implementation of VMI with distributors because it makes easy to identify and thus limit opportunistic behaviors. VMI requires that manufacturers monitor the customers' inventory level and, according to sales forecasts, make periodic replenishments, deciding order quantities, shipping and timing (Waller et al., 1999). Customers usually pay just for the products they sell. Thus, when a performance monitoring systems lacks, the customer could swell its sales forecasts in order to be sure of product availability also in case of an unexpected rise in demand. Only a wide adoption of SNPM can assure that DI actions are aimed at the efficiency of the whole network, rather than at generating opportunistic conducts and local optimization.

## V. Conclusions

This research contributes to theory building by "going behind the curtains" and questioning the common assumption that DI always improves supply network efficiency. As in other SCM studies, we posit that the implementation of SCM is only likely to be successful if it is recognized as a multi-dimensional change process, that simultaneously and explicitly addresses several SCM practices [2], [21], [22]. In particular, this study demonstrates that the adoption of supply network performance measurement systems act as moderator of the DI-supply network efficiency relationship. Interestingly enough, the role of this moderator is twofold. On the one hand, SNPM interacts with DI, strengthening the positive impact of DI on supply network efficiency, through a positive additional synergistic effect. The practical implication for managers is that performance optimization requires levering simultaneously on DI and SNPM systems to foster interaction, rather than investing and acting on DI only.

On the other hand, the multivariate analysis provided evidence of the existence of disordinal interactions between DI and the moderator considered. It follows that when DI is not accompanied by an high level of adoption of SNPM systems these latter can act as barriers that hinder the positive impact of DI on supply network efficiency. Therefore managers should be aware of this effect, that could vanish their efforts of improving efficiency through DI. Moreover, before deciding to invest on DI, managers should ascertain the level of adoption of the SNPM systems. In fact, they act as prerequisites for a successful implementation of DI, because their adoption limits a series of problems (e.g. opportunistic behaviors, etc.) that can offset DI benefits. These results are in line with most of studies on SCM sequences that emphasize the role of certain practice as prerequisites for the implementation of other ones [22], [23].

Finally, our findings extend studies on complementarities to the SCM context. The notion of complementarity between two or more activities derives from strategic management research and implies that "doing more of any one of them increases the returns to doing more of the others" [24]. We found that the role of the SNPM is complementary to DI because doing more of the moderator increases the marginal impact of DI on efficiency. However, we provide a better understanding of this phenomenon. For very low levels of the moderator, the marginal effect of DI can be negative. As the moderator adoption grows, this negative effect reduces; at a critical threshold it becomes positive; and, from this point, for increasing levels of the moderators this positive effect increases.

In conclusion, the limitations and future developments of this study should be considered along with the results. Firstly our research setting, firms operating in mechanical, electronic and transportation equipment industries, could limit the generalizability of our findings. Though we have not evidence to claim otherwise, it is likely that other sectors may show different patterns. Hence, future research should replicate and extend our model to samples drawn from other industries. Moreover, we focused our analysis on the moderating roles of the adoption of supply network performance measurement systems, but several other SCM practices may act as moderators and deserve further research (e.g. upstream integration, a fast supply network structure, design for SCM, lean supply, intra-company integration, etc.). A final limit is the cross-sectional nature of our database. A deeper analysis of the prerequisites/enablers for the implementation of SCM practices would require a longitudinal data set.

## REFERENCES


[1] Fabbe-Costes, N., Jahre, M., 2008. Supply chain integration and performance: a review of the evidence. The International Journal of Logistics Management 19 (2), 130-154.

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

[3] Rosenzweig, E.D., Roth, A.V. and Dean, G.V. (2003), "The influence of an integration strategy on competitive capabilities and business performance: an exploratory study of consumer product manufacturers", Journal of Operations Management, Vol. 21, pp. 437-456.

[4] Lee, H.L., Padmanabhan, V. and Seungjin, W. (1997), "The bullwhip effect in supply chains", Sloan Management Review, Vol. 38, No. 3, pp. 93-102.

[5] Lee, H.L., So, K.C. and Tang, C.S. (2000), "The value of information sharing in two level supply chain", Management Science, Vol. 46, No. 5, pp. 626-643.

[6] Gilbert, S.M. and Ballou, R.H. (1999), "Supply chain benefits from advanced customer commitments", Journal of Operations Management, Vol. 18, pp. 61-73.

[7] Sahin, F. and Robinson, E.P. (2005), "Information sharing and coordination in make-to-order supply chains", Journal of Operations Management, Vol. 23, pp. 579-598.

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

[9] Galbraith, J.R. (1973), Designing Complex Organizations. Addison-Wesley, Reading, MA.

[10] Rossetti, C. And Choi, T.Y. (2005), "On the dark side of strategic sourcing: experience from the aerospace industry", Academy of Management Executive, Vol. 19, No. 1, pp. 46-60.

[11] Danese P. (2006), "The extended VMI for coordinating the whole supply network", Journal of Manufacturing Technology Management, Vol.17, n.7, pp.888-907

[12] Christopher, M. and Jüttner, U. (2000), "Supply chain relationships: making the transition to closer integration", International Journal of Logistics: Research and Applications, Vol. 3, No. 3, pp. 5-23.

[13] Cousins, P.D. and Menguc, B. (2006), "The implications of socialization and integration in supply chain management", Journal of Operations Management, Vol. 24, pp. 604-620.

[14] Disney, S.M. and Towill, D.R. (2002), "A procedure for the optimization of the dynamic response of a vendor managed inventory system", Computers & Industrial Engineering, Vol. 43, pp. 27-58.

[15] Disney, S.M., Nain, M.M., and Potter, A. (2004), "Assessing the impact of e-business on supply chain dynamics", International Journal of Production Economics, Vol. 89, No. 2, pp. 109.

[16] Gunasekaran A., Patel, C., McGaughey, R.E. (2004), "A framework for supply chain performance measurement", International Journal of Production Economics, Vol.87, pp.333-347.

[17] Bechtel, C., Jayaram, J. (1997), "Supply Chain Management: a strategic perspective", The Internatioanl Journal of Logistics Management, Vol.8, n.1, pp.15-34.

[18] Forslund, H., and Jonsson, P., (2009), "Obstacles to supply chain integration of the performance management process in buyer-supplier dyads", International Journal of Operations & Production Management, Vol.29, n.1, pp.77-95.

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

[20] Brambor, T., Clark, W.R., Golder, M., (2006), "Understanding Interaction Models: Improving Empirical Analyses", Vol.14, pp.63-82.

[21] Cooper, M.C., Lambert, D.M, Pagh, J.D., 1997. Supply Chain Management: More Than a New Name for Logistics. The International Journal of Logistics Management 8(1), 1-13.

[22] Danese, P., P. Romano, Vinelli A. (2006). "Sequences of improvement in supply networks: case studies from the pharmaceutical industry." International Journal of Operations & Production Management, 26(11-12): 1199-1222.

[23] Fynes, B., Voss, C. and de Búrca, S. (2005), "The impact of supply chain relationships dynamics on manufacturing performance", International Journal of Operations and Production Management, Vol.25 No.1, pp.6-19.

[24] Siggelkow, N., 2001. Change in the Presence of Fit: the Rise, the Fall, and the Renaissance of Liz Caliborne. Academy of Management Journal 44, 838-857.. *(references)*