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## Assessing the effectiveness of supply flexibility sources: An empirical research

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► **To cite this version:**

Elcio Mendonça Tachizawa, Cristina Gimenez. Assessing the effectiveness of supply flexibility sources: An empirical research. *International Journal of Production Research*, 2009, 47 (20), pp.5791-5809. 10.1080/00207540802146122 . hal-00513038

**HAL Id: hal-00513038**

**<https://hal.science/hal-00513038>**

Submitted on 1 Sep 2010

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**Assessing the effectiveness of supply flexibility sources: An empirical research**

Journal:	<i>International Journal of Production Research</i>
Manuscript ID:	TPRS-2007-IJPR-0519.R2
Manuscript Type:	Original Manuscript
Date Submitted by the Author:	19-Mar-2008
Complete List of Authors:	Tachizawa, Elcio; Universitat Pompeu Fabra, Department of Economics and Business Gimenez, Cristina; Universitat Ramon Llul - ESADE Business School, Department of Operations and Innovation Management
Keywords:	FLEXIBILITY, PURCHASING, SUPPLY CHAIN MANAGEMENT, EMPIRICAL STUDY
Keywords (user):	FLEXIBILITY, PURCHASING



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3 **Article Type: Research paper**  
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6 **<sup>1</sup>Assessing the effectiveness of supply flexibility sources: An**  
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8 **empirical research**  
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22 This paper focus on supply flexibility, i.e. the ability of the purchasing function to  
23 respond in a timely and cost effective manner to changing requirements of purchased  
24 components, in terms of volume, mix and delivery date. It is argued that managerial  
25 actions may have different effects on different dimensions of supply flexibility. More  
26 specifically, we aim to answer the following research questions: What is the  
27 effectiveness of the different supply flexibility sources? Are there any variables that  
28 could moderate the relationship between supply flexibility sources and supply  
29 flexibility? We perform a regression analysis of the effectiveness of the different supply  
30 flexibility sources. In particular, we conduct a stepwise regression, setting the supply  
31 flexibility sources as independent variables, and the three dimensions of supply  
32 flexibility (identified in the factor analysis) as dependent variables. In order to refine the  
33 models and increase the generalizability of the study, some control variables (i.e. firm  
34 revenue and flexibility focus) are also included in the regression analysis. Results  
35 suggest that each dimension of supply flexibility is associated with a particular group of  
36 sources, i.e. the sources used to increase a certain dimension of supply flexibility (e.g.  
37 supplier responsiveness) may be ineffective for another dimension (e.g. adaptability).  
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48 **Keywords:** Sourcing, purchasing, Spain, empirical, survey  
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51 <sup>1</sup> The authors gratefully acknowledge the significant contribution of the reviewers. The authors also thank  
52 AERCE for facilitating the access to its members. Cristina Giménez acknowledges financial support from  
53 research grant BEC2006-12291.  
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## 1. Introduction

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The flexibility in the upstream side of supply chains has attracted the interest of many researchers in recent years. From an academic perspective, the study of flexibility across supply chains complements the vast research on manufacturing flexibility. However, Stevenson and Spring (2007), in an exhaustive literature review on supply chain flexibility, remarked the lack of empirical research on the subject, notably on assessment methodologies. From a practical viewpoint, many firms are increasingly relying on supply networks to assure a rapid response to the market. For example, the use of 'virtual integration' with suppliers and logistics providers is one of the methods that Dell uses to assure higher agility in the computer sector (Magretta 1998).

In this study, based on the definitions by Duclos *et al.* (2003) and Upton (1994), we consider supply flexibility as *the ability of the purchasing function to respond in a timely and cost effective manner to changing requirements of purchased components, in terms of volume, mix and delivery date*. Different management practices are applied to increase supply flexibility. For example: some firms emphasize supplier localization (e.g. high-fashion Italian firms prefer to maintain a network of domestic subcontractors (Jin 2004)). Other companies prioritise flexible supply contracts (Eppen and Iyer 1997). Alternatively, the use of information technology tools (e.g. EDI, e-marketplaces and supply chain planning software) is an option (Saeed *et al.* 2005).

Nonetheless, there are few empirical studies that compare the *effectiveness* (*i.e.* 'the capacity of producing a desired effect', according to the definition from the Merriam-Webster dictionary) of the different supply flexibility sources (e.g. Prater *et al.* 2001, Lee 2004). Indeed, Sawhney (2006) claims that 'opportunities exist for both theoretical and empirical researchers to examine the various management actions that promote both the acquisition of the dimensions of flexibility and the reduction of uncertainty in the value chain'. Moreover, most of the previous supply flexibility studies are theoretical or based on anecdotal evidence. Additionally, the literature on flexibility is generally limited to Operations Management (OM) issues and does not specifically address purchasing (Giunipero *et al.* 2005). Finally, there is a lack of studies analysing other variables (e.g. flexibility focus) that could affect the relationship between sourcing practices and supply flexibility.

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Based on these gaps found in the literature, the following research questions were proposed:

1. What is the effectiveness of the different supply flexibility sources?
2. Are there any variables that could moderate the relationship between supply flexibility sources and supply flexibility?

In the next section we review the literature on supply flexibility.

## 2. Literature review

### 2.1 Supply flexibility

There are some recent studies in the OM literature that focus on the flexibility in the upstream part of the supply chain. Zhang *et al.* (2002) drew from Porter (1985) to define purchasing flexibility as '*the ability of the organization to provide the variety of materials and supplies needed by manufacturing quickly and performance-effectively through cooperative relationships with suppliers.*' However, it was a theoretical study, i.e. it lacked empirical validation of the constructs. The same applies to the study of Duclos *et al.* (2003) on supply flexibility, defined as '*the ability to meet the changing needs of customers, changing the supply of products, including mix, volume, product variations and new products*'.

More recently, researchers followed an empirical approach to investigate flexibility in the upstream part of the supply chain. For example, Pujawan (2004) proposed a methodology to assess supply flexibility and provided a case study where this methodology was used. Swafford *et al.* (2006) were the first to develop and test a scale to measure sourcing flexibility, defined as '*the availability of a range of options and the ability of the purchasing process to effectively exploit them so as to respond to changing requirements related to the supply of purchased components*'. This type of flexibility was divided into two dimensions: *range* (i.e. the number of different states that can be achieved with the existing resources) and *adaptability* (i.e. the ability to change from one state to another in a timely and cost effective manner).

Previous definitions present some common drawbacks. First, some flexibility items and sourcing practices overlap, fact that can represent an obstacle in studies aiming to analyse the effect of sourcing practices on supply flexibility. Second, they

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consider as unit of analysis all the components purchased by a firm, neglecting the deployment of different sourcing strategies for different products.

Based on these limitations, and considering the definitions of Duclos *et al.* (2003) and Upton (1994), in this study supply flexibility was defined as *the ability of the purchasing function to respond in a timely and cost effective manner to changing requirements of purchased components, in terms of volume, mix and delivery date*. The main difference with respect to previous studies lies in the assessment methodology. Flexibility was assessed at a specific component level (rather than at firm level). Moreover, special attention was dedicated to the design of the assessment items in order to avoid overlapping with sourcing practices.

In the next section, we review the sourcing practices that have been acknowledged to increase supply flexibility (i.e. supply flexibility sources).

## 2.2 Sources of supply flexibility

Jack and Raturi (2002) defined *flexibility sources* as ‘*specific actions to generate flexibility*’. Accordingly, we define a supply flexibility source as a practice in the purchasing function that allows an increase in supply flexibility. In this section, we provide a literature review of the sources of supply flexibility. A schematic view of them is shown in Table 1.

INSERT TABLE 1 HERE

*Multiple sourcing*: Many authors (e.g. Quayle 1998, Zeng 2000, Minner 2003) have suggested the positive effect of multiple sourcing on supply flexibility. Networks of smaller contractors have been largely used in several sectors (e.g. fashion apparel) as a means of spreading the production risks, and increasing the responsiveness to sudden changes in demand.

*Domestic sourcing*: Many authors (e.g. Smith 1999, Christopher 2000, Stratton and Warburton 2003, Bruce *et al.* 2004) claim that the higher the demand volatility, the greater the inclination to buy from local suppliers. For example, Benetton insists on using local subcontractors in Italy rather than buying from low-wage countries, because it assures on-time delivery and immediate response to trends (Jin 2004).

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*Supplier integration:* Numerous studies suggest that integrative practices have a positive effect on supply flexibility (Das *et al.* 2006, Swafford *et al.* 2006). Furthermore, trust and collaborative efforts between buyers and suppliers (e.g. joint planning, cross-functional teams, establishing common goals) improve supply chain responsiveness to uncertain environments (Christopher 2000, Wei and Krajewski 2000).

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*Joint product development:* The early involvement of suppliers in product development can be used to increase supplier responsiveness during the production phase (Lee 2004), a typical example being the substantial involvement of key suppliers in the development of automotive systems (Womack *et al.* 1990). Moreover, joint product development may increase parts commonality (i.e. the same component can be used in several products), which reduces the need of supply flexibility (Pujawan 2004).

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*Supplier selection:* When the focus of a firm is to develop a market-responsive process, the supplier selection process should be based on flexibility, rather than cost (Fisher 1997, Giunipero *et al.* 2005). For example, Choi and Hartley (1996) found that the capability of suppliers to make volume changes is an important supplier selection criterion in the automotive industry.

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*Flexible contracts:* The amount of flexibility to be specified in a contract is one of the most important decision functions in materials procurement (Van der Vaart *et al.* 1996). Indeed, Wei and Krajewski (2000) argue that quantity flexible contracts, in which buyer and supplier negotiate the amount of deviation of actual orders from the forecasts, are an efficient source of flexibility in the upstream part of the supply chain.

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*Long-term relationships:* Long-term relationships with key suppliers are positively associated with supplier delivery synchronization (De Toni and Nassimbeni 1999). Similarly, the higher trust present in long-term relationships enables the supplier to develop a more buyer-focused operation, which may imply the delivery of batches of multiple sizes (Bruce *et al.* 2004), or fast adaptation of supplier schedules in order to expedite shipments (Van der Vaart and Van Donk 2004).

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*Third-party logistics providers:* Supply flexibility also depends on the process integration with another key element in the supply chain: the inbound logistics provider (Lee 2004). Integration can include operational (e.g. shipping garments on hangers (Bruce *et al.* 2004)) or strategic agreements with the logistics provider (e.g. a supplier hub managed by a third-party logistics company (Lee 2002)).

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*Alternative modes of transportation:* Having alternative inbound modes of transportation (e.g. maritime, aerial, rail, etc) is acknowledged as a source of supply

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2 flexibility (Pujawan 2004, Zhang *et al.* 2002). The varied operational features (i.e. in-  
3 transit time, cost, capacity, frequency of delivery, etc) of the different transportation  
4 modes increase the range of options available to meet the changing customer needs  
5 (Zhang *et al.* 2002).  
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8 *E-marketplaces:* Saeed *et al.* (2005) and Swafford *et al.* (2006b) argue that the  
9 use of inter-organizational systems in supply chains can be divided into two categories:  
10 electronic integration and electronic brokerage. Electronic integration will be explained  
11 in the next paragraph, and electronic brokerage corresponds to the use of e-  
12 marketplaces. Online searching for suppliers offers access to a larger number of  
13 potential suppliers (Peleg *et al.* 2002, Lee 2002), allowing the prompt scaling up and  
14 down of operations (Kaplan and Sawhney 2000).  
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18 *Electronic integration:* In this study, electronic integration is the use of  
19 information technology (IT) tools (e.g. Electronic Data Interchange (EDI), supply chain  
20 planning software, Internet, etc) to integrate with supply chain partners (Saeed *et al.*  
21 2005). Many authors consider electronic integration with suppliers as an important  
22 source of responsiveness in the upstream side of the supply chain (Wei and Krajewski  
23 2000, Stratton and Warburton 2003, Bruce *et al.* 2004).  
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28 *Internal Integration:* Stevens (1989) considered internal integration as a removal  
29 of the intra-organizational barriers between departments. This sort of integration (e.g.  
30 between Purchasing and Logistics) permits an increase in the responsiveness to  
31 changing materials requirements (Swafford *et al.* 2006, Narasimhan *et al.* 2006).  
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34 *Inventory buffers:* Buffer stocks of critical items are commonly used to hedge  
35 against uncertainty (Lee 2002, Fisher 1997). Some studies suggest that they can partly  
36 compensate a lack of supplier integration, specifically when there is high volume  
37 uncertainty and low mix uncertainty (Van Donk and Van der Vaart, 2005).  
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40 In this study, the moderating effect of flexibility focus on the effectiveness of  
41 the distinct supply flexibility sources is also analysed. In the next section, we revise  
42 briefly some studies concerning flexibility focus.  
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### 45 46 47 **2.3 Flexibility focus** 48 49

50 The deployment of flexibility sources depends on the firm strategy and, more  
51 specifically, on its flexibility focus. Some empirical studies on flexibility have proposed  
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measures of flexibility focus: ‘managerial emphasis on flexibility’ (Upton 1997) and ‘flexibility importance’ (Vickery *et al.* 1999), both based on perceptual assessment. Similarly, Krause *et al.* (2001) proposed a ‘flexibility’ factor, which measured the degree of importance of flexibility in the supplier selection procedure.

### 3. Model development

The objective of this paper is to analyse the effectiveness of several sourcing practices concerning the achievement of supply flexibility. Figure 1 depicts the research framework of this study.

INSERT FIGURE 1 HERE

In order to assure research generalizability, it is important to consider some control variables, the first one being *flexibility focus*. Most of the sourcing practices considered in this study can be employed to obtain goals different from flexibility (e.g. e-marketplaces may be introduced motivated by cost reduction, rather than flexibility increase). Therefore, it is important to add to the regression model a control variable in order to assure that the effects of the sourcing practices on flexibility are independent of the flexibility focus of the firm. Second, *firm revenue* may impact the level of utilization of each sourcing practice (e.g. bigger firms may have more resources to implement EDI than smaller ones). We observe that, in the OM literature, firm size is usually measured using either the number of employees, or the firm revenue. In our study, we used revenue, as the level of financial resources available to invest in many of the sourcing practices considered (e.g. EDI, e-marketplaces, 3PL, etc) may be determined by this figure (revenue) rather than by the number of employees. Firm revenue has also been used as a control variable in similar studies (e.g. Chen and Paulraj 2004, Narasimhan *et al.* 2006, Swafford *et al.* 2006). Thus, two control variables were added to the model: flexibility focus and revenue.

In the next section we explain the methodology used to design the questionnaire and to collect the data.

## 4. Methodology

### 4.1 The instrument

In order to assure *content validity*, questionnaire items were based on previous studies (see Appendix) and pre-tests with purchasing managers and academics were used to guarantee a perfect understanding of the questions. Based on the pre-tests, the final version of the questionnaire incorporated some minor changes to improve the readability and clarity of the survey items.

### 4.2 Sampling

The sample consisted of members of the Spanish Association of Purchasing Managers (AERCE). All 1 504 members of AERCE were asked to participate in the study, receiving an electronic message with a link to the web page of the survey. Non-respondents received a second message, two weeks after the first one. A total of 100 answers were received. In order to show more precisely the relationship between sourcing practices and supply flexibility, 'not flexibility-focused' firms (i.e. 'flexibility focus' less or equal than five) were excluded from the study. After dropping the cases with missing data or not flexibility-focused firms, the total sample size was reduced to 77 firms, which means a response rate of 5.10%. This slightly low response rate should be analysed in the context of other web-based surveys. Actually, studies suggest that the response rate in online surveys is lower than in mail questionnaires, being as low as 7% in some cases (Braunsberger *et al.* 2007). In addition, it is important to consider the length and broad nature of the questionnaire, as well as the confidential nature of the information requested. Moreover, a demonstrated lack of response bias is considerably more important than a high response rate (Babbie 1990). For this reason, non-response bias was checked, by comparing early and late respondents. In particular, the first 30 received surveys and the last 30 received surveys were compared, using 10 randomly selected variables. Results suggested no significant difference between both groups, indicating that non-response bias is not a cause of concern (Hair *et al.* 1998), and that the sample is adequate to make inferences about the whole population. Therefore, we

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2 may assume that the 77 usable responses provide enough data to attain the research  
3 objectives.  
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5 The industry and size distribution of the sample can be appreciated in Table 2.  
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## 10 11 12 13 **5. Data analysis and discussion** 14

### 15 16 **5.1 Factor analysis** 17

18 Exploratory factor analysis with varimax rotation was conducted in order to explore the  
19 underlying supply flexibility dimensions. In the interest of convergent and discriminant  
20 validity, we only considered items that had a factor loading higher than 0.50 and did not  
21 have a loading in excess of 0.40 on a second factor (Bagozzi and Yi 1988). Cronbach's  
22 alpha was used to evaluate *reliability* (i.e. how well a set of items measures a single  
23 one-dimensional latent construct values). In general, reliability coefficients of 0.70 are  
24 considered satisfactory, but some researchers consider 0.60 as a practical cut-off  
25 (Swafford *et al.* 2006, Chen and Paulraj 2004).  
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28 The final factor loadings of the supply flexibility retained items, as well as their  
29 underlying factors, can be appreciated in Table 3. The Kaiser-Meyer-Olkin test of  
30 sampling adequacy (KMO = 0.531) and the Bartlett's test of sphericity (significance =  
31 0.000) were within the generally accepted limits, suggesting that factor analysis could  
32 be applied (Malhotra 1996). Cronbach's alpha was at least 0.608 for all dimensions of  
33 supply flexibility (see Table 3), indicating that construct reliabilities were adequate.  
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44 Results of the factor analysis suggested the existence of three underlying  
45 dimensions of supply flexibility: delivery policy (FLEX1 and FLEX2), supplier  
46 responsiveness (FLEX3 and FLEX4) and adaptability (FLEX6, FLEX7 and FLEX9).  
47 The *delivery policy* dimension measures the capacity of varying delivery lot sizes and  
48 frequencies. Lot size and frequency are variables usually associated. For example, JIT  
49 studies often support the combination of small supplier lot sizes and frequent deliveries  
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(e.g. Womack *et al.* 1990, Ponce and Prida 2004). *Supplier responsiveness* is the ability of influencing supplier short-term capacity and delivery lead-time. Similarly, Choi and Krause (2006) define it as ‘the degree of promptness and accuracy of the supplier’s response to the focal company’s request for new requirements’. And, *adaptability* is the time or cost necessary to change the specification of components, implement supplier engineering change orders or alter short-term capacity of suppliers. This coincides with the ‘adaptability’ dimension of sourcing flexibility (i.e. the ease with which the firm can exercise its procurement options (Swafford *et al.* 2006)).

These results differ slightly from previous studies (e.g. Swafford *et al.* 2006). The main difference is the partitioning of the ‘range’ dimension of supply flexibility (Swafford *et al.* 2006) into two dimensions (i.e. ‘supplier responsiveness’ and ‘delivery policy’). The ‘adaptability’ dimension identified in our paper is analogous to previous studies (Swafford *et al.* 2006, Swafford *et al.* 2006b). Next, the different dimensions of supply flexibility are examined individually.

## 5.2 Regression analysis

According to the research framework presented in section three, we conducted a regression analysis using the flexibility sources as independent variables. Composite factor scores of each of the three dimensions of supply flexibility derived in the factor analysis (supplier responsiveness, delivery policy and adaptability) were used as dependent variables. The research model is depicted in Figure 2.

INSERT FIGURE 2 HERE

The underlying assumptions of regression analysis – normality, linearity and homoscedasticity were examined through the analysis of the normal probability plot of residuals and the plots of the residuals against the predicted values. This analysis suggested that there were no violations of the regression assumptions.

Multicollinearity can also be a problem in multiple regression. Thus, before running the multiple regression, we first checked the *bivariate collinearity* using the correlation matrix of the independent variables. The correlation matrix analysis suggested that there are some potential sources of bivariate collinearity among the flexibility sources SRC3 (supplier integration), SRC4 (joint product development), and

SRC11 (internal integration). There was a moderate correlation between SRC3 and SRC4 ( $r = 0.656$ ), between SRC11 and SRC4 ( $r = 0.438$ ) and between SRC3 and SRC11 ( $r = 0.434$ ). A content analysis also suggested some redundancy between variables SRC3 and SRC4. To prevent problems, the SRC4 variable was dropped from the regression analysis. We maintained SRC3 (supplier integration) because this variable was more general and encompassed much of SRC4 (joint product development). SRC11 was kept because the distinction between internal and external integration is conceptually important for the study.

In order to check for *multivariate collinearity*, we performed a preliminary analysis of the regression of each independent variable on the remaining independent variables. The variance inflation factors (VIF) scores obtained this way were smaller than the cut-off of 10 (Mason and Perrault 1991), suggesting no multicollinearity problems. However, an additional analysis of the condition indexes revealed that there were two values above 15, suggesting moderate multicollinearity (Belsley *et al.* 1980).

To minimize problems generated by multicollinearity, stepwise regression was applied to select the independent variables that would be included in the model, a procedure which has been largely used in OM studies (e.g. Johnson 2002, Gonzalez-Benito *et al.* 2003, Flynn and Saladin 2006). Later, the model was refined adding some control variables (revenue and flexibility focus). This regression procedure was repeated for each dependent variable (supplier responsiveness, delivery policy and adaptability). In the next sections, the results for each of the dependent variables (supplier responsiveness, delivery policy and adaptability) are analysed.

**5.2.1 Supplier responsiveness.** As previously explained, stepwise regression was applied to select the independent variables (sources) that affect supplier responsiveness. The model that best explained the observed variance in the supplier responsiveness construct had two independent variables: SRC2 (domestic sourcing) and SRC11 (internal integration). Therefore, as a first step we evaluated the model including these variables. In a second step we added the control variables ('revenue' and 'flexibility focus'), and in a third step we added the interaction effects. Schematically, we evaluated the following models:

$$SR = \beta_0 + \beta_1 * SRC2 + \beta_2 * SRC11 + \varepsilon$$

$$SR = \beta_0 + \beta_1 * SRC2 + \beta_2 * SRC11 + \beta_3 * REV + \beta_4 * IMP + \varepsilon$$

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$$SR = \beta_0 + \beta_1 * SRC2 + \beta_2 * SRC11 + \beta_3 * REV + \beta_4 * IMP + \beta_5 * SRC2 * REV + \beta_6 * SRC2 * IMP + \beta_7 * SRC11 * REV + \beta_8 * SRC11 * IMP + \varepsilon$$

where SR is 'supplier responsiveness'; SRC2 is 'domestic sourcing'; SRC11 is 'internal integration'; REV is 'firm revenue'; IMP is 'flexibility focus' and  $\varepsilon$  is the error term of the regression model.

The results can be appreciated in Table 4. After controlling for revenue and flexibility focus the model is still significant, as well as the regression coefficients. Results suggest that domestic sourcing (standardized beta = 0.290,  $p = 0.011$ ) and internal integration (standardized beta = 0.245,  $p = 0.031$ ) are positively associated to supplier responsiveness. As far as the control variables are concerned, 'revenue' and 'flexibility focus' have no significant effect on the dependent variable. After adding the interaction terms (SRC2\*IMP, SRC2\*REV, SRC11\*IMP and SRC11\*REV), the model is significant ( $p = 0.009$ ). However, none of the regression coefficients are statistically significant. Therefore, the model does not suggest a moderator effect of 'flexibility focus' or 'revenue' on the relationship between the flexibility sources and supplier responsiveness.

INSERT TABLE 4 HERE

Potential outliers and influential cases were examined. Univariate outliers were verified using the cutoff of three standard deviations from the mean. Multivariate outliers were checked using two cut-offs: an absolute (Cook's D should be less than 1), and a size-adjusted (Cook's D should be less than  $4/n$  (Hamilton 1992)). The absolute cut-off revealed no influential case. The size-adjusted (Cook's D  $> 0.052$ ) cut-off suggested seven influential cases. We ran the stepwise regression without those cases, and then the results suggested that the variable SRC11 (internal integration) was replaced by SRC3 (supplier integration). This can be explained by the moderate correlation ( $r = 0.434$ ,  $p < 0.01$ ) between both variables. Thus, generalizability of results should be looked at carefully, and further studies should investigate the separate effect of each variable on supply flexibility.

Interestingly, SRC2 (domestic sourcing), SRC3 (supplier integration) and SRC11 (internal integration) can be viewed as 'integration' variables (if domestic sourcing is considered as a sort of 'physical integration'), which suggests a positive

relationship between supply chain integration and supplier responsiveness. This result contributes to the increasing debate about the relationship between integration and flexibility. In fact, this relationship is somewhat controversial. Although some researchers claim that integration increases supplier responsiveness (e.g. Choi and Krause 2006, Swafford *et al.* 2006), Das *et al.* (2006) have suggested that integration actually slows an organization's response to change, by creating interdependencies and increased decision times (e.g. when firms implement cross-functional teams).

This study adds to this debate by analysing individually the effect of integration practices on supplier responsiveness, controlling for flexibility focus and firm size. Although the results suggest that this relationship is positive, further research is still needed. For example, future studies should take into consideration a wider array of integration practices (e.g. vendor-managed inventories) and context variables (e.g. environmental uncertainty).

**5.2.2 Delivery Policy.** Next, we describe the regression of the second supply flexibility dimension (delivery policy) on the flexibility sources. The model that best explains the observed variance in the delivery policy dimension has only one independent variable: SRC5 (supplier selection). As a first step we evaluated the model including this independent variable. In a second step we added the control variables ('revenue' and 'flexibility focus'), and in a third step we added the interaction effects. The regression equations evaluated are:

$$DP = \beta_0 + \beta_1 * SRC5 + \varepsilon$$

$$DP = \beta_0 + \beta_1 * SRC5 + \beta_2 * REV + \beta_3 * IMP + \varepsilon$$

$$DP = \beta_0 + \beta_1 * SRC5 + \beta_2 * REV + \beta_3 * IMP + \beta_4 * SRC5 * REV + \beta_5 * SRC5 * IMP + \varepsilon$$

where DP is 'delivery policy'; SRC5 is 'supplier selection'; REV is 'firm revenue'; IMP is 'flexibility focus' and  $\varepsilon$  is the error term of the regression model.

Results suggest that, controlling for firm size and flexibility focus, the model is still significant (p-value = 0.047), as well as the regression coefficient (p-value = 0.016). As far as the control variables are concerned, 'revenue' and 'flexibility focus' have no significant effect on the dependent variable. After adding the interaction terms (SRC5\*IMP and SRC5\*REV), the model is not significant. Therefore, the model does

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not suggest a moderator effect of ‘flexibility focus’ or ‘revenue’ on the relationship between the flexibility sources and delivery policy.

The results can be seen in Table 5.

INSERT TABLE 5 HERE

This positive relationship between supplier selection and having a flexible delivery policy (standardized beta = 0.283, p = 0.016) concurs with previous studies (Pujawan 2004, Swafford *et al.* 2006b). By carefully selecting its suppliers, a firm can assure that they possess crucial capabilities, like producing in small batches or having flexible delivery channels (i.e. capable of accommodating a significant range of lot sizes and delivery frequencies).

This result corroborates the idea that price should not be the sole criterion to select suppliers (Nassimbeni *et al.* 2003) and that a flexible delivery policy could compensate higher prices of material (Giunipero *et al.* 2005).

**5.2.3 Adaptability.** Next, we describe the regression of the ‘adaptability’ dimension of supply flexibility on the flexibility sources. The model that best explained the observed variance in the adaptability dimension had three independent variables: SRC8 (logistics provider integration), SRC9 (alternative transportation modes) and SRC12 (electronic integration). As a first step we evaluated the model including these independent variables. In a second step we added the control variables (‘revenue’ and ‘flexibility focus’), and in a third step we added the interaction effects. The regression equations evaluated are:

$$A = \beta_0 + \beta_1 * SRC8 + \beta_2 * SRC9 + \beta_3 * SRC12 + \varepsilon$$

$$A = \beta_0 + \beta_1 * SRC8 + \beta_2 * SRC9 + \beta_3 * SRC12 + \beta_4 * REV + \beta_5 * IMP + \varepsilon$$

$$\underline{A = \beta_0 + \beta_1 * SRC8 + \beta_2 * SRC9 + \beta_3 * SRC12 + \beta_4 * REV + \beta_5 * IMP + \beta_6 * SRC8 * REV + \beta_7 * SRC8 * IMP + \beta_8 * SRC9 * REV + \beta_9 * SRC9 * IMP + \beta_{10} * SRC12 * REV + \beta_{11} * SRC12 * IMP + \varepsilon}$$

where A is ‘adaptability’; SRC8 is ‘logistics provider integration’; SRC9 is ‘alternative transportation modes’; SRC12 is ‘electronic integration’; REV is ‘firm revenue’; IMP is ‘flexibility focus’ and  $\varepsilon$  is the error term of the regression model.

Results suggest that, controlling for revenue and flexibility focus, the model is still significant (p-value = 0.006), as well as the regression coefficients for SRC8 (p =

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2 0.033), SRC9 ( $p = 0.035$ ) and SRC12 ( $p = 0.003$ ). Regarding the control variables,  
3 'revenue' and 'flexibility focus' have no significant effect on the dependent variable.

4  
5 After including the interaction terms (SRC8\*IMP, SRC8\*REV, SRC9\*IMP,  
6 SRC9\*REV, SRC12\*IMP, SRC12\*REV), the model is not significant. Thus, the model  
7 does not support the hypothesized moderator effect of 'flexibility focus' or 'revenue' on  
8 the relationship between the flexibility sources and adaptability.  
9

10  
11 Results are displayed in Table 6.

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14 INSERT TABLE 6 HERE  
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17 The positive relationship between electronic integration and adaptability  
18 (standardized beta = 0.348,  $p = 0.003$ ) is somewhat different from the results from  
19 Swafford *et al.* (2006), who did not find a significant correlation between procurement  
20 IT capabilities and adaptability. Nevertheless, results coincide with most of the studies  
21 on supply chain agility, which support the effect of procurement IT on supply chain  
22 responsiveness (Christopher 2000, Bruce *et al.* 2004, Chung *et al.* 2004, Saeed *et al.*  
23 2005). Further research with a broader sample of firms and industrial sectors should be  
24 conducted to confirm these results and to contrast them with previous studies.

25  
26 Another finding was the positive relationship between the use of alternative  
27 transportation modes and adaptability (standardized beta = 0.244,  $p = 0.035$ ). This result  
28 coincides with the notion that customized logistics networks should be tailored to each  
29 customer segment (Lummus and Vokurka 1999).

30  
31 Interestingly, a negative association between logistics provider integration and  
32 adaptability (standardized beta = -0.259,  $p = 0.033$ ) was found. This result departs from  
33 previous studies, which associate third-party logistics provider integration with  
34 flexibility (Anderson *et al.* 1997). A plausible reason for such a finding could be due to  
35 potential negative effects of integration on flexibility. Das *et al.* (2006) argue that some  
36 causes for this phenomenon could be: excessive caution among inexperienced team  
37 members, need for consultations in decision-making, communication delays and  
38 coordination needs. Anyway, the discrepancy of results suggests the need for further  
39 studies and replication of analysis using a broader sample of firms. Further research  
40 should also incorporate other variables (such as length of relationship, type of  
41 product/service bought, etc) that could explain why integration with the supplier  
42 increases supply flexibility while integration with the logistics provider does not.  
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## 6. Conclusion

This study adds to previous literature on supply flexibility by suggesting that flexibility sources (e.g. supplier integration, domestic sourcing, flexible contracts, etc) act differently over each supply flexibility dimension (i.e. supplier responsiveness, delivery policy and adaptability). With respect to the first research question proposed in the introduction (i.e. what is the effectiveness of the different supply flexibility sources?), we conclude that this depends on the dimension of supply flexibility considered: when we consider supplier responsiveness, domestic sourcing and internal integration are more effective in achieving flexibility. When the dimension considered is delivery policy, supplier selection is the most significant source. Finally, when adaptability is considered, electronic integration and alternative modes of transportation are more strongly associated to flexibility.

With respect to the second research question (i.e. are there any variables that could moderate the relationship between supply flexibility sources and supply flexibility?), our results do not suggest a moderator effect considering any of the variables proposed (flexibility focus and revenue). Nevertheless, we believe that this remains a fertile stream of research. For instance, further studies could investigate the influence of different operating environments (e.g. product variety, product life cycle, type of operations (i.e. make-to-stock or make-to order)) on the relationship between flexibility sources and supply flexibility.

This study has several research implications. First, the relationship between flexibility sources and the supply flexibility is a complex issue that deserves a multi-dimensional analysis. Second, this study provides researchers with a framework that can be used to investigate quantitatively the effects of managerial practices on supply flexibility. Lastly, the focus on flexibility adds to the integration literature, which has been mostly restricted to the strategic objective of reducing costs or lead-times.

This study has some important managerial implications. First, this research supports the notion that integration affects positively supplier responsiveness. More specifically, firms that adopt supplier collaboration (e.g. collaborative planning, sharing of information, joint establishment of goals), integrate purchasing with other internal functions (e.g. production, logistics) and adopt domestic sourcing have higher supplier

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responsiveness. Second, there is a positive relationship between flexibility-based supplier selection and flexible supplier delivery policies. Therefore, firms seeking a flexible supplier delivery policy (i.e. adjustable lot sizes and delivery frequencies) should include some flexibility verifications (e.g. excess capacity and responsiveness) in the supplier selection procedures. Third, electronic integration has a positive effect on adaptability. In other words, by investing in procurement IT (e.g. EDI, supply chain planning software, etc), firms can increase their capacity of adapting quickly to changes in demand patterns (e.g. volume, mix and delivery fluctuations). Finally, these effects are independent of firm revenue or flexibility focus.

This study has several limitations that future researchers should consider. First, the sample was drawn from a single country, thus in future studies a more geographically diversified sample of firms should be considered. Second, although the statistical procedures suggest sufficient validity, the sample size should be larger in further studies, to increase the generalizability of the results. Third, the use of single-informants raises the issue of a potential informant bias. Accordingly, further studies considering multiple informants would lead to a more complete understanding of the approaches used by firms to increase supply flexibility. Finally, cross-sectional studies may assume causal relationships among variables that may not correspond to reality. In further research, causal relationships should be confirmed using longitudinal studies.

As a general conclusion, this study provided important clues for better understanding the effects of sourcing practices on supply flexibility. Nevertheless, considerable research is necessary before arriving at a general, empirical understanding of the actions managers should take to improve the various dimensions of supply flexibility.

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## Tables

Table 1. Sources of supply flexibility.

Source	References
Multiple sourcing	Quayle 1998, Zeng 2000, Minner 2003, Stratton and Warburton 2003
Domestic sourcing	Smith 1999, Christopher 2000, Stratton and Warburton 2003, Bruce <i>et al.</i> 2004, Jin 2004
Supplier integration	Wei and Krajewski 2000, Christopher 2000, Das <i>et al.</i> 2006, Swafford <i>et al.</i> 2006
Joint product development with suppliers	Womack <i>et al.</i> 1990, Lee 2004
Supplier selection	Fisher 1997, Nassimbeni 2003, Swafford <i>et al.</i> 2006
Flexible supply contracts	Eppen and Iyer 1997, Wei and Krajewski 2000
Long-term relationships with suppliers	De Toni and Nassimbeni 1999, Bruce <i>et al.</i> 2004
Third-party logistics providers	Lee 2002, Lee 2004, Bruce <i>et al.</i> 2004
Alternative transportation modes	Zhang <i>et al.</i> 2002, Pujawan 2004
E-marketplaces	Kaplan and Sawhney 2000, Peleg <i>et al.</i> 2002, Lee 2002, Saeed <i>et al.</i> 2005
Internal integration	Swafford <i>et al.</i> 2006, Narasimhan <i>et al.</i> 2006, Das <i>et al.</i> 2006
Electronic integration	Wei and Krajewski 2000, Stratton and Warburton 2003, Bruce <i>et al.</i> 2004, Chung <i>et al.</i> 2004, Saeed <i>et al.</i> 2005
Inventory buffers	Fisher 1997, Wei and Krajewski 2000, Lee 2002, Stratton and Warburton 2003

Table 2. Industry mix and sales.

Industrial sector	%	Revenue (million euros)	%
Electronics	13.0	< 1	1.3
Machinery	19.5	1-49	41.6
Industrial	2.6	50-99	23.4
Basic	31.2	100-499	24.7
Consumer packaged goods	15.6	>500	9.1
Not informed	18.2	Total	100
Total	100		

Table 3. Supply flexibility: reliability and convergent validity.

KMO and Bartlett's test			
Kaiser-Meyer-Olkin measure of sampling adequacy		0.531	
Bartlett's test of sphericity	Approx. $\chi^2$	99.537	
	d.f.	21	
	Sig.	0.000	
Supply flexibility sources	Factor 1 Delivery policy	Factor 2 Supplier responsiveness	Factor 3 Adaptability
Range of possible delivery frequencies from suppliers (FLEX1)	0.796	0.279	-0.041
Range of possible order sizes from suppliers (FLEX2)	0.888	-0.068	0.059
Extent to which supplier short-term capacity can be influenced (FLEX3)	0.076	0.787	0.111
Extent to which supplier lead-time can be expedited/changed (FLEX4)	0.058	0.834	-0.031
Cost / time needed to change the configuration and specification of orders (FLEX6)	-0.098	0.249	0.679
Cost / time needed to influence supplier's ability to implement engineering changes (FLEX7)	0.003	0.043	0.899
Cost / time needed to influence supplier's short-term capacity (FLEX9)	0.163	-0.328	0.765
Cost / time needed to change the delivery lead time (FLEX5) <sup>a</sup>			
Cost / time needed to change the quantity ordered (FLEX8) <sup>a</sup>			
Eigenvalue	1.475	1.569	1.867
Explained variance (%)	21.1	22.4	26.7
Cronbach's alpha	0.636	0.608	0.669

Extraction method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

<sup>a</sup> Items dropped (for having factor loadings of less than 0.5 or a loading in excess of 0.4 on a second factor)

Table 4. Regression results (supplier responsiveness).

Model	Adjusted R <sup>2</sup>	F-value	Significance F	Variables	Standardized $\beta$	T-value	Significance
Step 1	0.167	8.629	0.000	Constant		3.921	0.000
				SRC2	0.300	2.740	0.008
				SRC11	0.239	2.182	0.032
Step 2	0.155	4.487	0.003	Constant		0.999	0.321
				SRC2	0.290	2.620	0.011
				SRC11	0.245	2.200	0.031
				IMP	0.101	0.948	0.346
				REV	-0.031	-0.293	0.771
Step 3	0.161	2.83	0.009	Constant		0.94	0.352
				SRC2	-0.598	-1.46	0.150
				SRC11	0.434	1.04	0.301
				IMP	-0.005	-0.02	0.985
				REV	-0.183	-0.85	0.398
				SRC2*IMP	0.633	1.49	0.141
				SRC11*IMP	-0.379	-0.89	0.379
				SRC2*REV	0.227	1.02	0.311
SRC11*REV	0.027	0.09	0.926				

Dependent variable: SR.

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Table 5. Regression results (delivery policy).

Model	Adjusted R <sup>2</sup>	F-value	Significance F	Variables	Standardized $\beta$	T-value	Significance
Step 1	0.080	7.645	0.007	Constant		3.343	0.001
				SRC5	0.304	2.765	0.007
Step 2	0.065	2.775	0.047	Constant		0.959	0.340
				SRC5	0.283	2.472	0.016
				IMP	0.102	0.894	0.374
				REV	-0.012	-0.110	0.913
Step 3	0.071	2.16	0.068	Constant		8.455	0.342
				SRC5	-0.498	-0.045	0.669
				IMP	-0.123	-0.393	0.914
				REV	-1.594	0.140	0.128
				SRC5*IMP	0.0302	0.500	0.825
				SRC5*REV	0.2180	-0.221	0.126

Dependent variable: DP.

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Table 6. Regression results (adaptability).

Model	Adjusted R <sup>2</sup>	F-value	Significance F	Variables	Standardized $\beta$	T-value	Significance
Step 1	0.128	4.723	0.005	Constant		9.235	0.000
				SRC8	-0.311	-2.666	0.009
				SRC9	0.232	2.040	0.045
				SRC12	0.347	3.104	0.003
Step 2	0.143	3.546	0.006	Constant		4.802	0.000
				SRC8	-0.259	-2.175	0.033
				SRC9	0.244	2.152	0.035
				SRC12	0.348	3.058	0.003
				IMP	-0.188	-1.707	0.092
				REV	-0.055	-0.493	0.623
Step 3	0.094	1.72	0.089	Constant		2.09	0.04
				SRC8	-0.505	-1.08	0.284
				SRC9	0.460	0.93	0.356
				SRC12	0.079	0.18	0.858
				IMP	-0.175	-0.85	0.400
				REV	-0.086	-0.59	0.556
				SRC8*IMP	0.554	1.04	0.303
				SRC9*IMP	-0.502	-0.97	0.336
				SRC12*IMP	0.022	0.05	0.961
				SRC8*REV	-0.154	-0.64	0.523
SRC9*REV	0.187	0.84	0.403				
SRC12*REV	0.097	0.45	0.656				

Dependent variable: A.

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Figures

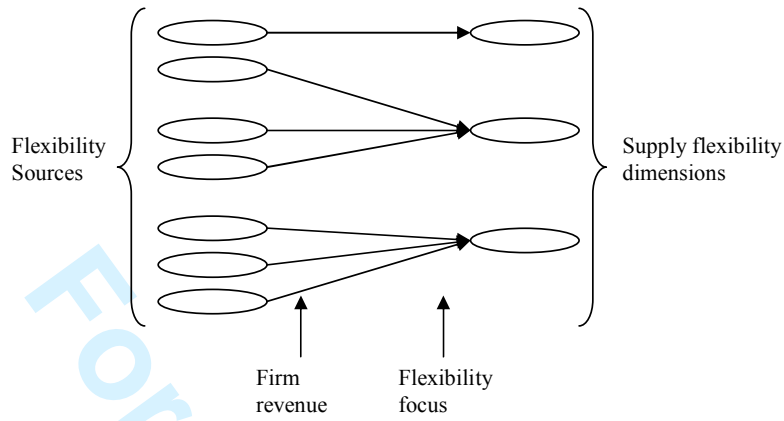


Figure 1. Research Framework.

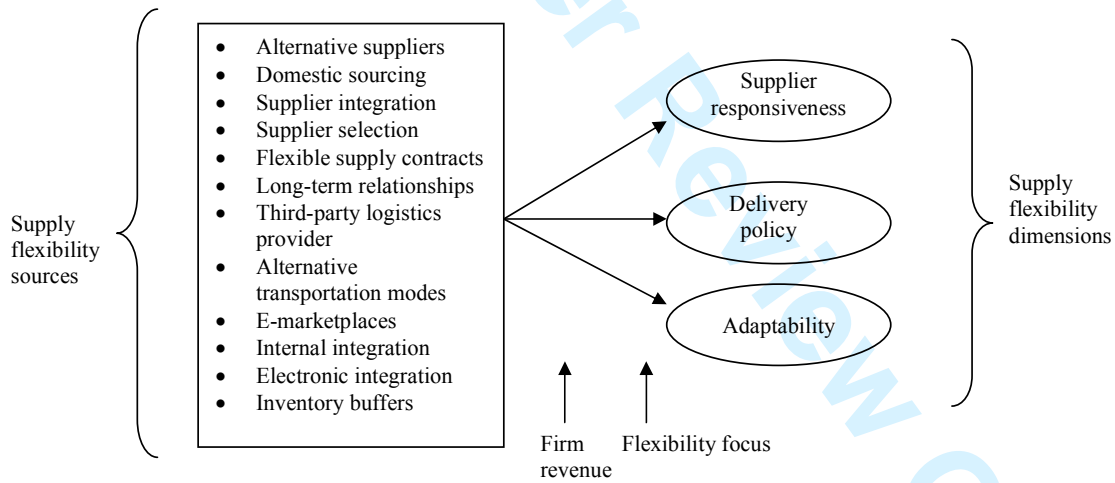


Figure 2. Research model.

## Appendix: Questionnaire

Please select the purchased material that requires the highest supply flexibility level (defined as the *ability of the purchasing function to respond in a timely and cost effective manner to changing requirements of purchased components, in terms of volume, mix and delivery date*).

All the following questions refer to this material.

### 1. Flexibility sources

Indicate the frequency you use these practices to increase the supply flexibility of this material (1 = never; 10 = very frequently):

- (1) We use multiple suppliers. (*Quayle 1998, Zeng 2000, Minner 2003, Stratton and Warburton 2003*)
- (2) We use local (i.e. same country) suppliers. (*Smith 1999, Christopher 2000, Stratton and Warburton 2003, Bruce et al. 2004, Jin 2004*)
- (3) We collaborate intensely with the suppliers (sharing information, forming cross-functional teams, joint planning, etc). (*Wei and Krajewski 2000, Christopher 2000, Das et al. 2006, Swafford et al. 2006*)
- (4) We involve the suppliers in joint product development activities. (*Womack et al. 1990, Lee 2004*)
- (5) We select the suppliers based on their flexibility (slack capacity, responsiveness, etc). (*Fisher 1997, Nassimbeni 2003, Swafford et al. 2006*)
- (6) We use flexible contracts (backup agreements, quantity-flexible contracts). (*Eppen and Iyer 1997, Wei and Krajewski 2000*)
- (7) We use long-term relationships with suppliers. (*De Toni and Nassimbeni 1999, Bruce et al. 2004*)
- (8) We collaborate with the inbound logistics provider. (*Lee 2002, Lee 2004, Bruce et al. 2004*)
- (9) We use alternative transportation modes. (*Zhang et al. 2002, Pujawan 2004*)
- (10) We use e-marketplaces to search alternative suppliers. (*Kaplan and Sawhney 2000, Peleg et al. 2002, Lee 2002, Saeed et al. 2005*)

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- (11) We collaborate intensely with other areas within our firm (production, logistics, etc). (Swafford *et al.* 2006, Narasimhan *et al.* 2006, Das *et al.* 2006)
  - (12) We use Information Technology planning tools (Supply Chain Planning, Suppliers Relationship Management, etc) and/or Electronic Data Interchange (EDI) with the suppliers. (Wei and Krajewski 2000, Stratton and Warburton 2003, Bruce *et al.* 2004, Chung *et al.* 2004, Saeed *et al.* 2005)
  - (13) We use inventory buffers. (Fisher 1997, Wei and Krajewski 2000, Lee 2002, Stratton and Warburton 2003)
  - (14) We use other sources of supply flexibility. Which one (s)?

## 2. Supply flexibility

Using a 10-point scale (1 = low; 10 = high), please evaluate the level of the following characteristics associated with the procurement/sourcing function in your business unit:

- (1) Range of supplier delivery frequencies (daily, weekly, etc). (Swafford *et al.*, 2006)
- (2) Range of possible order sizes from suppliers. (Swafford *et al.*, 2006)
- (3) Extent to which supplier lead-time can be expedited/changed. (Swafford *et al.*, 2006)
- (4) Extent to which supplier short-term capacity can be influenced. (Swafford *et al.*, 2006)

Using a 10-point scale (1 = low; 10 = high), please indicate the average level of cost/time associated with engaging in the following procurement/sourcing activities in your business unit:

- (1) Change quantity of supplier's order. (Swafford *et al.*, 2006)
- (2) Change specification/configuration of supplier's order. (Swafford *et al.*, 2006)
- (3) Influence supplier's ability to implement engineering change orders. (Swafford *et al.*, 2006)
- (4) Change delivery times of orders placed with suppliers. (Swafford *et al.*, 2006)
- (5) Influence supplier's short-term capacity. (Swafford *et al.*, 2006)

## 3. Flexibility focus

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4 Using a 10-point scale (1 = unimportant; 10 = critical), please indicate the level of the  
5 following characteristic:  
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- 8 (1) Which is the importance of flexibility in the sourcing strategy of your business  
9 unit? (*Vickery et al. 1999*)  
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13 *4. Annual revenue (million euros)*  
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16 (1) Less than 1 (2) Between 1 and 49 (3) Between 50 and 99  
17 (4) Between 100 and 499 (5) More than 500  
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