

UNCERTAINTY, INTEGRATION AND SUPPLY FLEXIBILITY

By Elcio Mendonça Tachizawa

PhD Dissertation

Universitat Pompeu Fabra

Department of Economics and Business

Thesis director: Cristina Giménez-Thomsen

2007

Acknowledgements

First of all, I would like to express my deep gratitude to my thesis supervisor, Cristina Giménez-Thomsen, for her constant orientation and encouragement. Her guidance and example were truly inspiring not only to this thesis, but also to my professional career. I am also in debt with my thesis tutor, Eva Ventura. Without their support this project would not have been possible.

I would also like to thank all my colleagues from GREL, in particular Juan Pablo Soto, for helping with the Internet survey.

I am also in debt with the technical director of AERCE (Asociación Española de Responsable de Compras y Existencias), Ferran Baños, for the support in the data gathering process.

I also wish to thank the anonymous reviewers of the *International Journal of Operations and Production Management*, for their comments and suggestions that improved the quality of the first paper of the thesis.

I am also grateful to all the participants of the IFPSM Summer School of Advanced Purchasing Research and the EurOMA Conferences, especially Taco Van der Vaart, for their suggestions.

Last but not least, I would like to thank my family, for their unconditional support.

Contents

CHAPTER 1: INTRODUCTION	5
CHAPTER 2: THE DRIVERS AND SOURCES OF SUPPLY FLEXIBILITY	10
2.1 Introduction	11
2.2 Literature review	12
2.2.1 Supply flexibility	12
2.2.2 Flexibility drivers	13
2.2.3 Flexibility sources	15
2.3 Methodology	17
2.4 Cross-case analysis	20
2.4.1 Drivers	20
2.4.2 Sources	24
2.5 Conclusions	30
References	32
Appendix. Interview protocol	37
CHAPTER 3: SUPPLY FLEXIBILITY STRATEGIES	38
3.1 Introduction	39
3.2 Literature review	40
3.2.1 Supply flexibility	40
3.2.2 Sources of supply flexibility	42
3.2.3 Flexibility focus	43
3.2.4 Environmental uncertainty	44
3.2.5 Switching costs	45
3.3 Model development	47
3.4 Methodology	47
3.4.1 The instrument	47
3.4.2 Sampling	48
3.5 Data analysis	49
3.5.1 Tests for scale validity and reliability	49
3.5.2 Cluster analysis	53
3.6 Discussion	62
3.7 Conclusion	66
References	68
Appendix A. Questionnaire	76
Appendix B. The matrix of the correlation coefficients	80
CHAPTER 4: ASSESSING THE EFFECTIVENESS OF SUPPLY FLEXIBILITY SOURCES	81
4.1 Introduction	82
4.2 Literature review	83
4.2.1 Supply flexibility	83

4.2.2 Sources of supply flexibility _____	84
4.2.3 Flexibility focus _____	88
4.3 Model development _____	89
4.4 Methodology _____	90
4.4.1 The instrument _____	90
4.4.2 Sampling _____	90
4.5 Data analysis and discussion _____	91
4.5.1 Factor analysis _____	91
4.5.2 Regression analysis _____	93
4.6 Conclusion _____	100
References _____	102
Appendix A. Questionnaire _____	108
Appendix B. The matrix of correlation coefficients _____	112
CHAPTER 5: CONCLUSION _____	113
Additional references _____	118

CHAPTER 1: INTRODUCTION

Substantial changes in the managerial practices are affecting dramatically the way firms compete. Increasing demand volatility, shorter product life cycles, global sourcing, just-in-time, e-business and mass customisation increase the turbulence in business environments. In order to cope with this, firms have to focus on the competitive dimension of flexibility (Slack, 1983; Hayes and Wheelwright, 1984; Upton, 1994). Although research in flexibility has been mostly conducted within firms (i.e. manufacturing flexibility), many researchers argue that it should be studied from a supply chain perspective. After all, competition occurs often between supply chains, rather than between firms (Christopher, 1998).

Sourcing is a critical element of flexibility in supply chains (Swafford *et al.*, 2006). The problems faced by Sony when launching the Playstation3 illustrate the importance of this issue. In May 2006, Sony said it would have 2 million PlayStation3 consoles available for the holiday-buying season. However, in November it had only 400,000 game players ready, due to the shortage of a console's blu-ray DVD player included in the package. Consequently, Sony stocks fell, and competitors were motivated to increase their efforts to steal Sony's market share. Similar examples can be found in other sectors: for example, production ramp-ups of automotive manufacturers are frequently halted because suppliers just cannot respond quickly enough.

This paper focus on supply flexibility, which is 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* (Upton (1994); Duclos *et al.*, 2003).

In order to achieve meaningful research conclusions, supply flexibility should not be studied isolated from other constructs. For example, researchers often posit the connections between flexibility and two constructs: uncertainty (Swamidass and Newell, 1987) and supply chain integration (Jack and Raturi, 2002; Swafford *et al.*, 2006). Accordingly, the common theme throughout this thesis is the relationship between uncertainty, integration and supply flexibility. We believe that the relationship between those three constructs is a topic not sufficiently explored in the current OM literature. Hence, our research aims to shed light on this important issue. Specifically, we explore the relationship between uncertainty and supply flexibility, and the relationship between integration and supply flexibility.

Swamidass and Newell (1987) hypothesize that flexibility can be seen as a response to *environmental uncertainty*. Uncertainty has been an important concept in OM, particularly in recent studies in Supply Chain Management (e.g. Chen and Paulraj, 2004). Uncertainty is “an individual’s perceived inability to predict something accurately” (Milliken, 1987), and it usually contributes to explain the relationship between management practices and the environment. The contingency theory is based on the belief that matching organizational resources with environmental characteristics leads to different “optimal sets” of choices (Gingsberg and Venkatraman, 1985).

Supply chain integration is often associated to flexibility (Jack and Raturi, 2002; Swafford *et al.*, 2006). Integration as a concept is not well defined and it is hard to measure it empirically (Frohlich and Westbrook, 2001). Research usually focuses on one of three perspectives of integration: as a series of interactions, as collaborative behaviours, or as a combination of both. We concentrate on the collaborative dimension (i.e. a process of decision making among interdependent parties), as in previous OM studies (e.g. Stank *et al.*, 2001; Giménez and Ventura, 2005).

Accordingly, the objective of this thesis is to provide empirical evidence for better understanding the concept of supply flexibility, i.e. its motivations (e.g. environmental uncertainty), how it is achieved (e.g. supply chain integration), and which factors determine the strategy used to increase it. In order to do so, qualitative (a multiple case study) and quantitative study methods (survey statistical analysis) are used. The combination of both methods increases practitioner validity and generalizability of the study. Qualitative methods allow a “prior view of the general constructs or categories we intend to study and their relationships” (Voss *et al.*, 2002). In addition, previous to developing a conceptual framework the researcher has to reflect carefully the most adequate variables to be incorporated into the model (Miles and Huberman, 1994). Statistical methods, on the other hand, allow a more structured analysis and permit to determine the validity of formulated hypothesis. Thus, both methods are complementary and required to perform consistent empirical research (Mentzer and Flint, 1997).

The initial stage in theory building usually consists in exploratory research (Eisenhardt, 1989). Although there has been considerable research on other types of flexibility (e.g. manufacturing), supply flexibility is still an under-explored topic. Thus, the *first paper* of the thesis is a multiple case study that aims to answer the following research questions: *Why* do firms need to increase supply flexibility? *How* do firms

increase supply flexibility? Is there any relationship between the *whys* and *hows* of supply flexibility? In this paper, we propose a framework that can be used to study supply flexibility. It is based on two central concepts: *supply flexibility driver*, i.e. a supply chain characteristic over which the purchasing function has little or no control, and which determines the level of supply flexibility required (for example, demand uncertainty); and *supply flexibility source*, i.e. a specific action to generate supply flexibility (for example, the use of multiple sourcing). As the main result of this study, a list of drivers and sources is generated. In addition, we categorize the sources and relate factors that potentially influence the election of the supply flexibility sources. The results of the first paper suggest the existence of alternative strategies to achieve supply flexibility: improved supplier responsiveness (single sourcing, a high level of internal and external integration, co-location of suppliers and supplier selection based on supplier responsiveness capability), and flexible sourcing (multiple sourcing, lower levels of supplier responsiveness and faster supply network redesign).

In the *second paper*, the taxonomy of supply flexibility strategies is proposed. It is a quantitatively-based study that aims to identify supply flexibility strategies using cluster analysis, a method used previously in manufacturing strategy and supply chain management studies. Empirical evidence was gathered through a web-based survey mailed to the members of the Spanish Association of Purchasing managers (AERCE). The supply flexibility strategies are depicted in terms of the sets of flexibility sources used jointly by the firms in the sample. The main result is the identification of three major strategies to achieve supply flexibility: “integrated”, “offshore” and “domestic”. Some context variables are also used to further characterize the different clusters. Results suggest that the groups present some differences according to firm revenue, supply uncertainty and supplier responsiveness.

Lastly, in the *third paper* it is argued that managerial actions may have different effects on different dimensions of supply flexibility (i.e. delivery policy, supplier responsiveness and adaptability). Specifically, the aim of this paper is to identify the sources that are more effective to achieve each dimension of supply flexibility. Using the same dataset used in the second paper, we perform a regression analysis of each supply flexibility dimension on the different supply flexibility sources. Results suggest that each dimension of supply flexibility is associated with a particular group of sources, i.e. the sources used to increase a certain dimension of supply flexibility (e.g. supplier responsiveness) may be ineffective for another dimension (e.g. adaptability).

The thesis is organized as follows: chapter two introduces the multiple case study of supply flexibility. Chapter three describes the cluster analysis of supply flexibility strategies. Chapter four assesses the effectiveness of each supply flexibility source. Lastly, chapter five provides a summary of the main conclusions of the thesis and discusses further lines of research.

CHAPTER 2: THE DRIVERS AND SOURCES OF SUPPLY FLEXIBILITY

Tachizawa, E.M. and Giménez, C. (2007), *International Journal of Operations and Production Management*, Vol.27 No.10, pp.1115-1136.

2.1 Introduction

Nowadays, many companies are facing a highly volatile and uncertain environment: short product life cycles, frequent and unpredictable changes in demand, and global logistics issues. In this environment, the ability to change or react to environmental uncertainty is key for competitiveness; in other words, flexibility is a critical aspect.

Flexibility is “*the ability to change or react to environmental uncertainty with little penalty in time, effort, cost or performance*” (Upton, 1994). In the last decade, there has been a considerable amount of research on manufacturing flexibility (e.g. Upton, 1994; Koste and Malhotra, 1999; Vokurka and O’Leary-Kelly, 2000; Jack and Raturi, 2002; Koste *et al.*, 2004) and an increasing tendency to extend this approach to other processes within the supply chain. It is widely considered that complex supply chains are progressively connecting firms, and that the focus on internal (i.e. manufacturing) flexibility might be insufficient to deal with an increasingly turbulent environment (Prater *et al.*, 2001; Jack and Raturi, 2002; Narasimhan and Das, 2000). Indeed, supply chain flexibility is a complex and multi-dimensional construct. Recent studies have considered four types of supply chain flexibility: supply, manufacturing, distribution and product development (Swafford *et al.*, 2006; Pujawan, 2004).

Recent empirical studies on supply chain management have highlighted the importance of supply management (e.g. Chen and Paulraj, 2004; Ponce and Prida, 2004). The ongoing outsourcing trend in several sectors and the use of information technology to create truly global supply chains increase the strategic importance of procurement. Accordingly, the impact of sourcing practices on supply chain flexibility has been increasingly recognized (Swafford *et al.*, 2006). Hence, we have decided to focus our study on supply flexibility, which, taking as our basis the definition by Upton (1994), we define 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*.

Although some studies have recognized the influence of sourcing practices on manufacturing flexibility (e.g. Narasimhan and Das, 2000; Jack and Raturi, 2002), supply flexibility has rarely been studied as a separate construct. Furthermore, the drivers (reasons why supply flexibility is needed) and the sources (how supply flexibility is achieved) have seldom been studied simultaneously, and even when this has been done, the approach used has been mostly theoretical (e.g. Pujawan, 2004). Following the sequence of investigation previously found in the manufacturing

flexibility literature, research focus should move from theoretical frameworks to empirical studies. Consequently, future studies should focus on construct validation, using a variety of methods such as interviews, case studies, and surveys (e.g. Jack and Raturi, 2002; Koste *et al.*, 2004).

Hence, the aim of this paper is to study the supply flexibility construct empirically. More specifically, we aim to answer the following research questions:

1. Why do firms need to increase supply flexibility? In other words: What are the drivers of supply flexibility?
2. How do firms increase supply flexibility? In other words: What are the sources of supply flexibility?
3. Is there any relationship between the drivers and sources of supply flexibility?

In order to answer these research questions, we first performed a literature review on supply flexibility and related topics. As a second step, we carried out an exploratory multiple case study based on interviews conducted in seven Spanish manufacturing firms.

The remainder of the paper is structured as follows. Section 2 briefly examines the literature on supply flexibility; Section 3 describes the research methodology; Section 4 presents the research results; and Section 5 draws conclusions from the research and provides some managerial implications of this work.

2.2 Literature review

The following section establishes a theoretical foundation for studying supply flexibility. The section begins with an introduction to supply flexibility. Next, we present a description of the drivers of supply flexibility (reasons why a firm needs supply flexibility). A discussion of the sources of supply flexibility (methods employed to increase supply flexibility) follows. The section concludes with a proposed research model that will be analysed with a multiple case study.

2.2.1 Supply flexibility

There is no single definition of supply flexibility. The literature has proposed several constructs to represent the flexibility related to purchasing, sourcing or supply. Zhang *et al.* (2002) defined 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". Duclos *et al.* (2003) defined supply flexibility as "*the ability to meet the changing needs of customers, changing the supply of product, including mix, volume, product variations and new products*". Both studies were theoretical and highlighted the need for cross-industry empirical studies that could give deeper insights into what constitutes flexibility in different industries. However, they did not present any methodology for assessing flexibility, being restricted to a conceptual framework. Pujawan (2004) drew on these previous definitions and the manufacturing flexibility framework to propose a set of items to assess supply flexibility. These items were based on operational issues encompassing not only the supplier base, but also inbound logistics and sourcing policy. Using empirical data, Swafford *et al.* (2006) developed and tested a sourcing flexibility scale. They defined sourcing flexibility 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*".

The above definitions present some important limitations. First, they refer to the flexibility of the firm as a whole. Accordingly, they do not consider the fact that different purchased components may require different levels of supply flexibility and thus different sourcing strategies. Second, they do not tie in supply flexibility and dimensions of uncertainty (e.g. volume, mix and delivery) that could motivate the utilization of certain practices instead of others.

In our study, in order to consider different dimensions of uncertainty 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*. Also, in our study, in order to take into account the different flexibility requirements of different components we analyse the supply flexibility for the purchased component that requires the highest level of supply flexibility in each company.

2.2.2 Flexibility drivers

In order to analyse the supply flexibility construct properly, we need to know *why* firms need this type of flexibility. A *flexibility driver* is "*a factor that determines the need for flexibility*" (Pujawan, 2004). In this paper, a supply flexibility driver is defined as a supply chain characteristic over which the purchasing function has little or no control,

and which determines the level of supply flexibility required. It is important to note that in this study we focus on *operational* drivers, i.e. we do not take into consideration the impact of the business unit strategy on sourcing practices (Virolainen, 1998). Flexibility drivers could include: demand volatility, fluctuations in the production schedule, etc. If we consider a very simple supply chain (see Figure 1), we can appreciate that supply flexibility drivers can be internal (related to the characteristics of the focal company) or external (related to the characteristics of its upstream and/or downstream supply chain). Demand volatility and seasonality are examples of downstream external drivers; low component commonality among the products of the company is an example of an internal driver; and incomplete supply is an example of an upstream external driver.

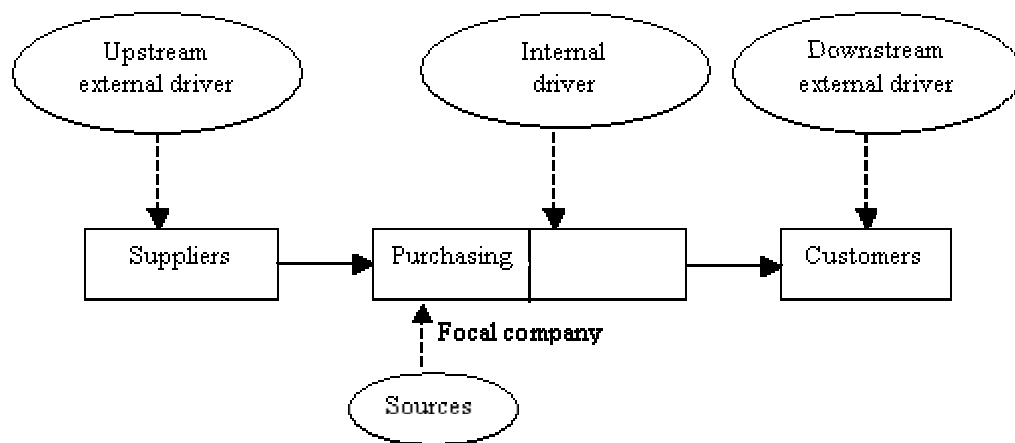


Figure 1. Supply flexibility drivers and sources

Flexibility drivers are related to uncertainty, as flexibility has been often seen as a reaction to environmental uncertainty (Swamidass and Newell, 1987; Gerwin, 1993). Slack (1983), Beamon (1999), Christopher (2000), and Van Donk and Van der Vaart (2005) distinguished three main types of uncertainty:

- *Volume uncertainty*: The level of uncertainty related to (1) the actual volume demanded of a specific component and/or (2) the real volume of a component that will be received. For example, will it be 10 or 15 units of a certain component?
- *Mix uncertainty*: The level of uncertainty related to the exact mix/specification of a component. For example, will it be “red” or “blue”?

- *Delivery uncertainty*: The level of uncertainty related to the date on which the component will be (1) needed and/or (2) received. For example, will the delivery be on June 15th or June 18th?

For example, demand volatility and incomplete supplies are examples of volume uncertainty. Frequent changes in a production schedule that has been sent to a supplier are related to volume, mix and delivery uncertainty. However, if these frequent changes in the production schedule are in mix and dates, rather than quantities (which may have been frozen for a particular time window), frequent changes in the production schedule are related only to mix and delivery uncertainty.

2.2.3 Flexibility sources

As well as analysing *why* supply flexibility is required, it is important to investigate *how* it is achieved in different contexts. 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 (as can be seen in Figure 1, flexibility sources are only considered in the purchasing function). For example, a supply flexibility source could be the practice of establishing single-sourcing contracts with co-located key suppliers.

Several authors have analysed the impact of specific sourcing practices on supply flexibility, as can be appreciated in Table 1. Nevertheless, there is a lack of studies that depict how these various practices combine to increase supply flexibility, and the conditions that could support a set of sources in relation to another.

Industry characteristics may explain the utilization of the sources. For example, Stuckey and White (1993) and Bensaou (1999) suggest that asset specificity may determine decisions such as number of suppliers or level of integration, by increasing the switching costs. Similarly, Grover and Malhotra (2003) claim that there are considerable opportunities to apply concepts such as asset specificity and searching costs to the investigation of supply chain integration and coordination. A more holistic analysis of sourcing practices (i.e. identifying strategies based on sets of sourcing practices) is found in the purchasing portfolio literature. Several frameworks have been proposed for categorizing suppliers and the correspondent sourcing strategies (e.g. Kraljic, 1983; Olsen and Ellram, 1997; Bensaou, 1999). However, these classifications are focused on cost considerations, i.e. none of them explicitly addresses the supply flexibility implications of each sourcing strategy proposed. And, as mentioned above,

flexibility is becoming an increasingly important competitive dimension, influencing the sourcing strategy (Virolainen, 1998).

Table 1. Supply flexibility sources and references

Source	References
Single vs. multiple sourcing	Quayle, 1998; Lee, 2002; Pujawan, 2004; Swafford <i>et al.</i> , 2006
Global vs. domestic sourcing	Smith, 1999; Lee, 2002; Stratton and Warburton, 2003; Jin, 2004
Supplier selection	Stratton and Warburton, 2003; Nassimbeni, 2003; Swafford <i>et al.</i> , 2006
Reducing supplier switching costs	Pujawan, 2004; Chung <i>et al.</i> , 2004; Swafford <i>et al.</i> , 2006
External integration	Zhang <i>et al.</i> , 2002; Lee, 2002; Chung <i>et al.</i> , 2004; Swafford <i>et al.</i> , 2006
Internal integration	Pagell, 2004; Swafford <i>et al.</i> , 2006
Long-term relationships with suppliers	Nassimbeni, 2003; Bruce <i>et al.</i> , 2004
Third-party logistics providers	Prater <i>et al.</i> , 2001; Lee, 2002; Chung <i>et al.</i> , 2004; Pujawan, 2004
Alternative transportation modes	Prater <i>et al.</i> , 2001; Pujawan, 2004; Swafford <i>et al.</i> , 2006
Joint product development with suppliers	Christopher, 2000; Lee, 2002
Supplier certification	Zsidisin and Ellram, 2003
Supplier development	Zsidisin and Ellram, 2003
Supplier quality management programmes	Zsidisin and Ellram, 2003
Inventory buffers	Fisher, 1997; Stratton and Warburton, 2003

In the existing literature we have found only one paper that relates the type of supply flexibility strategy with the drivers. Zsidisin and Ellram (2003) conducted an exploratory factor analysis among the sourcing practices used to manage supply risk and found two main strategies: “behaviour-based management” (supplier certification, supplier development, target costing and supplier quality management programmes) and “buffer-oriented management” (multiple sourcing, safety stock and keeping inventory at suppliers). They found that purchasing organizations become increasingly involved in behaviour-based management given the threat of supply risk due to the inability of some suppliers to meet technological advances and quality standards; however, buffers were found to be implemented regardless of the extent of the perceived risk.

Pujawan (2004) also considered drivers and sources. He suggested a framework for assessing supply flexibility (using various sources, such as multiple sourcing,

availability of multiple transport modes, etc.) and provided a list of drivers (such as length of product life cycle, product variety, order stability, etc.). However, the relationship between drivers and sources was not analysed in this paper.

We share with Zsidisin and Ellram (2003) and Pujawan (2004) the framework of considering drivers and sources of supply flexibility simultaneously. Our study is empirically based, as is that of Zsidisin and Ellram (2003). The main difference between our study and theirs is that they focus on the sources of supply risk while we consider any flexibility driver along the supply chain (internal, upstream external or downstream external). Another main difference is that our study, due to the fact that is based on an exploratory multiple case study, has a wider scope (i.e. data collection is not constrained by rigid questionnaires), allowing for a broader set of sourcing practices.

Our research framework is summarized in Figure 2. First, we try to explore the reasons why firms in different sectors need to increase supply flexibility (drivers). We also try to analyse how firms increase supply flexibility (sources). And finally, we aim to analyse whether there is any relationship between the drivers and the sources.

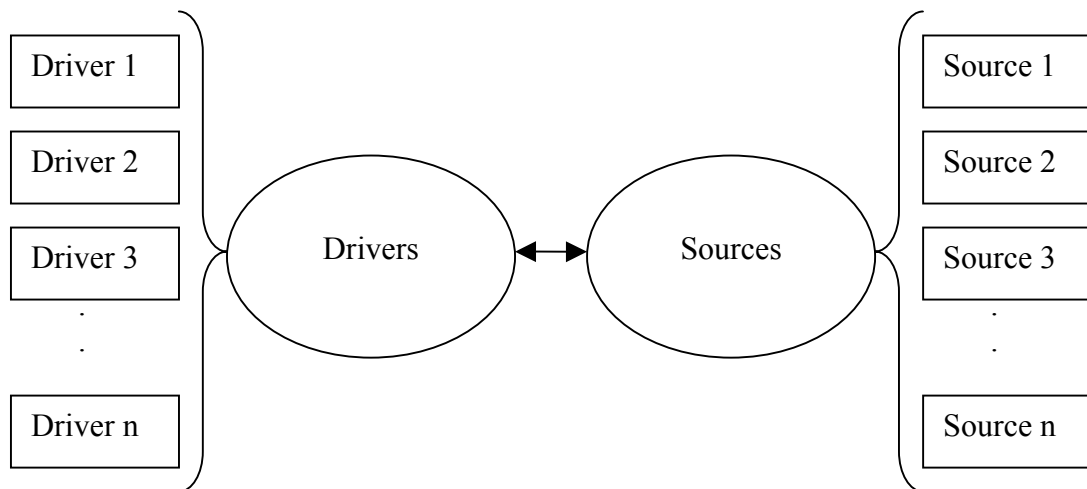


Figure 2. Research framework

2.3 Methodology

As mentioned in the literature review, there is a lack of cross-industry empirical studies on supply flexibility, especially those regarding not the construct *per se*, but its *whys* and *hows*. Flexibility drivers and sources have seldom been studied simultaneously, and when this has been done, the approach used has been mostly theoretical (e.g. Pujawan,

2004). Since the underlying dynamics of the drivers and sources of supply flexibility (i.e. how specific sets of drivers relate to each group of sources) is still not well understood, we have chosen to use an exploratory approach. In particular, this study aimed to fill the gap of empirical studies relating drivers and sources of supply flexibility. Thus, the research focus of this exploratory study is theory building, which has commonly three objectives: 1) identify / describe key variables, 2) identify linkages between variables, and 3) identify “why” these relationships exist (Handfield and Melnyk, 1998).

Due to the exploratory nature of this paper and the need to obtain an in-depth knowledge of drivers (reasons to increase supply flexibility), sources (how do firms increase supply flexibility?) and the relationship between them (drivers and sources), we adopted the case study methodology, as recommended by Yin (1994) and Eisenhardt (1989). The case study methodology is very useful when the research aims to answer “why” and “how” questions (Yin, 1994). This methodology has also been called to be more used by operations management researchers (Voss *et al.*, 2002). The process followed to design and implement this methodology has been adopted from Yin (1994). The sample consisted of seven Spanish manufacturers belonging to different industries. The sampling process was as follows: first, we selected sectors with high unpredictable demand (fashion apparel, electronics, automotive and electrical equipment), based on the “innovative” sectors (i.e. with high demand uncertainty) identified by Fisher (1997) and Lee (2002). This is justified by the fact that demand uncertainty is considered to be the most important component of supply chain uncertainty (Chung *et al.*, 2004; Pujawan, 2004). Then, we used the SABI database of Spanish firms to select our sample, which was composed of all firms in the aforementioned industries (i.e. fashion apparel, electronics, electrical equipments and automotive) that were located in the Barcelona’s metropolitan area and had a revenue’s figure greater than 20 million euros. The original sample was made up by 71 firms. Out of these 71 firms, 19 had an incorrect phone number, had ceased their activities or were in process of fusion with other companies. In 27 firms, informants were absent or could not be reached. In 8 companies, an initial contact showed that firms were not adequate for the study (e.g. were dedicated to retailing). Therefore, only 17 potential informants were reached and considered adequate for the study. Out of these 17 firms, 7 accepted to participate in the study, representing a participation rate of approximately 41%. The profile of the firms studied is shown in Table 2.

Table 2. Profile of firms

Sector	Firm	Number of employees	Revenue (euros)	Informant position	Product	Production system	Demand uncertainty
Automotive	Manufacturer 1	306	51 million	Purchasing manager	Steering columns, shafts and gears	JIT (PULL)	Moderate
	Manufacturer 2	245	54 million	Logistics manager	Acoustic and thermal systems	JIT (PULL)	Moderate
	Manufacturer 3	12,931	6.1 billion	Purchasing manager	Automobiles	JIT (PULL)	Moderate
Fashion apparel	Manufacturer 1	770	142 million	Logistics manager	Apparel and accessories	MTS (PUSH)	High
Electronics	Manufacturer 1	190	102 million	Materials manager	Cathode-ray tubes	MTS (PUSH)	High
	Manufacturer 2	182	168 million	Purchasing manager	TV sets	MTS (PUSH)	High
Electrical equipment	Manufacturer 1	126	26 million	Materials manager	Electric motors	MTS (PUSH)	Moderate

To maintain data consistency, we used a semi-structured interview approach (Yin, 1994). In order to increase the reliability of the case study analysis, it was decided to create an interview protocol (see Appendix) and a case study database. A pilot test was performed with practitioners before the interviews. As a result, the wording of some of the questions was changed in order to make them easier to understand. Interviewing the purchasing manager or equivalent minimized the limitation of using a single informant. High-ranking respondents tend to be more reliable sources of information than their subordinate ranks (Philips, 1981). A suitable informant was defined to be a person with in-depth knowledge of the supply base, purchasing and inbound logistics processes. Informants were selected as follows. When we contacted each firm, we asked for the purchasing manager. If, after we had explained our research, he/she felt he/she could not answer our questions, then he/she told us whom we should contact (in some of the firms analysed, the logistics or materials manager). The questionnaire was then pre-mailed to the key informant, two days before the interview.

In each firm, data was collected in the course of a one-hour interview. The interviews were conducted in February and March 2005. At the beginning of each interview, the informants were asked to present their own definition of supply flexibility, in order to verify how consistent was with our definition. The answers showed that our definition was compatible with the perception of the informants. Then, we used the interview protocol questions as a guideline, asking for further information

when needed. The answers were transcribed and analysed regarding clarity and sufficiency. If any information remained unclear and/or we felt more data was needed, informants were contacted later by phone for additional questions. Also, other sources of evidence such as industry databases, newspaper clippings and company websites were used to corroborate and augment evidence. If there was any sort of discrepancy between the data collected during the interview and the other sources of evidence, we checked all the information again and contacted the interviewee for clarification.

We believe all these procedures assured an adequate level of validity and reliability to our analysis. Following the case study methodology proposed by Yin (1994), we tried to assure *construct validity* by using multiple sources of evidence and establishing a chain of evidence. We tried to increase the *external validity* by using multiple case studies. And finally, *reliability* was assured by using a case study protocol and developing a case study database.

2.4 Cross-case analysis

2.4.1 Drivers

A supply flexibility driver is a supply chain characteristic over which the purchasing function has little or no control, and which determines the level of supply flexibility required. From our interviews, we have identified internal drivers (characteristics of the focal company) and external drivers (characteristics of its upstream and/or downstream supply chains). Table 3 summarizes the results of the case studies. In this table, we display the flexibility drivers for each firm (based on the data collected on the interviews), classifying them by their position in the supply chain (internal, upstream or downstream). This table can be read vertically, e.g. automotive company 1 mentioned an internal driver (production schedule uncertainty) as the most important one. Also, the table can be interpreted horizontally, e.g. low component commonality was mentioned as an important driver by automotive firm 2, the fashion apparel firm, and consumer electronics firms 1 and 2. Table 4 relates each driver and the type of uncertainty associated with it (volume, mix or delivery), based on the literature and case evidence. Regarding internal drivers we found the following:

- *Production schedule uncertainty*, i.e. the uncertainty regarding production plans in the short run (Krajewski *et al.*, 2005). This driver is related mostly to mix and delivery uncertainty, because in the firms analysed the exact definition of

component specification and delivery date is delayed as long as possible. Volume uncertainty is less affected because in the short run there is no significant uncertainty in the volume to be produced (most of these companies are working under a JIT philosophy, in which volumes are relatively stable for a given period of time).

- *Low component commonality*, i.e. the extent to which the same purchased component can be used in several final products (Pujawan, 2004). This basically affects the mix uncertainty, although studies suggest that it has an indirect effect on volume uncertainty (Salvador *et al.*, 2005). Accordingly, this driver is related to mix and volume uncertainty.
- *JIT purchasing*, i.e. the use of small purchasing batches and frequent deliveries (Womack *et al.*, 1990; Ponce and Prida, 2004). This practice generates mix and delivery uncertainty. Volume uncertainty is less important, because a precondition for JIT is to have stable supplier purchase orders in terms of volume (Womack *et al.*, 1990; Ponce and Prida, 2004).
- *Manufacturer slack capacity*, i.e. the difference between the manufacturer's maximum output rate and the normal production rate (Jack and Raturi, 2002). This basically affects the volume uncertainty, because capacity is generally measured at an aggregate level.

We identified the following downstream supply chain drivers:

- *Demand volatility*, i.e. variability in the demand of the manufacturer's customer, in terms of volume and mix (Fisher, 1997; Lee, 2002; Pujawan, 2004). The effect on delivery uncertainty is not so significant, because none of the companies that stated this driver was producing in a "make-to-order" environment.
- *Demand seasonality*, i.e. the extent to which the demand of the manufacturer's customer is concentrated in the same periods each year. This driver has a direct impact on the level of volume uncertainty (Jack and Raturi, 2002), rather than mix and delivery uncertainty, since it affects medium and long-term materials planning, which are based on aggregate demand forecasts. Therefore, this driver is mainly related to volume uncertainty.
- *Forecast accuracy*, i.e. the deviation of customer's actual demand from the sales forecast. This driver mainly affects the volume and mix uncertainty (Stratton and

Warburton, 2003). Delivery flexibility needs are not significantly affected, since the delivery date is defined according to short-term requirements (i.e. not according to forecasts).

And finally, regarding upstream supply chain drivers, we found only one:

- *Non-responsive suppliers*, i.e. the use of suppliers who do not send the right quantities on the established dates. This affects volume, mix and delivery uncertainty (Pujawan, 2004).

Table 3. Supply flexibility drivers

Position in the supply chain	Driver	Automotive			Fashion apparel	Consumer electronics		Electrical equipment
		Case 1	Case 2	Case 3	Case 1	Case 1	Case 2	Case 1
Internal	Production schedule uncertainty	x		x		x		
	Low component commonality		x		x	x	x	
	JIT purchasing			x				
	Slack capacity at focal company				x			
Downstream	Demand volatility				x	x	x	
	Demand seasonality				x			
	Low forecast accuracy				x		x	
Upstream	Unresponsive suppliers				x			

Table 4. Supply flexibility drivers and type of uncertainty

Driver	Type of uncertainty		
	Volume	Mix	Delivery
Production schedule uncertainty		x	x
JIT purchasing		x	x
Unresponsive suppliers	x	x	x
Low component commonality	x	x	
Demand volatility	x	x	
Low forecast accuracy	x	x	
Demand seasonality	x		
Slack capacity at focal company	x		

This list of drivers differs slightly from the supply flexibility drivers proposed by Pujawan (2004). In our study we observed that sometimes the uncertainties that drive the required supply flexibility are actually introduced by the focal company (e.g. through frequent changes in the production schedule). This is in line with recent

empirical studies in build-to-order supply chains (Krajewski *et al.*, 2005). The focal company can reduce the required supply flexibility by changing certain practices that are internal to the company but not under the control of the purchasing area. For example, automotive firm 3 reduced the delivery flexibility required from its suppliers by freezing a part of its production schedule. The decision to freeze a part of the production schedule was the responsibility of the production function. All the internal drivers (production schedule uncertainty, low component commonality, JIT purchasing and manufacturer slack capacity) are under the control not of the purchasing area but of other departments or functional areas of the company. Some highly disseminated practices of Supply Chain Management (e.g. integrated production planning, collaboration among functional areas) could reduce the need for supply flexibility. Interestingly, none of the companies in the study had a Supply Chain Management department, fact that possibly increased the level of supply flexibility required. Further studies should include firms that have implemented Supply Chain Management, and verify whether this practice can effectively reduce the supply flexibility needs.

Regarding internal drivers it is important to note that production schedule uncertainty is a driver that is only present in make-to-order or assemble-to-order environments (Krajewski *et al.*, 2005). The companies interviewed that were working with forecasts and a make-to-stock environment did not mention this driver.

As far as external drivers are concerned, there are more downstream drivers than upstream ones. Drivers related to demand uncertainty (demand volatility and low forecast accuracy) are the most important ones, which is consistent with previous studies (Chung *et al.*, 2004; Pujawan, 2004). Upstream drivers relate to uncertainty in the suppliers' delivery (e.g. the supplier does not deliver the quantities ordered, or does not meet the agreed date). As can be observed in Table 3, only one company mentioned unresponsiveness of suppliers as a driver. This result was expected, since reliability is a prerequisite to becoming a supplier of a critical component (Nassimbeni, 2003; Stratton and Warburton, 2003).

Table 3 suggests some clear industry patterns: the automotive sector firms, for example, have significant internal drivers (i.e. most of the required flexibility is driven by internal decisions such as frequency of changes in production plans). The use of JIT purchasing increases the dependency on stable production plans to keep a smooth supply of components (Womack *et al.*, 1990; Ponce and Prida, 2004). On the other hand, the firms in the fashion apparel and consumer electronics sectors present a more

balanced distribution among internal and external drivers. In these sectors, demand volatility plays a more important role in determining the required flexibility. This is consistent with previous cross-sector studies (e.g. Fine, 1998; Ponce and Prida, 2004).

2.4.2 Sources

Table 5 shows the responses of the companies analysed in our study. In this analysis, based on empirical data, we tried to detect some patterns (i.e. supply flexibility sources that are used jointly). In parallel, we checked the literature in order to verify if the detected patterns were consistent. Naturally, this was just an exploratory study, and all conclusions should be regarded cautiously (especially considering the limited sample of firms). Our objective with this analysis was to formulate some propositions that should be tested in future confirmatory studies. On observing these results it seems that there are some common practices used by most of the firms to increase supply flexibility (e.g. long-term relationships with suppliers, inventory buffers, sending forecasts to suppliers). Also, there seem to be two main strategies (i.e. sets of practices), which we call *improved supplier responsiveness* and *flexible sourcing*:

- *Improved supplier responsiveness*. This first strategy includes practices aimed to increase supplier responsiveness capabilities, such as suppliers' short-term process flexibility (i.e. the ability to make frequent schedule changes efficiently (Krajewski *et al.*, 2005)) or a supplier's ability to produce efficiently in small quantities (Fisher *et al.*, 1997). Single sourcing, geographical proximity of suppliers, supplier selection based on flexibility, internal collaboration (e.g. between the purchasing and production departments) and process integration with logistics providers are important elements of this strategy. The firms that apparently adopt this strategy are automotive firms 1 and 3 and consumer electronics firm 1.

Empirical evidence of similar flexibility-focused strategies include several industrial sectors such as the Italian eyewear district (Nassimbeni, 2003), cosmetics (Smock, 2005) and aeronautical (Rosseti and Choi, 2005). In all these examples, supply flexibility was achieved through a reduced, co-located and high-response supply base.

- *Flexible sourcing*. The second strategy is to adopt a larger supplier base and constantly reconfigure the supply chain. The firms that seem to adopt such a strategy are automotive firm 2, the fashion apparel firm and the consumer

electronics firm 2. In this case, the main source of supply flexibility is not a particular supplier's responsiveness capability, but the leading firm's ability to coordinate the entire supply chain and redesign the supply network quickly and at a low cost. Likewise, Fine (1998) and Chung *et al.* (2004) argue that, in uncertain environments, a company's real core capability lies in the ability to design and manage the supply chain. For example, in the high-tech computer and peripheral sectors firms limit inter-dependence and retain the ability to easily switch partners, allowing greater organizational flexibility (Chung *et al.*, 2004). A similar pattern is found in the apparel sector, where the main job of the core company is to manage the production and trade networks and to make sure that all the pieces of the business come together as an integrated whole (Gereffi, 1994). In addition, suppliers are not located so close as in the "improved supplier responsiveness" strategy. In fact, studies suggest that lower-cost suppliers located further away may be more responsive than suppliers close to the market, since low wage rates enable suppliers to afford excess capacity, which compensates for longer transportation times (Fisher *et al.*, 1997).

It should be mentioned that the firm in the electrical equipment sector was not classified in either of the supply flexibility strategies, because it did not present any significant driver, i.e. its supply flexibility requirements were very small. This classification ("improved supplier responsiveness" and "flexible sourcing") is in line with previous segmentations of sourcing strategies, i.e. "strategic" or "leverage" components (Kraljic, 1983), and "strategic" or "market exchange" dyadic relationships (Bensaou, 1999). Nevertheless, neither of these previous frameworks focused on supply chain uncertainties (demand volatility, production schedule uncertainty, etc.). Moreover, they did not explicitly relate supplier segmentation and the corresponding impacts on supply flexibility.

It is important to make some comments on these results: Firstly, most of the supply flexibility sources may be also used to achieve other competitive priorities (e.g. cost, quality). However, due to the need of limiting the scope of our study we only asked companies for the practices used to increase supply flexibility. Other studies in the literature have followed the same approach - i.e. analysing broad sourcing practices focusing on a single competitive priority (e.g. Jack and Raturi, 2002; Zsidisin and Ellram, 2003). Nevertheless, in further studies it would be useful to understand to what

extent those sourcing practices are selected as a consequence of a mix of competitive priorities.

Secondly, although the segmentation of supply flexibility strategies coincides with previous studies, other results may seem counter-intuitive. For example, in case 2 supplier relationships are long term oriented with a multiple sourcing strategy and low cooperation with suppliers. The explanation can be that a long-term relationship is a prerequisite for establishing cooperation with suppliers, but it is not a sufficient condition, i.e. there are companies that have long-term relationships but they do not cooperate (Van der Vaart *et al.*, 2006).

Another result that may seem counter-intuitive is how firms in the “flexible sourcing” strategy may adopt joint product development and long-term relationships (case 2, consumer electronics). This may happen because in areas of fast technological development suppliers are maintained and collaborate in product development as long as they are leaders in technology and quality. If they lose their leadership, they are quickly replaced. In a similar way, Dell’s sourcing strategy combines long-term commitments, joint product development and quick redesign of the supply chain (Magretta, 1998). Whether this is a particular situation for high-tech sectors should be verified in further studies.

Finally, although it was not mentioned in the interviews, the literature suggests that *ordering policy* may be an important source of flexibility. By reducing order batching and shortage gaming (i.e. in a situation in which several buyers compete for a limited supply, the buyer’s orders may exceed his actual needs, aiming to prevent potential shortages) the purchasing function may avoid the well known “bullwhip effect” (Lee *et al.*, 1997), a major source of supply disruptions and fluctuations in the manufacturers’ orders to suppliers.

In accordance with these results we establish the following propositions, which should be analysed in further studies:

Proposition 1. *Firms use two strategies to increase their supply flexibility: “improved supplier responsiveness” and “flexible sourcing”. The former is characterized by single sourcing, a high level of internal and external integration, co-location of suppliers and supplier selection based on supplier responsiveness capability. The latter is characterized by a larger supply base, lower levels of supplier responsiveness and faster supply network redesign (when compared to the first strategy).*

Proposition 2. *Some sources of supply flexibility are employed by firms using both strategies: inventory buffers, long-term relationships with suppliers, forecast sharing with suppliers and joint product development.*

Table 5. Supply flexibility sources

Supply flexibility strategy	Source	Automotive			Fashion apparel	Consumer electronics		Electrical equipment
		Case 1	Case 2	Case 3*	Case 1	Case 1	Case 2	Case 1
Improved supplier responsiveness	Single sourcing	x		x		x		x
	Supplier selection based on flexibility			x		x		
	Internal collaboration	x		x		x		
	Integration with logistics provider	x						
	Co-location of suppliers	x		x				x
Flexible sourcing	Multiple suppliers		x		x		x	
	Alternative transportation modes						x	
	Reduction in time needed to replace unresponsive suppliers				x			
Both	Joint product development with suppliers			x			x	
	Sending delivery forecasts to suppliers	x	x	x	x	x	x	x
	Long-term relationship with suppliers	x	x	x	x	x	x	x
	Inventory buffers at the focal company	x	x		x	x	x	x

* Results shown for the JIT supplier of the most critical item.

Furthermore, firms may act concurrently on the supply flexibility drivers in order to reduce the required supply flexibility. For example, electronics firm 2, as well as adopting a flexible sourcing strategy, is increasing the parts commonality; and automotive firm 3, as well as adopting the “improved supplier responsiveness” strategy, has reduced the required supply flexibility by increasing the frozen part of the production schedule. This means that companies can reduce the supply flexibility gap (difference between the supply flexibility required and the supply flexibility achieved) by (1) working on the drivers, thus reducing the supply flexibility required, and/or (2) implementing a “flexible sourcing” or “improved supplier responsiveness” strategy and/or the other common practices such as inventory buffers or sending delivery forecasts to suppliers, thus increasing the supply flexibility achieved.

Table 6 summarizes the results of Tables 3, 4 and 5, and depicts the relationship between flexibility drivers, type of uncertainty, level of switching costs and sources.

This table can be read as follows: first, we show the relationship between each driver and the type of uncertainty (volume, mix or delivery) associated with it; second, we mark the cases in which this driver was mentioned as an important factor for defining the level of flexibility needed. Then, each case is categorized into one of the two strategies proposed (improved supplier responsiveness or flexible sourcing). Moreover, the level of searching and switching costs is depicted for each firm. Our objective in this table was to study what factors (types of uncertainty, drivers and switching costs) could explain why firms select a particular supply flexibility strategy (“improved supplier responsiveness” or “flexible sourcing”).

Table 6. Drivers, type of uncertainty and sources

	Volume uncertainty	Mix uncertainty	Delivery uncertainty	Automotive 1	Automotive 3	Consumer electronics 1	Automotive 2	Fashion apparel	Consumer electronics 2	Electrical Equipment
Drivers										
Production schedule uncertainty		X	X	X	X	X				
JIT purchasing		X	X		X					
Unresponsive suppliers	X	X	X					X		
Low component commonality	X	X				X	X	X	X	
Demand volatility	X	X				X		X	X	
Low forecast accuracy	X	X						X	X	
Slack capacity at focal company	X							X		
Demand seasonality	X							X		
Switching costs										
				↑	↑	↑	↓	↓	↓	↑
Strategy implemented										
				Supplier Response	Supplier Response	Supplier Response	Flexible sourcing	Flexible sourcing	Flexible sourcing	

The decision between the “improved supplier responsiveness” and “flexible sourcing” strategies seems to be affected by two factors: the supplier searching and switching costs, and the type of uncertainty.

In this study, we consider supplier searching and switching costs as *the costs associated with finding, certifying and switching a supplier, without a significant decrease in performance (in terms of cost, quality and price)*. These costs can be estimated by the buyer's specific investments in relation to the supplier (Bensaou, 1999). These can be (1) tangible investments in buildings or physical assets dedicated to the components of a specific supplier, (2) internal processes customized to the components produced by this supplier, or (3) time and effort dedicated to learning the supplier's business processes and nurturing the relationship (Stuckey and White, 1993; Bensaou, 1999).

On the basis of the results of the case studies (which are summarized in Table 6), it seems that when supplier searching and switching costs are low, companies increase supply flexibility by implementing a “flexible sourcing” strategy; however, when these costs are high, companies increase supply flexibility by implementing a “supplier responsiveness” strategy. In our case studies, consumer electronics firm 2, which can search and switch suppliers quickly (in less than three months), uses a “flexible sourcing” strategy. On the other hand, automotive firm 3, which has high supplier switching costs (due to supplier-specific investments), adopts an “improved supplier responsiveness” strategy. This is in line with previous research in supply chain management. Bensaou (1999) argues that the level of the buyer's specific investments in the relationship influences the profile of the buyer-supplier dyad: the higher the level of specific investments, the higher the collaboration level. Similarly, Klein *et al.* (1990) found that the level of asset specificity positively affects the integration level in the supply chain. In accordance with these results, we establish the following propositions:

Proposition 3. *The supplier searching and switching costs influence the selection of the supply flexibility strategy.*

(a) *When supplier searching and switching costs are high, firms select the “improved supplier responsiveness” strategy.*

(b) *When supplier searching and switching costs are low, firms select the “flexible sourcing” strategy.*

Table 6 also suggests a relationship between the supply flexibility strategy adopted and the type of uncertainty. When the main driver of flexibility is the uncertainty in the production schedule and JIT purchasing (delivery and mix uncertainty), companies seem to increase flexibility by implementing the “improved supplier responsiveness” strategy. On the other hand, firms seem to select the “flexible

sourcing” strategy when the drivers of flexibility are low component commonality, demand volatility and low forecast accuracy (volume and mix uncertainty).

Proposition 4. *The type of uncertainty influences the supply flexibility strategy adopted.*

(a) *When mix and delivery uncertainties are predominant, firms select the “improved supplier responsiveness” strategy.*

(b) *When volume and mix uncertainties are predominant, firms select the “flexible sourcing” strategy.*

2.5 Conclusions

Our study suggests that firms increase supply flexibility for a variety of reasons, using different strategies. Supply flexibility drivers can be either external (demand volatility and seasonality, forecast accuracy) or internal to the firm (production schedule uncertainty, low component commonality, JIT purchasing, slack capacity at the focal company and unresponsive suppliers). The sources of supply flexibility can be divided into “improved supplier responsiveness” and “flexible sourcing”, but these strategies share some common practices (long-term relationships with suppliers, forecast sharing with suppliers, joint product development, and inventory buffers at the focal company).

Although most of these results were in line with the literature, it is surprising to note that collaborative planning practices were not mentioned as important sources of supply flexibility. Firms collaborated with suppliers by sharing delivery forecasts, but the forecasting and delivery planning processes were done individually (i.e. without suppliers’ involvement) in all firms studied. The reasons for this should be investigated in further studies.

Our contribution to the literature is twofold. First, we have explored the relationship between drivers and sources of supply flexibility. The results of the case study analysis suggest that this relationship can be summed up in the following propositions: When the main driver of flexibility is the uncertainty in the production schedule and JIT purchasing (mix and delivery uncertainty), companies can increase supply flexibility by implementing a strategy aimed at “improved supplier responsiveness”. On the other hand, when the drivers of flexibility are low component commonality, demand volatility and low forecast accuracy (volume and mix uncertainty), companies seem to increase supply flexibility by implementing a “flexible

sourcing” strategy. Moreover, the results suggest that supplier searching and switching costs may determine the supply flexibility strategy: the higher these costs, the more likely the firm is to adopt the “improved supplier responsiveness” strategy.

Our second contribution to the literature lies in the methodology adopted (multiple case study). As we pointed out earlier, most of the previous studies on supply flexibility aimed to build conceptual frameworks and lacked empirical validation. We believe that the concept of supply flexibility will benefit considerably from the insights provided by real business problems and constraints faced by firms in different industrial sectors, like those presented in this study.

Like many exploratory case studies, this paper has some limitations. Firstly, the reduced sample size restrains the level of generality of the theory. Moreover, the huge quantity of data makes it difficult to assess which are the most important relationships and which are idiosyncratic to a particular case (Eisenhardt, 1989). Also, there could be some sort of context bias, since the firm sample presented a limited environment differentiation (i.e. industries, countries). Another difficulty is the subjective criterion for some variables, such as the production schedule uncertainty or the integration level. Furthermore, the impact of the business unit strategy (e.g. flexibility focus) on the sourcing practices has not been covered in this study. Despite these limitations, our study contributes to the existing literature by empirically investigating the main reasons why companies need to increase supply flexibility and how they increase this flexibility, and by suggesting some factors that could influence the selection of a particular supply flexibility strategy.

We believe that this paper will be both informative and insightful for professionals and researchers in the area of supply chain management: Professionals are provided with a list of drivers and sources of flexibility and some guidelines on how to increase flexibility while taking into account the reasons why this flexibility is needed. Researchers are provided with some preliminary lists of drivers and sources of flexibility, which should be further analysed. The results could also be extended to other sectors in further studies. For example, the similarities between the automotive and aircraft industries, or between fashion apparel and toy firms, suggest that those sectors may have the same supply flexibility requirements and/or strategies. Researchers are also given some further lines of research into supply flexibility. Regarding this latter aspect, some lines of future research include:

- Testing the abstract constructs of flexibility drivers and sources

- Testing the relationship between the two constructs
- Studying the interactions between the strategic goals of the business unit and the supply flexibility strategies identified (e.g. “What is the impact of other strategic objectives, such as cost or quality, on the selection of these strategies?”).

References

- Beamon, B. (1999), “Measuring supply chain performance”, *International Journal of Operations and Production Management*, Vol. 19 No. 3, pp. 275-292.
- Bensaou, M. (1999), “Portfolios of buyer-supplier relationships”, *Sloan Management Review*, Vol. 40 No. 4, pp. 35-44.
- Bruce, M., Daly, L. and Towers, N. (2004), “Lean or agile: a solution for supply chain management in the textiles and clothing industry?”, *International Journal of Operations and Production Management*, Vol. 24 No. 2, pp. 151-170.
- Chen, I.J. and Paulraj, A. (2004), “Towards a theory of supply chain management: The constructs and measurements”, *Journal of Operations Management*, Vol. 22 No. 2, pp. 119-150.
- Christopher, M. (2000), “The agile supply chain: Competing in volatile markets”, *Industrial Marketing Management*, Vol. 29 No. 1, pp. 37-44.
- Chung, W.W.C., Yam, A.Y.K. and Chan, M.F.S. (2004), “Networked enterprise: A new business model for global sourcing”, *International Journal of Production Economics*, Vol. 87 No. 3, pp. 267-280.
- Duclos, L.K., Vokurka, R.J. and Lummus, R.R. (2003), “A conceptual model of supply chain flexibility”, *Industrial Management & Data Systems*, Vol. 103 No. 6, pp. 446-456.
- Eisenhardt, K.M. (1989), ”Building theories from case study research”, *Academy of Management Review*, Vol. 14 No. 4, pp. 532-550.
- Fine, C. (1998), *Clockspeed: Winning Industry Control in the Age of Temporary Advantage*, Perseus, Reading, MA.
- Fisher, M.L. (1997), “What is the right supply chain for your product?”, *Harvard Business Review*, Vol. 75 No. 2, pp. 105-116.

- Fisher, M., Hammond, J., Obermeyer, W. and Raman, A. (1997), "Configuring a supply chain to reduce the cost of demand uncertainty", *Production and Operations Management*, Vol.6 No. 3, pp. 211-225.
- Gereffi, G. (1994), "The organization of buyer-driven global commodity chains: how US retailers shape global production networks", in Gereffi, G. and Korzeniewicz, M. (Eds), *Commodity Chains and Global Capitalism*, Greenwood Press, Westport, CT, pp. 95-122.
- Gerwin, D. (1993), "Manufacturing flexibility: A strategic perspective", *Management Science*, Vol. 39 No. 4, pp. 395-410.
- Grover, V. and Malhotra, M.K. (2003), "Transaction cost framework in operations and supply chain management research: theory and measurement", *Journal of Operations Management*, Vol. 21 No. 4, pp. 457-473.
- Handfield, R.S. and Melnyk, S.A. (1998), "The scientific theory-building process: a primer using the case of TQM", *Journal of Operations Management*, Vol. 16 No. 4, pp. 321-339.
- Jack, E.P. and Raturi, A. (2002), "Sources of volume flexibility and their impact on performance", *Journal of Operations Management*, Vol. 20 No. 5, pp. 519-548.
- Jin, B. (2004), "Achieving an optimal global versus domestic sourcing balance under demand uncertainty", *International Journal of Operations and Production Management*, Vol. 24 No. 12, pp. 1292-1305.
- Klein, S., Frazier, G.L. and Roth, V.J. (1990), "A transaction cost analysis model of channel integration in international markets", *Journal of Marketing Research*, Vol. 27 No. 2, pp. 196-208.
- Koste, L.K. and Malhotra, M.K. (1999), "A theoretical framework for analyzing the dimensions of manufacturing flexibility", *Journal of Operations Management*, Vol. 18 No. 1, pp. 75-93.
- Koste, L.L, Malhotra, M.K. and Sharma, S. (2004), "Measuring dimensions of manufacturing flexibility", *Journal of Operations Management*, Vol. 22 No. 2, pp. 171-196.
- Krajewski, L., Wei, J. and Tang, L.L. (2005), "Responding to schedule changes in build-to-order supply chains", *Journal of Operations Management*, Vol. 23, No. 5, pp. 452-469.
- Kraljic, P. (1983), "Purchasing must become supply management", *Harvard Business Review*, Vol. 61 No. 5, pp. 109-117.

- Lee, H.L. (2002), "Aligning supply chain strategies with product uncertainties", *California Management Review*, Vol. 44 No. 3, pp. 105-119.
- Lee, H.L., Padmanabhan and V., Whang, S. (1997), "Information distortion in a supply chain: The Bullwhip Effect", *Management Science*, Vol. 43 No. 4, pp. 546-558.
- Magretta, J. (1998), "The power of virtual integration: An interview with Dell Computer's Michael Dell", *Harvard Business Review*, Vol. 76, No. 2, pp. 72-84.
- Narasimhan, R. and Das, J. (2000), "An empirical examination of sourcing's role in developing manufacturing flexibilities", *International Journal of Production Research*, Vol. 38 No. 4, pp. 875-893.
- Nassimbeni, G. (2003), "Local manufacturing systems and global economy: Are they compatible? The case of the Italian eyewear district", *Journal of Operations Management*, Vol. 21 No. 2, pp. 151-171.
- Olsen, R.F. and Ellram, L.M. (1997), "A portfolio approach to supplier relationships", *Industrial Marketing Management*, Vol. 26 No. 2, pp. 101-113.
- Pagell, M. (2004), "Understanding the factors that enable and inhibit the integration of operations, purchasing and logistics", *Journal of Operations Management*, Vol. 22 No. 5, pp. 459-487.
- Philips, J. (1981), "Assessing measurement error in key informant reports: a methodological note on organizational analysis in marketing", *Journal of Marketing Research*, Vol. 18 No. 1, pp. 395-415.
- Ponce, E. and Prida, B. (2004), *La logística de aprovisionamientos para la integración de la cadena de suministros*, Pearson Educación, Madrid.
- Prater, E., Biehl and M., Smith, M.A. (2001), "International supply chain agility: Tradeoffs between flexibility and uncertainty", *International Journal of Operations and Production Management*, Vol. 21, No. 5/6, pp. 823-839.
- Pujawan, N. (2004), "Assessing supply chain flexibility: a conceptual framework and a case study", *International Journal of Integrated Supply Management*, Vol. 1 No. 1, pp. 79-97.
- Quayle, M. (1998), "Industrial procurement: Factors affecting sourcing decisions", *European Journal of Purchasing and Supply Management*, Vol.4 No. 1, pp. 199-205.

- Rossetti, C. and Choi, T.Y. (2005), "On the dark side of strategic sourcing: Experiences from the aerospace industry", *Academy of Management Executive*, Vol. 19, No. 1, pp. 46-60.
- Salvador, F., Rungtusanatham, M., Forza, C. and Trencin, A. (2005), "Understanding synergies and trade-offs between volume flexibility and mix flexibility in build-to-order strategies", *Proceedings of the 12th International EurOMA Conference*, Budapest, pp. 1313-1322.
- Slack, N. (1983), "Flexibility as a manufacturing objective", *International Journal of Operations and Production Management*, Vol. 7 No. 4, pp. 35-45.
- Smith, J.M. (1999), "Item selection for global purchasing", *European Journal of Purchasing and Supply Management*, Vol. 5 No. 1, pp. 117-127.
- Smock, D. (2005), "Avon calling", *Purchasing*, Vol. 132, No. 1, pp. 24C7-24C10.
- Stratton, R. and Warburton, R.D.H. (2003), "The strategic integration of agile and lean supply", *International Journal of Production Economics*, Vol. 85 No. 2, pp. 183-198.
- Stuckey, J. and White, D. (1993), "When and when not to vertically integrate", *Sloan Management Review*, Vol. 34 No. 3, pp. 71-83.
- Swafford, P., Ghosh, S. and Murthy, N. (2006), "The antecedents of supply chain agility of a firm: Scale development and model testing", *Journal of Operations Management*, Vol. 24 No. 2, pp. 170-188.
- Swafford, P., Ghosh, S. and Murthy, N. (2006b), "A framework for assessing value chain agility", *International Journal of Operations and Production Management*, Vol. 26 No. 2, pp. 118-140.
- Swamidass, P.M. and Newell, W.E. (1987), "Manufacturing strategy, environmental uncertainty and performance: A path analytic model", *Management Science*, Vol. 33 No. 4, pp. 509-524.
- Upton, D.M. (1994), "The management of manufacturing flexibility", *California Management Review*, Vol. 36, No. 2, pp. 72-89.
- Van der Vaart, T.; Giménez, C. & Van Donk, D. (2006), "Supply Chain Integration and Performance: The Impact of Business Conditions", *Proceedings of the 13th EurOMA International Conference*, Glasgow, UK, pp.473-482.
- Van Donk, D.P. and Van der Vaart, T. (2005), "A case of shared resources, uncertainty and supply chain integration in the process industry", *International Journal of Production Economics*, Vol. 96 No. 1, pp. 97-108.

- Violainen, V.M. (1998), "A survey of procurement strategy development in industrial companies", *International Journal of Production Economics*, Vol. 56-57, pp. 677-688.
- Vokurka, R.J. and O'Leary-Kelly, S.W. (2000), "A review of empirical research on manufacturing flexibility", *Journal of Operations Management*, Vol. 18 No. 4, pp. 485-501.
- Voss, C., Tsikriktsis, N. and Frohlich, M. (2002), "Case research in operations management", *International Journal of Operations and Production Management*, Vol. 22 No. 2, pp. 195-219.
- Womack, J.P., Jones and D.T., Roos, D. (1990), *The Machine that Changed the World*, Macmillan Publishing Company, New York, NY.
- Yin, R.K. (1994), *Case Study Research: Design and methods*; Sage Publications, Beverly Hills, CA.
- Zhang, Q., Vonderembse, M.A. and Lim, J. (2002), "Value chain flexibility: a dichotomy of competence and capability", *International Journal of Production Research*, Vol. 40 No. 3, pp. 561-583.
- Zsidisin, G.A. and Ellram, L.M. (2003), "An agency theory investigation of supply risk management", *Journal of Supply Chain Management*, Vol. 39 No. 3, pp. 15-27.

Appendix. Interview protocol

Q1. How do you define supply flexibility?

Q2. How important is supply flexibility for your firm, compared to other purchasing performance dimensions (cost, quality, reliability)?

Q3. How do you measure supply flexibility?

Q4. Please describe the following processes: purchasing planning, purchasing, delivery and supply base management.

Q5. How often is the production schedule revised? Is there a “frozen schedule” policy for deliveries?

For the following questions, please consider the purchased item that requires the highest level of supply flexibility:

Q6. How many suppliers deliver this product? Where are they located? Do these suppliers have other important customers for this product?

Q7. Why is this material critical with respect to supply flexibility?

Q8. What factors are important to increase supply flexibility? How do you increase supply flexibility?

Q9. How many units are purchased each year?

Q10. How many different configurations/specifications are produced?

Q11. How long is the final product life cycle?

Q12. How large is the supplier-specific investment for this product (in terms of specific assets, time and effort dedicated to nurturing the relationship, etc)?

CHAPTER 3: SUPPLY FLEXIBILITY STRATEGIES

Submitted to the *International Journal of Production Economics*¹

Presented at the 10th *SIMPOI / POMS Conference*, 2007, Rio de Janeiro, Brazil

¹ Edited version

3.1 Introduction

Flexibility reflects an organization's ability to effectively adapt or respond to change (Upton, 1995). It is an increasingly important competitive priority in many sectors (Hayes and Wheelwright, 1984; Gerwin, 1993). Indeed, the requirement for increased flexibility applies to both traditional smokestack industries and completely new industries (Gerwin, 1993). Additionally, a firm doesn't need to be competing on the basis of its flexibility for it to be a relevant managerial issue (Upton, 1994).

The objective of this paper is to study the different approaches that firms use to achieve *supply flexibility*, which is defined based on Duclos *et al.* (2003) and Upton (1994) 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*. Many examples of the importance of supply flexibility can be found in the literature. For example, the problems faced by GM and Boeing, when trying to implement a production ramp up in the 1990's, and their suppliers could not adjust their capacity (Cachon and Lariviere, 2001). Similarly, Hong Kong's achievements as an OEM producer can be imputed to the flexibility of its subcontracting networks (Jin, 2004).

Although sourcing strategy has been studied extensively, the study of supply flexibility is at its infancy stage. In particular, the relationship between sourcing practices and supply flexibility has not been sufficiently explored. There is not a unique approach to achieve supply flexibility. "Flexibility is not free" (Jack and Raturi, 2002), and different environments can suggest different approaches to flexibility (Anand and Ward, 2004).

These different approaches mean the adoption of different sourcing practices. In the *supply chain integration* literature, Swafford *et al.* (2006) suggest that it is possible to increase flexibility by building an effective coordination with suppliers. Alternatively, firms may keep buffer stocks to counterbalance the lack of information or coordination (Stratton and Warburton, 2003; Saeed *et al.*, 2005). Moreover, from an *information systems* perspective, firms can either intensify the integration of information systems with a few key suppliers, or rely on e-marketplaces to contact a wider range of supply sources (Kaplan and Sawhney, 2000). Considering *localization decisions*, firms may use domestic sourcing to increase flexibility (Jin, 2004). However, suppliers located in developing countries can offer a better flexibility/cost ratio owing to less restrictive environmental regulations, lower site costs, accessibility to certain

natural resources, and lower wages (Prasad and Babbar, 2000). To summarize, there is not a unique way to increase supply flexibility.

Interestingly, the analysis of the different approaches to increment supply flexibility has deserved little attention so far in the literature. Previous studies have focused on the assessment of flexibility and its impact on performance (Zhang *et al.*, 2002; Pujawan, 2004; Swafford *et al.*, 2006) and not on the different strategies that firms use to achieve it. The characterization of different strategies as sets of managerial practices has been largely used in OM (e.g. Cagliano *et al.*, 2003; Caniato *et al.*, 2004). A similar approach can be used to contrast alternative supply flexibility strategies, as it was done for manufacturing flexibility by Miller and Roth (1994). In fact, previous studies (e.g. Prater *et al.*, 2001) suggest that some sourcing practices are often used jointly to increase flexibility (e.g. firms employing JIT purchasing tend to rely more on supplier collaboration initiatives and domestic sourcing, and less on inventory buffers (Womack *et al.*, 1990)).

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

1. How are the sourcing practices combined to form particular supply flexibility strategies?
2. How do these strategies differ with respect to the level of supply flexibility achieved?
3. Are there any environmental variables that could explain why firms are driven to a certain strategy?

Our contribution to the literature will be to provide a taxonomy of supply flexibility strategies, and to compare these different approaches with respect to context and environmental variables. In the next section, we review previous studies on supply flexibility.

3.2 Literature review

3.2.1 Supply flexibility

There is no universally accepted definition of supply flexibility. Researchers have proposed several constructs to represent the flexibility in the upstream side of the supply chain, referring to it as purchasing, sourcing or supply flexibility. Porter (1985) and Zhang *et al.* (2002) defined 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”. Similarly, Duclos *et al.* (2003) defined supply flexibility as “the ability to meet the changing needs of customers, changing the supply of product, including mix, volume, product variations and new products”. However, all these studies were theoretical, i.e. there was neither empirical data nor a methodology to measure flexibility. Furthermore, all of them highlighted the need for empirical cross-industry studies that could give deeper insights into what constitutes flexibility in different industries.

Pujawan (2004) suggested a methodology to assess supply flexibility, based on the manufacturing flexibility framework. Accordingly, the measurement items encompassed supplier responsiveness (e.g. availability of urgent delivery requests option), inbound logistics (e.g. the possibility of mixing different items into a delivery load) and sourcing policy (e.g. number of suppliers per item). Nevertheless, the methodology had some clear limitations. First, there was an overlap between some flexibility assessment items and sourcing practices (e.g. multiple modes of transportation). As a practical implication, it would hinder the analysis of the effect of sourcing practices (e.g. multiple modes of transportation) on supply flexibility. Moreover, flexibility was assessed at firm level, thus it was rather difficult to gather information regarding different sourcing strategies for different products.

Swafford *et al.* (2006) were the first to develop and test a scale that measured flexibility in the upstream part of the supply chain. Accordingly, they defined sourcing flexibility 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”. The measurement items encompassed not only questions related to flexibility performance (e.g. the extent to which supplier lead-time can be expedited), but also the range of flexibility options (e.g. the extent of flexibility options within supplier contracts, number of suppliers, etc).

Comparing previous definitions, their limitations can be summarized as follows:

- First, there is an overlap between flexibility assessment items and sourcing practices (e.g. the use of flexible contracts could be both a flexibility item and a sourcing practice). This makes it difficult to carry out empirical studies; more specifically those aiming to contrast managerial practices and flexibility (e.g. Jack and Raturi, 2002).

- More importantly, their scope of analysis encompasses the whole set of components that a firm purchases. Accordingly, they do not consider the fact that different purchased components may require different levels of supply flexibility and thus different sourcing strategies (Virolainen, 1998). Similarly, Lee (2004) claims that the level of required flexibility should be met not at a company level, but at a brand level.

In this study, supply flexibility is 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 (Upton, 1994; Duclos *et al.*, 2003). We now discuss how this definition can overcome the aforementioned limitations. It differs from previous definitions in two aspects: (1) Measurement items that coincided with flexibility sources (e.g. flexible contracts) were not included in the supply flexibility measures. The reason is that, as mentioned before, previous approaches mixed the measurement of flexibility and its potential sources (e.g. Swafford *et al.*, 2006). (2) Flexibility is assessed at the component level, not at the firm level. Thus, in order to gather richer information, respondents were asked to take into consideration the purchased component that required the highest level of supply flexibility in their firm.

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

3.2.2 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. For example, a supply flexibility source could be the practice of establishing single-sourcing contracts with co-located key suppliers. Several authors have analysed the impact of specific sourcing practices on supply flexibility, as can be appreciated in Table 1. Nevertheless, there is a lack of studies that depict how these various practices combine to increase supply flexibility.

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

In this study, we also analyse some context variables (i.e. flexibility focus, environmental uncertainty and switching costs) that may explain why firms are driven to a certain flexibility strategy. In sections 2.3, 2.4 and 2.5 the literature concerning these concepts is briefly reviewed.

3.2.3 Flexibility focus

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

3.2.4 Environmental uncertainty

Another type of variable that may explain why a firm is driven to a certain flexibility strategy is the environmental uncertainty. Although there is a general agreement that flexibility may be interpreted as a response to environmental uncertainty (Gerwin, 1993; Upton, 1994), there are few studies analysing the relationship between both variables (e.g. Swamidass and Newell, 1987; Sawhney, 2006).

Davis (1993) identifies three sources of supply chain uncertainty: suppliers, manufacturing and customers. Chen and Paulraj (2004) argued that from the procurement viewpoint there are three main types of uncertainty: supply (e.g. deliveries from suppliers), demand (e.g. MPS schedule changes and final demand fluctuations) and technology (e.g. rate of process obsolescence and technology change). Similar approaches were used on subsequent studies in the supply chain management area (Lee, 2002; Fynes *et al.*, 2004).

However, the focus on the sources of uncertainty is not the only characterization approach. For example, supply chain uncertainty can also be studied based on its dimensions. Das and Abdel-Malek (2003) categorize four dimensions of supply chain uncertainty: Product mix, sales quantities, order delivery time and design changes. Those categories correspond to the four first-order flexibility dimensions proposed by Suarez *et al.* (1996) and Beamon (1999), based on Slack (1991). Similarly, Van der Vaart and Van Donk (2004) distinguish three dimensions of uncertainty in the buyer-supplier interface: volume, mix and delivery/lead-time. These studies provided the basis to the environment uncertainty items used in this study, which are shown in Table 2.

Finally, one of the most frequent debates concerning environmental uncertainty is the use of perceptual versus objective measures. Several researchers support the use of perceptual measures, because only through managerial perception uncertainty becomes known to the organization (Swamidass and Newell, 1987; Zhang *et al.*, 2002).

Table 2. Environmental uncertainty items

Construct	Item	References
Supply uncertainty	The supplier delivers on the required date.	Add. from Chen and Paulraj, 2004
	The supplier delivers the quantity required.	Add. from Chen and Paulraj, 2004
	The supplier delivers the mix/configuration required.	Add. from Chen and Paulraj, 2004
Demand uncertainty	The volume requirements of this component vary drastically from week to week.	Add. from Chen and Paulraj, 2004
	The configuration / mix of this component fluctuates drastically from week to week.	Add. from Chen and Paulraj, 2004
	The required leadtime for this component fluctuates drastically from week to week.	Add. from Chen and Paulraj, 2004
Technology uncertainty	Our industry is characterized by rapidly changing technology.	Slater and Narver, 1994; Fynes <i>et al.</i> , 2004; Chen and Paulraj, 2004
	Technological changes provide considerable opportunities in our industry.	Slater and Narver, 1994; Fynes <i>et al.</i> , 2004
	It is very hard to predict where will be the technology in 3-5 years.	Slater and Narver, 1994; Fynes <i>et al.</i> , 2004

3.2.5 Switching costs

Another variable that may explain why a firm is driven to a certain flexibility strategy is the supplier switching cost. In this study, we consider the general term switching costs as the costs of searching, developing and changing suppliers (Bakos and Treacy, 1986; Grover and Malhotra, 2003).

Switching costs may affect the supply flexibility strategy through the decision about single or multiple sourcing (Minner, 2003). High switching costs are usually associated to single sourcing. Conversely, low switching costs are considered to be an incentive to multiple sourcing (De Toni and Nassimbeni, 1999; Minner, 2003). Moreover, the searching costs may affect indirectly other flexibility sources, e.g. supplier integration and long-term relationships: high searching costs may be an incentive to establish long-term relationships with key suppliers and high levels of collaboration initiatives (De Toni and Nassimbeni, 1999).

Many studies agree that switching costs can be estimated using the concept of asset specificity (Bensaou and Venkatraman, 1995; Bensaou, 1999; Grover and Malhotra, 2003). High asset specificity increases switching costs whereas low asset specificity lowers them (Minner, 2003). An asset is specific if its value is significantly

lower if used outside the current contractual relationship (Grover and Malhotra, 2003). There are some distinct views regarding the dimensions used to measure asset specificity: From an Industrial Organization perspective, Stuckey and White (1993) classify asset specificity into site, technical and human specificities. Grover and Malhotra (2003), following an Operations Management approach, claim that the most important asset specificities are physical (e.g. equipment, tools) and human (e.g. training). They also refer to procedural specificity, “whereby firms develop processes that are unique to the relationship and which may require learning time if developed with other suppliers”. Despite all these possibilities, asset specificity has been measured in the OM literature considering mainly human and procedural dimensions (e.g. Bensaou and Venkatraman, 1995). The reason is that scales for other types of asset specificity (e.g. physical asset specificity) are less available, due to the difficulty associated with its measurement (Grover and Malhotra, 2003). Taking this into consideration, the following searching and switching costs measurement items were proposed (see Table 3):

Table 3. Switching costs items

Construct	Item	References
Switching costs	It is difficult to identify a certified supplier to supply this component.	Bakos and Treacy, 1986
	It is difficult to establish the contractual details of the relationship.	Grover and Malhotra, 2003
	We made major specific investments specifically for the relationship with this supplier (in tooling, or tailoring products to using this supplier’s component).	Bensaou and Venkatraman, 1995
	It takes time and effort to learn the specific processes of each supplier.	Bensaou and Venkatraman, 1995
	It takes time and effort to develop the relationship with each supplier.	Bensaou and Venkatraman, 1995

3.3 Model development

Based on the research gaps identified, the following research questions are proposed:

1. How are the sourcing practices combined to form particular supply flexibility strategies?
2. How do these strategies differ with respect to the level of supply flexibility achieved?
3. Are there any environmental variables that could explain why firms are driven to a certain strategy?

Figure 1 depicts the research framework of the study.

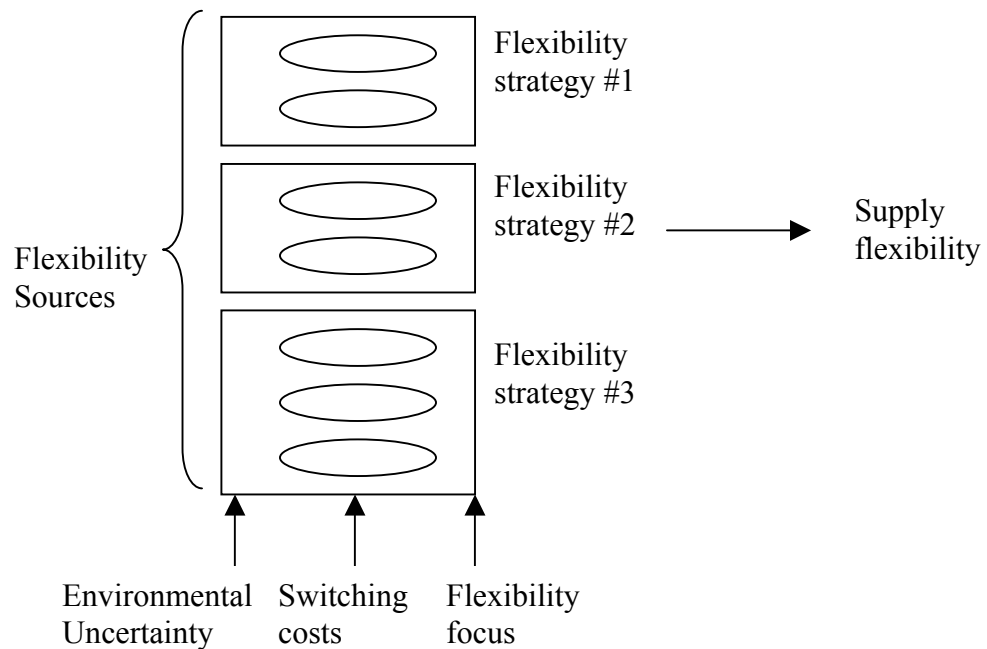


Figure 1. Research framework

3.4 Methodology

3.4.1 The instrument

The questionnaire used in the survey was elaborated based on the literature review. The first concern was the content validity of the questionnaire items, i.e. the extent to which they cover adequately the construct domain being measured (Churchill, 1979). Prior to data collection, content validity was assessed grounding the questionnaire items on previous studies and using pre-tests with purchasing managers and researchers. These

experts were asked to review the questionnaire for structure, readability, ambiguity and completeness (Dillman, 1978). The final survey instrument incorporated some minor changes to improve the understanding of the questionnaire items. The final questionnaire items, using a 10-point scale, can be seen in the Appendix A.

3.4.2 Sampling

An online survey was used for the data collection. The target sample frame consisted of members of the Spanish Association of Purchasing Managers (AERCE). The 1,504 members of AERCE received an email in which they were asked to answer the survey in the indicated web page. After two weeks, a new email was sent to remind those members that did not answer the survey. A total of 100 answers were received. The “not flexibility-focused” firms (i.e. “flexibility focus” less or equal than 5) were excluded from the study, in order to depict more precisely the different supply flexibility strategies. After the deletion of cases with missing data and not flexibility-focused firms, the total sample size was reduced to 77 firms, resulting in a response rate of 5.1%. This somewhat low response rate may be related to the length and comprehensive nature of the questionnaire as well as the web-based data collection methodology. 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). Furthermore, the confidential nature of the information requested was an issue. Anonymity was guaranteed, but it is likely that some executives doubted this assurance, particularly considering the fact that it was an Internet-based survey. Also, senior executives have little free time and usually are overwhelmed with surveys. Moreover, a demonstrated lack of response bias is far more important than a high response rate (Babbie, 1990). Accordingly, non-response bias was checked by comparing early and late respondents, using t-tests (Hair *et al.*, 1998). More specifically, the first 30 received surveys and the last 30 received surveys were compared, using 10 randomly selected variables. Results showed no significant difference between both groups, suggesting that non-response bias is not an issue. These results suggested that the sample is adequate to make inferences about the considered population. Finally, several studies claim that there is no generally accepted minimum response rate (Fowler, 1993; Prater and Ghosh, 2006). Thus, we consider that the 77 usable responses provide sufficient data to achieve meaningful research conclusions.

The industry and size distribution of the sample can be seen in Table 4.

Table 4. 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		

3.5 Data analysis

3.5.1 Tests for scale validity and reliability

Exploratory factor analysis was used to identify the main underlying dimensions of supply flexibility. This analysis was also performed for the environmental items.

Construct validity is the extent to which the items in a scale measure the theoretical or abstract construct (Churchill, 1987). In this study, construct validity was assessed using exploratory factor analysis. A construct was considered to have validity if it presented an eigenvalue greater than 1 (Hair *et al.*, 1998). In order to consider both convergent and discriminant validity, only items that had a factor loading of at least 0.50 and did not have a loading in excess of 0.40 on a second factor were retained (Bagozzi and Yi, 1988).

Reliability was assessed using Cronbach's alpha, which indicates how well a set of items measures a single one-dimensional latent construct values. Typically, reliability coefficients of 0.70 are considered adequate, but most researchers consider 0.60 as a practical cut-off criterion (Swafford *et al.*, 2006; Chen and Paulraj, 2004).

Supply flexibility

Table 5 presents the final factor loadings of the supply flexibility retained items and their underlying factors. The Kaiser-Meyer-Olkin test of sampling adequacy (KMO = 0.531) and the Bartlett's test of sphericity (significance = 0.000) were within the generally accepted criteria for factor analysis utilization (Malhotra, 1996). Results indicated that construct reliabilities were adequate: Cronbach's alpha was at least 0.608 for all dimensions of supply flexibility (see Table 5).

Table 5. 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. χ^2	99.537	
	d.f.	21	
	Sig.	0.000	
Supply flexibility items	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) ^a			
Cost / time needed to change the quantity ordered (FLEX8) ^a			
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.

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

Results of the factor analysis suggested three underlying dimensions of supply flexibility: delivery policy (FLEX 1 and FLEX2), supplier responsiveness (FLEX3 and FLEX4) and adaptability (FLEX6, FLEX7 and FLEX9).

The *delivery policy* dimension is the ability of changing delivery lot sizes and frequencies. In JIT purchasing, small lot sizes and frequent deliveries are usually associated (e.g. Womack *et al.*, 1990; Ponce and Prida, 2004).

Supplier responsiveness corresponds to the ability of influencing suppliers' short-term capacity and delivery lead-time. It is viewed by Choi and Krause (2006) as "the degree of promptness and accuracy of the supplier's response to the focal company's request for new requirements". It is also similar to the concept of supplier's short-term process flexibility (Krajewski *et al.*, 2005), which encompasses supplier's capacity slack and expediting efficiency (i.e. the capability to expedite batches of product at low cost).

Adaptability is the time or cost necessary to change the specification of components, implement supplier engineering change orders or alter suppliers' short-term capacity. This is consistent 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 somewhat from previous studies (e.g. Swafford *et al.*, 2006). The main difference is the subdivision of the "range" dimension of supply flexibility (Swafford *et al.*, 2006) into two dimensions (i.e. supplier responsiveness and delivery policy). The "adaptability" dimension is similar to previous studies (Swafford *et al.*, 2006; Swafford *et al.*, 2006b).

Environmental constructs

A factor analysis of the environmental variables (uncertainty and switching costs) was also performed. The objective in this case was to delineate constructs that could help understand why firms are driven to a certain strategy. The results suggested four environmental constructs: supply uncertainty, demand uncertainty, technological uncertainty and switching costs (see Table 6).

Table 6. Environmental constructs: reliability and convergent validity

KMO and Bartlett's test				
Kaiser-Meyer-Olkin measure of sampling adequacy	0.599			
Bartlett's test of sphericity	Approx. χ^2	262.486		
	d.f.	55		
	Sig.	0.000		
Variables	Factor 1 Supply uncertainty	Factor 2 Demand uncertainty	Factor 3 Technological uncertainty	Factor 4 Switching costs
The supplier delivers on the required date.	0.855	-0.076	-0.042	0.117
The supplier delivers the quantity required.	0.877	0.039	0.006	0.158
The supplier delivers the mix/configuration required.	0.775	0.034	0.075	-0.149
The volume requirements of this component vary drastically from week to week.	-0.178	0.747	0.004	0.193
The required leadtime for this component fluctuates drastically from week to week.	0.169	0.821	0.105	0.062
The configuration / mix of this component fluctuates drastically from week to week. ^a				
Our industry is characterized by rapidly changing technology.	0.089	0.148	0.923	0.041
Technological changes provide considerable opportunities in our industry.	-0.060	-0.030	0.937	0.086
It is very hard to predict where will be the technology in 3-5 years. ^a				
It is difficult to identify a certified supplier to supply this component.	0.111	0.129	0.002	0.704
It is difficult to establish the contractual details of the relationship.	0.285	-0.053	0.234	0.683
It takes time and effort to learn the specific processes of each supplier.	-0.004	0.144	0.152	0.769
It takes time and effort to develop the relationship with each supplier.	-0.234	0.095	-0.185	0.651
We made major specific investments specifically for the relationship with this supplier (in tooling, on tailoring products to using this supplier's component). ^a				
Eigenvalue	2.650	1.114	1.688	2.132
Explained variance (%)	24.088	10.124	15.343	19.380
Cronbach's alpha	0.808	0.441	0.877	0.679

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

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

Reliabilities were adequate for supply uncertainty ($\alpha = 0.808$), technological uncertainty ($\alpha = 0.877$) and switching costs constructs ($\alpha = 0.679$), but below the usual cut-off of 0.60 for the demand uncertainty ($\alpha = 0.441$). However, Van de Venn and Ferry (1980) state that acceptable values may be as low as 0.40 for broadly defined constructs (Swafford *et al.*, 2006). This is the case of demand uncertainty, since three dimensions of demand uncertainty (i.e. mix, volume and delivery) were included in this construct. In general, results of the factor analysis for environmental constructs are similar to previous studies (e.g. Chen and Paulraj, 2004; Fynes *et al.*, 2004).

3.5.2 Cluster analysis

Cluster analysis to identify sub-groups

The review of the literature suggested that supply flexibility sources are deployed following certain patterns (e.g. JIT sourcing). In order to investigate these patterns, a two-stage cluster analysis was performed, following the approach of previous OM studies (Miller and Roth, 1994; Narasimhan *et al.*, 2006). This two-stage approach is recommended because it combines the strengths of the K-means procedure and the hierarchical method. The K-means method is robust to the presence of outliers, errors of the distance metrics, and the selection of a distance metric. However, the performance of the K-means method depends on the adequate choice of the initial cluster seeds. Thus, the use of a hierarchical method to establish the number of clusters and the starting cluster seeds for subsequent refinement through the K-means method is recommended (Punj and Stewart, 1983).

The cluster analysis procedure is now detailed. First, a hierarchical cluster analysis using Ward's method and the squared euclidian distance metric was performed. Ward's method was selected because of its robustness, its ability to maximize within-cluster homogeneity and between-cluster heterogeneity, and its ability to retrieve known cluster structure (Aldenderfer and Blashfield, 1984). The squared euclidean distance, combined with Ward's method, leads to clusters with the smallest sum of squares errors (Arabie and Huber, 1994). In order to refine the clusters, a K-means clustering procedure was used, establishing as initial seeds the hierarchical cluster centroids. To avoid problems of multicollinearity, the variable SRC4 (joint product development) was dropped, because it had a moderate Pearson correlation with SRC3 (supplier integration, $r = 0.656$) and with SRC11 (internal integration, $r = 0.438$). All the other correlations among sources were smaller than these values (see correlation table in the Appendix B).

Although SRC 3 (“supplier integration”) and SRC 11 (“internal integration”) also presented a moderate correlation coefficient ($r = 0.434$), both variables were maintained, because the distinction between internal and supplier integration is conceptually important in this study.

Two criteria were used to determine the number of clusters. First, Lehmann’s (1979) suggestion that the number of clusters should range from $n/30$ to $n/60$, where n is the sample size, was considered. Based on this criterion, the two-group and three-group cluster solutions should be investigated. Second, the % change in the agglomeration index (see Table 7) was analysed. Although the two-group solution presented a higher % change in the agglomeration index, it did not provide sufficient detail to a proper characterization of the distinct groups, so the three-group solution seemed to be a more consistent alternative. Moreover, the use of agglomeration as a stopping rule has the tendency to indicate too few clusters (Hair *et al.*, 1998). Therefore, the three-group solution was selected. Clusters descriptions can be seen in Table 8.

Table 7. Cluster analysis agglomeration coefficients

Number of clusters	Agglomeration coefficient	% change
8	3185	6%
7	3365	8%
6	3629	8%
5	3909	8%
4	4228	9%
3	4603	10%
2	5053	15%
1	5817	-

Cluster validation

The final cluster solution was validated with discriminant analysis, using the flexibility sources as independent variables and group membership as criterion variables. Only the sources that presented a significant difference among the groups (according to the ANOVA results) were considered in the discriminant analysis. Thus, the following sources were eliminated from the discriminant analysis: multiple sourcing, long-term relationships with suppliers, e-marketplaces and inventory buffers.

Next, the classification indexes for two types of analysis were examined. First, discriminant analysis was performed using the entire sample data set to predict

membership in the clusters. In this analysis, 94.8% of the cases were correctly classified. The second analysis was cross-validation, in which each case is classified by the functions derived from all cases other than that case. In this analysis, 92.2 % of the cases were correctly classified. These results suggest a satisfactory predictive validity. In the next section, the different groups suggested by the cluster analysis are interpreted.

Interpreting the clusters

The distinct groups were named based on two criteria: first, the multiple comparison tests of the scores between groups; second, the relative ranking of sources within a cluster. Where statistically significant effects were found (i.e. $p < 0.05$), a comparison of means with Scheffe post hoc multiple comparison tests was executed. In addition, when variables did not comply with Levene's test of variance homogeneity, the Tamhane post hoc multiple comparisons test was used instead of the Scheffe test (Hochberg and Tamhane, 1987). As a result, we have labelled the groups "integrated", "domestic" and "offshore".

Cluster 1: "Integrated". This is the most numerous group, with 35 respondents. It presents higher scores than the other groups for the "integration" variables (i.e. supplier integration, logistics provider integration, internal integration and electronic integration). Additionally, it ranks first in domestic sourcing, which can be interpreted as a sort of physical integration. This suggests that this group achieves flexibility by collaborating with supply chain partners, through exchange of information, joint planning of activities, cross-functional teams, etc. In addition, this collaboration is supported by the suppliers' proximity. Furthermore, this group presents the highest scores for supplier selection, indicating that suppliers are selected based on their flexibility (i.e. considering not only cost, but also their responsiveness level and production capacity). Another significant source of flexibility in this group is the use of flexible contracts, which suggests a high level of process coordination with key suppliers and complements the aforementioned collaboration initiatives.

Cluster 2. "Domestic". There are 24 firms in this group. This "domestic" cluster is well ranked in domestic sourcing and supplier selection: scores for these variables were higher than the "offshore" group and equivalent to the "integrated" group. This suggests that, like the "integrated" cluster, the "domestic" strategy achieves flexibility by carefully selecting their suppliers, based on criteria such as proximity and responsiveness. Nevertheless, the level of integration with supply chain partners is not

so important, when compared to the “integrated” group. This suggests little emphasis on supply chain coordination. Instead, firms tend to rely on initiatives *before* starting a relationship with a specific supplier (e.g. supplier selection based on proximity and flexibility) to increase flexibility.

Cluster 3. “Offshore”. The 18 firms in this group present higher scores than the “integrated” and “domestic” groups for alternative transportation modes and integration with the logistics provider. Additionally, this group presents the lowest score for domestic sourcing, for which it was labelled “offshore”. The use of overseas suppliers in this group increases the need of an integrated and reliable inbound logistical process. This group also presents a higher score for flexible contracts and electronic integration, when compared to the “domestic” strategy. This suggests more emphasis on coordinating the upstream supply chain, rather than merely selecting the “right” suppliers (as in the “domestic” group). When compared to the “integrated” group, the “offshore” group presents a lower score for both supplier and internal integration. This suggests that integration is not focused on behavioural-based collaboration (e.g. cross-functional teams), but rather on information technology and logistical infrastructure. Interestingly, inventory buffers are the second highest ranked source (after long-term relationships). This is coherent with the use of overseas suppliers: firms need to build buffers to decouple production from uncertainty derived from the logistical channels.

Furthermore, it can be seen that some sources (multiple sourcing, long-term relationships, e-marketplaces and inventory buffers) present no statistically significant differences among the three groups. It is interesting to observe that all groups rely heavily on long-term relationships to achieve flexibility (the lowest group average is 8.5). However, the use of e-marketplaces is very low in all groups (the maximum group average is 3.5).

Table 8. Flexibility sources by group

Flexibility sources	Group 1: “Integrated” (n=35)	Group 2: “Domestic” (n=24)	Group 3: “Offshore” (n=18)	F-value (significance)***
Multiple sourcing	2.66	2.71	3.61*	1.500 (0.230)
Domestic sourcing	8.83 (3)**	8.29 (3)	3.56 (1,2)	40.197 (0.000)
Supplier integration	8.14 (2,3)	6.21 (1)	5.89 (1)	9.653 (0.000)
Supplier selection	7.63 (3)	6.92	6.06 (1)	4.888 (0.010)
Flexible supply contracts	7.97 (2)	4.54 (1,3)	6.39 (2)	15.187 (0.000)
Long-term relationships with suppliers	9.06	8.67	8.50	1.325 (0.272)
Third-party logistics providers	6.00 (2)	2.71 (1,3)	6.33 (2)	14.592 (0.000)
Alternative transportation modes	3.57 (3)	2.75 (3)	5.78 (1,2)	7.794 (0.001)
E-marketplaces	2.43	2.08	3.50	2.440 (0.094)
Internal integration	8.51 (2,3)	6.79 (1)	6.39 (1)	6.751 (0.002)
Electronic integration	6.66 (2)	1.71 (1,3)	5.50 (2)	31.808 (0.000)
Inventory buffers	7.17	6.46	7.22	0.519 (0.597)

*Numbers in **bold** indicate the highest group centroid for that measure.

**The numbers in parenthesis indicate the group numbers from which this group was significantly different at the 0.05 level as indicated by the pair wise comparison test.

***The observed F-statistics were derived from one-way ANOVAs and the p-values are associated with the observed F-statistics.

Next, a canonical discriminant analysis was performed in order to help interpreting the results of the cluster analysis (Miller and Roth, 1994; Narasimhan *et al.*, 2006). The results of the canonical discriminant analysis can be seen in Table 9. Two significant canonical functions were obtained, which retain 64.4% and 35.5% of the variance, respectively. Both discriminant functions were significant ($p = 0.000$), as measured by the Wilk’s lambda and chi-square statistics.

In order to interpret the canonical functions, the discriminant loadings were analysed. Discriminant loadings measure the linear correlation between each independent variable and the extracted canonical function (Hair *et al.*, 1998). They are considered to be equivalent to factor loadings, and represent the relative contribution of each variable to the discriminant function (Dillon and Goldstein, 1984). While there are no rigid rules about cut-off values, the usual guideline is that loading values above 0.30 are considered acceptable (Hair *et al.*, 1998). Results suggest that the first function is correlated with “electronic integration” and “logistics provider integration”. Thus, this function was labelled “logistics optimisation”. The second function is correlated with “domestic sourcing”, “supplier integration”, “flexible contracts” and “internal integration”. Accordingly, this function was labelled “integration”.

Table 9. Results of canonical discriminant analysis

Canonical function	Eigenvalue	Canonical correlation	Significance of canonical correlation	Squared canonical correlation
1	2.699	0.854	0.000	0.73
2	1.491	0.774	0.000	0.60
Predictor set	Canonical loadings		Canonical coefficients	
	Function 1 “Logistics optimisation”	Function 2 “Integration”	Function 1 “Logistics optimisation”	Function 2 “Integration”
Electronic integration	0.499	0.355	-0.574	0.668
Third-party logistics providers	0.375	0.098	0.016	0.354
Alternative transportation modes	0.231	-0.212	0.045	0.159
Domestic sourcing	-0.337	0.742	0.386	0.262
Supplier integration	0.084	0.403	0.542	0.035
Flexible supply contracts	0.296	0.342	0.394	-0.301
Internal integration	0.060	0.340	0.070	0.104
Supplier selection	-0.031	0.294	0.790	0.346

Bold numbers indicate high loadings in canonical functions (+/- 0.30).

Figure 2 depicts the supply flexibility clusters against the scores for the two canonical functions: “logistics optimisation” and “integration”. The numbers on the plot

indicate the cluster membership (1 = “integrated”, 2 = “domestic”, and 3 = “offshore”). The discriminant functions plot graphically illustrates the canonical functions, and suggests a distinct clustering of the firms’ scores.

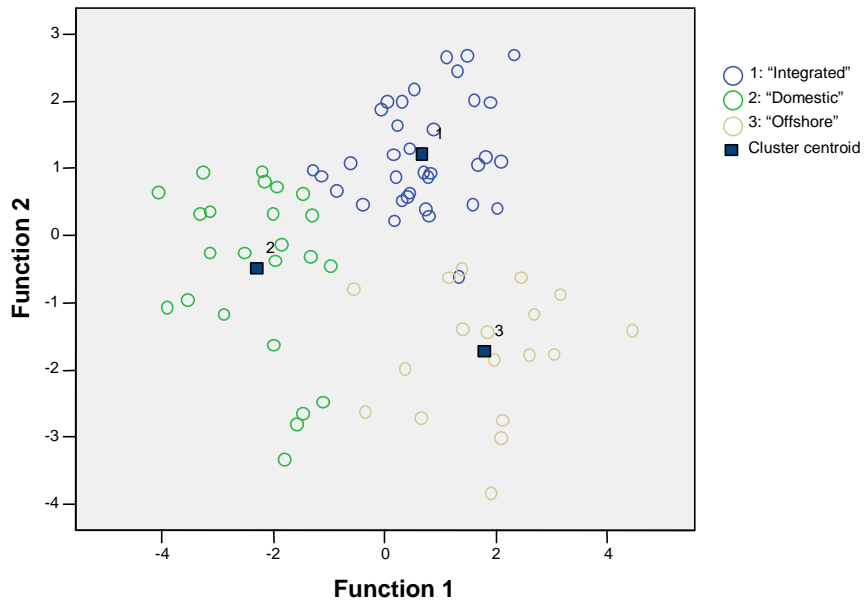


Figure 2. Discriminant functions plot

Overall, Figure 2 suggests that:

1. The “integrated” and “offshore” clusters present a higher score in the “logistics optimisation” function, when compared to the “domestic” cluster.
2. However, the “integrated” and “offshore” clusters differ with respect to the “integration” function: the “offshore” group is significantly less “integrated”.
3. The “integration” scores of the “domestic” cluster are in an intermediary level between the other clusters.

These results corroborate the previous comparison of cluster centroids. Additionally, the canonical functions plot depicts concisely the differences between the “integrated”, “domestic” and “offshore” groups. However, in order to assure validity, it is recommended to compare the clusters using additional variables (Narasimhan *et al.*, 2006). In the next section, the clusters are contrasted with respect to some context variables.

Clusters profiles

In order to further characterize the distinct clusters, ANOVA and post hoc multiple comparisons tests of group means differences were performed. Two types of constructs were used: *causes*, i.e. constructs that could explain why firms choose a specific strategy (switching costs; demand, supply and technology uncertainty) and *effects*, i.e. the different dimensions of supply flexibility (adaptability, delivery policy and supplier responsiveness). Results can be appreciated in Table 10.

Significant differences were found among the groups with respect to revenue, supply uncertainty and supplier responsiveness. The multiple comparisons test suggested that: (1) The “integrated” group presents higher revenue than the “domestic” group. This can be explained by the higher level of resources needed to invest in integration initiatives (e.g. EDI, ERP). (2) The “integrated” group presents higher supplier responsiveness than the “offshore” group. Moreover, results suggest (at the 10.3% level) that this group presents higher delivery policy score than the other groups. (3) Although the pairwise comparisons tests were not conclusive, the ANOVA suggests that the “offshore” group presents higher supply uncertainty than the “integrated” and “domestic” groups. Apparently, this high supply uncertainty might explain why inventory buffers are so important to the “offshore” strategy (average score = 7.22). Interestingly, no significant difference between demand uncertainty levels for each group was detected. When considering the demand uncertainty items (i.e. volume, mix and delivery uncertainty) without being aggregated in a common factor called “demand uncertainty”, no difference was detected among the groups. A possible interpretation is that the strategies identified apply equally to several dimensions of demand uncertainty. Nevertheless, we believe these results still need to be contrasted with further studies.

Table 10. Context / environmental variables by group

Context / Environmental variable	Group 1: "Integrated" (n=35)	Group 2: "Domestic" (n=24)	Group 3: "Offshore" (n=18)	F-value (significance) ***
Revenue	3.37* (2)**	2.54 (1)	2.83	5.276 (0.007)
Flexibility focus	8.09	7.92	8.28	0.528 (0.592)
Switching costs	6.29	5.79	6.64	2.112 (0.128)
Demand uncertainty	4.89	5.44	5.03	0.560 (0.573)
Supply uncertainty	2.42	2.81	3.37	3.294 (0.043)
Technology uncertainty	5.43	4.90	5.42	0.508 (0.604)
Delivery policy	6.13	5.12	5.06	2.343 (0.103)
Adaptability	5.51	4.82	5.70	1.442 (0.243)
Supplier responsiveness	6.40 (3)	5.69	4.75 (1)	4.715 (0.012)

*Numbers in **bold** indicate the highest group centroid for that measure.

**The numbers in parenthesis indicate the group numbers from which this group was significantly different at the 0.05 level as indicated by the pair wise comparison test.

***The observed F-statistics were derived from one-way ANOVAs and the p-values are associated with the observed F-statistics.

Additionally, chi-square tests were used to analyze the clusters distribution across the industrial sectors. The industrial classification used was equivalent to previous OM studies (Miller and Roth, 1994; Narasimhan *et al.*, 2006), i.e. based on the aggregation of the three-digit Standard Industrial Classification (SIC) codes. Accordingly, firms were segmented in the following categories: electronics, machinery (machine tools, transportation equipments, and machinery groups), industrial (parts, components, and intermediate goods producer), basic (chemical, paper, and primary metals) and consumer (foods, cosmetics, and pharmaceutical).

Results suggest that the distribution of clusters across the industrial sectors is not homogeneous (see Table 11). In particular, there is a concentration of "integrated" strategies in the "basic" and "consumer" sectors. "Domestic" strategies, alternatively,

are more likely to belong to the “consumer” sector. Finally, “offshore” strategies are predominant in the “electronics” and “machinery” sectors.

Table 11. Industry representation by groups (Number of Respondents)

	Integrated	Domestic	Offshore	Total (%)
Consumer				
Count	6	6	0	12 (15.6)
Expected	5.5	3.7	2.8	
Industrial				
Count	1	1	0	2 (2.6)
Expected	0.9	0.6	0.5	
Basic				
Count	14	4	6	24 (31.2)
Expected	10.9	7.5	5.6	
Machinery				
Count	6	3	6	15 (19.5)
Expected	6.8	4.7	3.5	
Electronics				
Count	4	1	5	10 (13.0)
Expected	4.5	3.1	2.3	
Not informed				
Count	4	9	1	14 (18.2)
Total (%)				
	35 (45.5)	24 (31.2)	18 (23.4)	77 (100)
Chi-square = 21.841 d.f. = 10 p = 0.016				

3.6 Discussion

“Integrated” cluster. The most significant characteristic of this group is a high score for the “integration” variables (supplier, internal, electronic and logistics provider integration). Interestingly, this coincides with the dimensions of supply chain integration identified by Narasimhan and Das (2001). Most of these dimensions of integration are interrelated, as shown next. Moreover, this strategy resembles the “improved supplier responsiveness” alternative described in the exploratory study of chapter two, which was based on single sourcing, a high level of internal and external integration, co-location of suppliers and supplier selection.

The combination of high scores for supplier and internal integration coincides with previous studies on integration. Internal and external integration are often associated (Stank *et al.*, 2001; Gimenez and Ventura, 2005). Before external integration, the purchasing department must engage in internal integration initiatives to guarantee

the strategic relevance of purchasing actions with the supply base (Das *et al.*, 2006). For example, a large part of the success of the “Toyota production system” can be attributed to the considerable role of purchasing in first understanding and formulating Toyota’s production philosophy, before expanding it to Toyota’s primary supply base (Hines, 1996).

Additionally, the high scores for electronic and supplier integration concur with previous studies. As the level of transaction-specific investments in electronic integration with suppliers (e.g. EDI) increases, the supplier switching costs increase (Saeed *et al.*, 2005). Consequently, there is an incentive for buyers to engage in supplier development initiatives (Krause *et al.*, 2001). Also, some researchers have demonstrated that IT can decrease coordination costs (Clemons *et al.*, 1993; Clemons and Row, 1992), and therefore, it is expected to bring about increased coordination (Vickery *et al.*, 2003). Sanders and Premus (2005) found that electronic integration has a significant impact on supply chain collaboration.

In addition, this group is notably well ranked in the use of flexible contracts. This is in accordance with the findings from Van der Vaart and Van Donk (2004), who claim that supply contracts with quantity flexibility clauses facilitate close co-ordination in buyer-supplier relationships. Flexible contracts are also associated to high levels of supplier responsiveness (Krajewski *et al.*, 2005). This coincides with the higher group average for supplier responsiveness, when compared to the “domestic” and “offshore” groups.

Lastly, the relationship between supplier selection and internal integration is well described in the literature (Narasimhan *et al.*, 2001; Pagell, 2004). In order to carefully select suppliers according to multiple criteria, coordination and exchange of information between the several departments is crucial, concerning both supplier performance and the needs of the different departments.

“Offshore” cluster. This group can be characterized by its reliance on overseas supply. It presents some points in common with the “flexible sourcing” strategy described in chapter two (lower supplier responsiveness and less domestic sourcing).

Although usually associated to low-cost motivations, offshore supply may also be a source of flexibility. Prasad and Babbar (2000) argue that suppliers located in developing countries can offer a better flexibility/cost ratio (due to less restrictive environmental regulations, lower site costs, accessibility to certain natural resources, and lower wages). Additionally, they have extra financial resources to invest in higher

capacity, due to the lower production costs (Fisher *et al.*, 1997). Finally, worldwide diffusion of information and communication technologies makes firms less dependent on local suppliers (Nassimbeni, 2003, Howard *et al.*, 2006).

Searching for suppliers globally, combined with less supplier integration can be associated to what Chung *et al.* (2004) refer to as the new paradigm of buyer-seller relationships, also called networked enterprise. Since supply sources are equally accessible to all competitors, competitive advantage in the new paradigm consists in taking control of the supply chain and coordinating suppliers so that they connect quickly and smoothly to that model (Chung *et al.*, 2004). In a networked enterprise, temporary supply chains are shaped, operate for the lifetime of the market opportunity, and then break up (Saeed *et al.*, 2005). So, under these conditions, using information systems to closely connect processes may not be adequate (Saeed *et al.*, 2005). Accordingly, the “offshore” group is less electronically integrated than the “integrated” group.

Considering such a dynamic supply architecture, it is interesting to note the high score for “long-term relationships” in this group. A plausible explanation is that, although the buyer firm maintains long-term relationships with several potential suppliers, the decision about which suppliers will be selected for a particular order is made on the short term. An example is Dell, which allocates the orders among a portfolio of established suppliers, based on factors such as supplier’s available capacity on the short term and order characteristics (Ponce and Prida, 2004).

The “offshore” group presents lower supplier responsiveness, compared to the “integrated” group. This can be justified by the reduced level of both supplier integration and flexibility-based supplier selection. Furthermore, the “offshore” group presents a high use of inventory buffers, which corroborates suggestions from previous studies. Offshore supply demands high levels of inventory, in order to compensate the higher risk of supply disruptions (Stratton and Warburton, 2003; Sawhney, 2006).

“Domestic” cluster. This group relies heavily on domestic sourcing and supplier selection to achieve supply flexibility. This is in line with recent empirical studies on industrial clusters. Nassimbeni (2003) shows that the Italian eyewear district emphasizes domestic supply and flexibility-based supplier selection (i.e. based on delivery reliability and volume elasticity). Similarly, the supply chain management literature provides many examples of the association between domestic sourcing and supplier selection based on flexibility (e.g. Stratton and Warburton, 2003; Jin, 2004).

The “domestic” strategy, as the “integrated” strategy, has characteristics of the “improved supplier responsiveness” strategy identified in the first paper of the thesis (domestic sourcing and supplier selection). However, the “domestic” strategy differs from the “integrated” strategy with respect to the integration level (which is lower in the “domestic” strategy). In that sense, the “domestic” strategy could be viewed as a variant of the “improved supplier responsiveness” strategy.

Another significant characteristic of this group is the low level of electronic integration, compared to the “integrated” group. A possible motivation for this is to avoid supplier opportunistic behaviour. In particular, Howard *et al.* (2006) argue that the supplier can act opportunistically when contracts are renewed (by increasing prices or decreasing service levels), if the buyer has assets that are highly specific to that relationship (e.g. inter-organizational systems). Moreover, the need for selecting suppliers based on flexibility is accentuated when information sharing is limited (as it was for the companies in this group), since suppliers do not have adequate visibility to anticipate change (Swafford *et al.*, 2006).

Although this group presents a lower deployment of most sources, it presents a relatively high score for supplier responsiveness. A plausible reason could be the use of *buyer-focused operations*, in which critical resources at the seller’s facilities are singled out to serve a specific buyer (Van der Vaart and Van Donk, 2004). The use of domestic, carefully selected suppliers may be associated to the suppliers’ adoption of buyer-focused operations, e.g. in industrial clusters (Nassimbeni, 2003). This hypothesis could not be confirmed because in this study only the buyer firm’s perspective was analysed. Nevertheless, further research analysing the buyer-supplier dyadic relationships should verify this hypothesis.

Lastly, we have to compare these results with the exploratory study in chapter two, with respect to environmental variables. As can be seen in Table 10, we couldn’t identify significant differences between the three clusters regarding switching costs and demand uncertainty, contrary to what was proposed in the exploratory study. However, we believe further studies with more firms would be required to corroborate this idea.

3.7 Conclusion

This study has some important research implications. First, three strategies to achieve supply flexibility were identified: “integrated”, “offshore”, and “domestic”. Although these approaches imply different sourcing practices, results suggest that integrative practices, in different types (e.g. supplier, internal, logistics provider, electronic, physical, etc) seem to be effective to achieve flexibility in most contexts.

It was also observed that some practices are highly used by firms belonging to all groups: multiple sourcing, long-term relationships with suppliers and inventory buffers. Another point in common among the three groups is that the use of e-marketplaces was not significant: the group averages ranged from 2.43 to 3.50 (in a scale from 1 to 10). This might be explained by the cost-reduction focus (rather than a flexibility emphasis) of e-marketplace initiatives in the studied firms. In further studies, this low utilization of e-marketplaces should be analysed. Interestingly, environmental variables, such as demand uncertainty and switching costs, were similar among groups, suggesting that there might be other variables that explain why a firm is driven to a strategy in particular. The nature and the level of influence of these variables should be investigated in further studies.

These conclusions complement recent studies on sourcing strategy taxonomies. Particularly, they reflect a focus on supply flexibility, whereas previous studies (e.g. Narasimhan *et al.*, 2006) covered simultaneously multiple strategic objectives (cost, quality, flexibility, etc). Considering the supply chain agility literature, our contribution is a quantitatively based taxonomy of the different approaches to flexibility. As mentioned before, most empirical studies on this area are anecdotal (Christopher, 2000; Lee, 2002; Pujawan, 2004) and the few quantitative studies fail to contrast different approaches to flexibility (e.g. Swafford *et al.*, 2006, 2006b). Moreover, this study was more focused, in two ways: first, only critical components (i.e. not the entire set of purchased materials) were analysed. Second, sourcing practices and supply flexibility were clearly differentiated in the data collection instrument, contrary to previous studies.

This study has some important managerial implications. First, there is not a unique approach to achieve supply flexibility, i.e. a firm can rely on different combinations of sourcing practices. Although there is a general agreement about the impact of integrative practices on supply flexibility, which specific dimension of integration should be emphasized depends on the particularities of the firm. Second,

there are some common practices that are highly used by firms, regardless of the selected approach: multiple sourcing, long-term relationships with suppliers and inventory buffers. Finally, results suggest that there are some differences among groups, in terms of flexibility performance. The “integrated” approach seems to be superior to the “domestic” and the “offshore” groups, considering supplier responsiveness. As to the other dimensions (i.e. delivery policy and adaptability), the “integrated” group has superior averages for both (although results are not statistically significant). It would be convenient to perform a similar analysis with a larger sample size, in order to confirm those findings. These results suggest that there are two countervailing forces at work: integration costs and flexibility. The adoption of integrative practices has positive effects over supply flexibility, but they are costly (e.g. EDI, supply chain planning software, dedicated personnel, highly qualified logistics providers, etc). Therefore, if the required flexibility is low, the “domestic” or “offshore” strategies could be possibly preferred, since they provide an acceptable level of flexibility: the investments on integration, in this case, would be less significant than in the “integration” strategy. Interestingly, this coincides with recent studies on integration. In particular, Narasimhan *et al.* (2006) posits that there is a curvilinear relationship between integrative practices and flexibility, implying an “optimal” level of flexibility for each firm.

The limitations of this study should be considered. First, the sample was drawn from a single country, thus in future studies a more geographically diversified sample of firms should be used, since the sourcing strategies can vary significantly across countries. Second, although the statistical procedures suggest sufficient validity, the sample size should be increased in further studies, to improve the generalizability of the results. Third, the use of single informants is a potential source of bias. Accordingly, further studies considering multiple informants would lead to a more complete understanding of the approaches used by firms to increase supply flexibility. Also, researchers should explore other variables that could explain how firms select their supply flexibility approaches. For example, power and dependency have been recently used to explain movements among the Kraljic matrix quadrants (Caniels and Gelderman, 2005), and could also be used to investigate the selection of supply flexibility strategies. And finally, further research should consider the relation between flexibility and corporate social responsibility. Some firms rely on overseas supply as a source of flexibility, and as Simon Hodgson (senior partner at the Acona consultancy)

stated, “many ethical problems are caused by the client’s need for flexibility” (Clarke, 2007).

To summarize, this research supports the notion that there are different strategies to increase supply flexibility. Nevertheless, considerable research efforts are still needed, before arriving at a general understanding of the different paths to achieve supply flexibility.

References

- Aldenderfer, M.S. and Blashfield, R.K. (1984), *Cluster Analysis*, Sage, London.
- Anand, G. and Ward, P.T. (2004), “Fit, flexibility and performance in manufacturing: coping with dynamic environments”, *Production and Operations Management*, Vol. 13 No. 4, pp. 369-385.
- Arabie, P. and Huber, L. (1994), “Cluster analysis in marketing research”. In: Bagozzi, R.P. (Ed.), *Advanced Methods in Marketing Research*, Blackwell, Oxford, pp. 160-189.
- Babbie, E. (1990), *Survey Research Methods*, Wadsworth Publishing Company, Belmont, CA.
- Bagozzi, R.P. and Yi, Y. (1988), “On the evaluation of structural equation models”, *Journal of Academy of Marketing Science*, Vol. 16 No. 1, pp. 74-94.
- Bakos, Y.J. and Treacy, M.E. (1986), “Information technology and corporate strategy: A research perspective”, *MIS Quarterly*, Vol. 10 No. 2, pp. 107-119.
- Beamon, B. (1999), “Measuring supply chain performance”, *International Journal of Operations and Production Management*, Vol. 19 No. 3, pp. 275-292.
- Bensaou, M. (1999), “Portfolios of buyer-supplier relationships”, *Sloan Management Review*, Vol. 40 No. 4, pp. 35-44.
- Bensaou N. and Venkatraman, N. (1995), “Configurations of interorganizational relationships: A comparison between U.S. and Japanese automakers”, *Management Science*, Vol. 41 No. 9, pp. 1474-1492.
- Braunsberger, K., Wybenga, H. and Gates, R. (2007), “A comparison of reliability between telephone and web-based surveys”, *Journal of Business Research*, Vol.60 No.7, pp.758-764.

- Bruce, M., Daly, L. and Towers, N. (2004), "Lean or agile: a solution for supply chain management in the textiles and clothing industry?", *International Journal of Operations and Production Management*, Vol. 24 No. 2, pp. 151-170.
- Cachon, G.P. and Lariviere, M.A. (2001), "Contracting to assure supply: How to share demand forecasts in a supply chain", *Management Science*, Vol. 47 No. 5, pp. 629-646.
- Cagliano, R., Caniato, F. and Spina, G. (2003), "E-business strategy: How companies are shaping their supply chain through the internet", *International Journal of Operations and Production Management*, Vol. 23 No. 10, pp. 1142-1162.
- Caniato, F., Spina, G. and Cagliano (2004), "Supply chain flexibility: A taxonomy of strategies", *Proceedings of the 11th International EurOMA Conference*, INSEAD, Fontainebleau, pp. 115-124.
- Caniels, M.C.J and Gelderman, C.J. (2005), "Purchasing strategies in the Kraljic matrix – A power and dependence perspective", *Journal of Purchasing and Supply Management*, Vol. 11 pp. 141-155.
- Chen, I.J. and Paulraj, A. (2004), "Towards a theory of supply chain management: The constructs and measurements", *Journal of Operations Management*, Vol. 22 No. 2, pp. 119-150.
- Choi, T. and Krause, D.R. (2006), "The supply base and its complexity: Implications for transaction costs, risks, responsiveness, and innovation", *Journal of Operations Management*, Vol. 24 No. 5, pp. 637-652.
- Christopher, M. (2000), "The agile supply chain: Competing in volatile markets", *Industrial Marketing Management*, Vol. 29 No. 1, pp. 37-44.
- Chung, W.W.C., Yam, A.Y.K. and Chan, M.F.S. (2004), "Networked enterprise: A new business model for global sourcing", *International Journal of Production Economics*, Vol. 87 No. 3, pp. 267-280.
- Churchill, G.A. (1979), "A paradigm for developing better measures of marketing constructs", *Journal of Marketing Research*, Vol. 16 No. 2, pp. 64-73.
- Churchill, G.A. (1987), *Marketing Research: Methodological Foundations*, fourth ed., The Dryden Press, Chicago, IL.
- Clarke, E. (2007), "Chain reaction", *Financial Management*, April, pp.10-14.
- Clemons, E. and Row, M. (1992), "Information technology and industrial cooperation: the changing economics of coordination and ownership", *Journal of Management Information Systems*, Vol. 9 No. 2, pp. 9-28.

- Clemons, E., Reddi, S. and Row, M. (1993), "The impact of information technology on the organization of economic activity: the move to the middle hypothesis", *Journal of Management Information Systems*, Vol. 10 No. 2, pp. 9-35.
- Das, S.K. and Abdel-Malek, L. (2003), "Modeling the flexibility of order quantities and lead-times in supply chains", *International Journal of Production Economics*, Vol. 85 No. 2, pp. 171-181.
- Das, A., Narasimhan, R. and Talluri, S. (2006), "Supplier integration – Finding an optimal configuration", *Journal of Operations Management*, Vol. 24 No. 5, pp. 563-582.
- Davis, T. (1993), "Effective supply chain management", *Sloan Management Review*, Vol. 34 No. 4, pp. 35-46.
- De Toni, A. and Nassimbeni, G. (1999), "Buyer-supplier operational practices, sourcing policies and plant performances: results of an empirical research", *International Journal of Production Research*, Vol. 37 No. 3, pp. 597-619.
- Dillman, D.A. (1978), *Mail and telephone survey: The total design method*, John Wiley & Sons, New York.
- Dillon, W.R. and Goldstein, M. (1984), *Multivariate Analysis: Methods and applications*, John Wiley & Sons, New York.
- Duclos, L.K., Vokurka, R.J. and Lummus, R.R. (2003), "A conceptual model of supply chain flexibility", *Industrial Management & Data Systems*, Vol. 103 No. 6, pp. 446-456.
- Eppen, G.D and Iyer, A.V. (1997), "Backup agreements in fashion buying: The value of upstream flexibility", *Management Science*, Vol. 43 No. 11, pp. 1469-1484.
- Fisher, M.L. (1997), "What is the right supply chain for your product?", *Harvard Business Review*, Vol. 75 No. 2, pp. 105-116.
- Fisher, M., Hammond, J., Obermeyer, W. and Raman, A. (1997), "Configuring a supply chain to reduce the cost of demand uncertainty", *Production and Operations Management*, Vol.6 No. 3, pp. 211-225.
- Fowler Jr., F.J. (1993), *Survey Research Methods*, Sage Publications, Newbury Park, California.
- Fynes, B., de Búrca, S. and Marshall, D. (2004), "Environmental uncertainty, supply chain relationship quality and performance", *Journal of Purchasing and Supply Management*, Vol. 10 No. 4-5, pp. 179-190.

- Gerwin, D. (1993), "Manufacturing flexibility: A strategic perspective", *Management Science*, Vol. 39 No. 4, pp. 395-410.
- Gimenez, C. and Ventura, E. (2005), "Logistics-production, logistics-marketing and internal integration", *International Journal of Operations and Production Management*, Vol. 25 No. 1, pp. 20-38.
- Grover, V. and Malhotra, M.K. (2003), "Transaction cost framework in operations and supply chain management research: theory and measurement", *Journal of Operations Management*, Vol. 21 No. 4, pp. 457-473.
- Hair, J.F., Tatham, R.L., Anderson, R.E. and Black, W. (1998), *Multivariate Data Analysis*, Prentice-Hall, 5th edition, New York.
- Hayes, R.H. and Wheelwright, S.C. (1984), *Restoring our competitive edge: Competing through manufacturing*, John Wiley & Sons, New York, NY.
- Hines, P. (1996), "Purchasing for lean production: The new strategic agenda", *International Journal of Purchasing and Materials Management*, Vol. 32 No. 1, pp. 2-12.
- Hochberg, Y. and Tamhane, A.C. (1987), *Multiple comparison procedures*, John Wiley & Sons, New York.
- Howard, M., Miemczyk, J. and Graves, A. (2006), "Automotive supplier parks: An imperative for build-to-order?", *Journal of Purchasing and Supply Management*, Vol. 12 No. 2, pp. 91-104.
- Jack, E.P. and Raturi, A. (2002), "Sources of volume flexibility and their impact on performance", *Journal of Operations Management*, Vol. 20 No. 5, pp. 519-548.
- Jin, B. (2004), "Achieving an optimal global versus domestic sourcing balance under demand uncertainty", *International Journal of Operations and Production Management*, Vol. 24 No. 12, pp. 1292-1305.
- Kaplan, S. and Sawhney, M. (2000), "E-hubs: The new B2B marketplaces", *Harvard Business Review*, Vol. 78 No. 3, pp. 97-102.
- Krajewski, L., Wei, J. and Tang, L.L. (2005), "Responding to schedule changes in build-to-order supply chains", *Journal of Operations Management*, Vol. 23, No. 5, pp. 452-469.
- Krause, D.R., Pagell, M. and Curkovic, S. (2001), "Toward a measure of competitive priorities for purchasing", *Journal of Operations Management*, Vol. 19 No. 4, pp. 497-512.

- Lee, H.L. (2002), "Aligning supply chain strategies with product uncertainties", *California Management Review*, Vol. 44 No. 3, pp. 105-119.
- Lee, H.L. (2004), "The triple-A supply chain", *Harvard Business Review*, Vol. 82 No. 10, pp. 102-112.
- Lehmann, D.R. (1979), *Market Research and Analysis*, Irwin, Homewood, IL.
- Malhotra, N.K. (1996), *Marketing Research: An applied orientation*, 2nd edition, Englewood Cliffs, Prentice-Hall, New Jersey.
- Miller, J.G. and Roth, A.V. (1994), "A taxonomy of manufacturing strategies", *Management Science*, Vol. 40 No. 3, pp. 285-304.
- Minner, S. (2003), "Multiple-supplier inventory models in supply chain management: A review", *International Journal of Production Economics*, Vol. 81-82 No. 11, pp. 265-279.
- Narasimhan, R. and Das, J. (2001), "The impact of purchasing integration and practices on manufacturing performance", *Journal of Operations Management*, Vol. 19 No. 5, pp. 593-609.
- Narasimhan, R., Jayaram, J. and Carter, J.R. (2001), "An empirical examination of the underlying dimensions of purchasing competence", *Production and Operations Management*, Vol. 10 No. 1, pp. 1-15.
- Narasimhan, R., Swink, M. and Kim, S.W. (2006), "Disentangling leanness and agility: An empirical investigation", *Journal of Operations Management*, Vol. 24 No. 5, pp. 440-457.
- Nassimbeni, G. (2003), "Local manufacturing systems and global economy: Are they compatible? The case of the Italian eyewear district", *Journal of Operations Management*, Vol. 21 No. 2, pp. 151-171.
- Pagell, M. (2004), "Understanding the factors that enable and inhibit the integration of operations, purchasing and logistics", *Journal of Operations Management*, Vol. 22 No. 5, pp. 459-487.
- Peleg, B., Lee, H.L. and Haussman, W.H. (2002), "Short-term e-procurement strategies versus long-term contracts", *Production and Operations Management*, Vol. 11 No. 4, pp. 458-479.
- Ponce, E. and Prida, B. (2004), *La logística de aprovisionamientos para la integración de la cadena de suministros*, Pearson Educación, Madrid.
- Porter, M.E. (1985), *Competitive advantage*, Free Press, New York.

- Prasad, S. and Babbar, S. (2000), "International operation management research", *Journal of Operations Management*, Vol. 18 No. 2, pp. 209-247.
- Prater, E., Biehl and M., Smith, M.A. (2001), "International supply chain agility: Tradeoffs between flexibility and uncertainty", *International Journal of Operations and Production Management*, Vol. 21, No. 5/6, pp. 823-839.
- Prater, E. and Ghosh, S. (2006), "A comparative model of firm size and global operational dynamics of U.S. firms in Europe", *Journal of Operations Management*, Vol. 24 No. 5, pp. 511-529.
- Pujawan, N. (2004), "Assessing supply chain flexibility: a conceptual framework and a case study", *International Journal of Integrated Supply Management*, Vol. 1 No. 1, pp. 79-97.
- Punj, G. and Stewart, D.W. (1983), "Cluster analysis in marketing research: Review and suggestions for application", *Journal of Marketing Research*, Vol. 20 No. 2, pp. 134-148.
- Quayle, M. (1998), "Industrial procurement: Factors affecting sourcing decisions", *European Journal of Purchasing and Supply Management*, Vol.4 No. 1, pp. 199-205.
- Saeed, K.A., Malhotra, M.K. and Grover, V. (2005), "Examining the impact of interorganizational systems on process efficiency and sourcing leverage in buyer-supplier dyads", *Decision Sciences*, Vol. 36 No. 3, pp. 365-396.
- Sanders, N. and Premus, R. (2005), "Modeling the relationship between firm IT capability, collaboration and performance", *Journal of Business Logistics*, Vol. 26 No. 1, pp. 1-23.
- Sawhney, R. (2006), "Interplay between uncertainty and flexibility across the value-chain: Towards a transformation model of manufacturing flexibility", *Journal of Operations Management*, Vol. 24 No. 5, pp. 476-493.
- Slack, N. (1991), *The Manufacturing Advantage*, Mercury Books, London.
- Slater, S.F. and Narver, J.C. (1994), "Does competitive environment moderate the market orientation-performance relationship?", *Journal of Marketing*, Vol. 58 No. 1, pp. 46-55.
- Smith, J.M. (1999), "Item selection for global purchasing", *European Journal of Purchasing and Supply Management*, Vol. 5 No. 1, pp. 117-127.

- Stank, T.P., Keller, S.B. and Daugherty, P.J. (2001), "Supply chain collaboration and logistical service performance", *Journal of Business Logistics*, Vol. 22 No. 1, pp. 29-48.
- Stratton, R. and Warburton, R.D.H. (2003), "The strategic integration of agile and lean supply", *International Journal of Production Economics*, Vol. 85 No. 2, pp. 183-198.
- Stuckey, J. and White, D. (1993), "When and when not to vertically integrate", *Sloan Management Review*, Vol. 34 No. 3, pp. 71-83.
- Suarez, F., Cusumano, M.A. and Fine, C.H., (1996), "An empirical study of manufacturing flexibility in printed circuit board assembly", *Operations Research*, Vol. 44 No. 1, pp. 223-241.
- Swafford, P., Ghosh, S. and Murthy, N. (2006), "The antecedents of supply chain agility of a firm: Scale development and model testing", *Journal of Operations Management*, Vol. 24 No. 2, pp. 170-188.
- Swafford, P., Ghosh, S. and Murthy, N. (2006b), "A framework for assessing value chain agility", *International Journal of Operations and Production Management*, Vol. 26 No. 2, pp. 118-140.
- Swamidass, P.M. and Newell, W.E. (1987), "Manufacturing strategy, environmental uncertainty and performance: A path analytic model", *Management Science*, Vol. 33 No. 4, pp. 509-524.
- Upton, D.M. (1994), "The management of manufacturing flexibility", *California Management Review*, Vol. 36, No. 2, pp. 72-89.
- Upton, D.M. (1995), "Flexibility as process mobility: the management of plant capabilities for quick response manufacturing", *Journal of Operations Management*, Vol. 12 No. 3-4, pp. 205-224.
- Upton, D.M. (1997), "Process range in manufacturing", *Management Science*, Vol. 43 No. 8, pp. 1079-1092.
- Van de Venn, A.H. and Ferry, D.I. (1980), *Measuring and assessing organizations*, John Wiley and Sons, New York, NY.
- Van der Vaart, T. and Van Donk, D.P. (2004), "Buyer focus: Evaluation of a new concept for supply chain integration". *International Journal of Production Economics*, Vol. 92 No. 1, pp. 21-30.
- Vickery, S., Calantone, R. and Dröge, C. (1999), "Supply chain flexibility: an empirical study", *The Journal of Supply Chain Management*, Vol. 35 No. 1, pp. 16-24.

- Vickery, S., Jayaram, J., Dröge, C. and Calantone, R. (2003), "The effects of an integrative supply chain strategy on customer service and financial performance: An analysis of direct versus indirect relationships", *Journal of Operations Management*, Vol. 21 No. 5, pp. 523-539.
- Violainen, V.M. (1998), "A survey of procurement strategy development in industrial companies", *International Journal of Production Economics*, Vol. 56-57, pp. 677-688.
- Wei, J. and Krajewski, L. (2000), "A model for comparing supply chain schedule integration approaches", *International Journal of Production Research*, Vol. 38 No. 9, pp. 2099-2123.
- Womack, J.P., Jones and D.T., Roos, D. (1990), *The Machine that Changed the World*, Macmillan Publishing Company, New York, NY.
- Zeng, A.Z. (2000), "A synthetic study of sourcing strategies", *Industrial Management & Data Systems*, Vol. 100 No. 5, pp. 219-226.
- Zhang, Q., Vonderembse, M.A. and Lim, J. (2002), "Value chain flexibility: a dichotomy of competence and capability", *International Journal of Production Research*, Vol. 40 No. 3, pp. 561-583.

Appendix A. 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.

A.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.
- (2) We use local (i.e. same country) suppliers.
- (3) We collaborate intensely with the suppliers (sharing information, forming cross-functional teams, joint planning, etc).
- (4) We involve the suppliers in joint product development activities.
- (5) We select the suppliers based on their flexibility (slack capacity, responsiveness, etc).
- (6) We use flexible contracts (backup agreements, quantity-flexible contracts).
- (7) We use long-term relationships with suppliers.
- (8) We collaborate with the inbound logistics provider.
- (9) We use alternative transportation modes.
- (10) We use e-marketplaces to search alternative suppliers.
- (11) We collaborate intensely with other areas within our firm (production, logistics, etc).
- (12) We use Information Technology planning tools (Supply Chain Planning, Suppliers Relationship Management, etc) and/or Electronic Data Interchange (EDI) with the suppliers.
- (13) We use inventory buffers.

- (14) We use other sources of supply flexibility. Which one (s)?

A.2. Supply uncertainty

Use a 10-point scale for each (1 = never; 10 = very frequently).

- (1) The suppliers deliver the required quantity.
- (2) The suppliers deliver in the required date.
- (3) The suppliers deliver the required specification/configuration.

A.3. Demand uncertainty

Use a 10-point scale for each (1 = never; 10 = very frequently).

- (1) The required quantities fluctuate drastically from week to week (for example: to change orders from 10 to 100 units)- *Volume uncertainty*.
- (2) The required specification/configuration fluctuates drastically from week to week (for example: to change order specification from “blue” to “red”) - *Mix uncertainty*.
- (3) The required lead-times vary drastically from week to week (for example: to anticipate an order) - *Delivery uncertainty*.

A.4. Technology uncertainty

Use a 10-point scale for each (1 = never; 10 = very frequently).

- (1) Our sector is characterized by rapidly changing technologies.
- (2) Technological changes provide big opportunities in our industry.
- (3) It is very difficult to predict where technology in our industry will be in 3-5 years.

A.5. 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).

- (2) Range of possible order sizes from suppliers.
- (3) Extent to which supplier lead-time can be expedited/changed.
- (4) Extent to which supplier short-term capacity can be influenced.

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

A.6. Flexibility focus

Using a 10-point scale (1 = unimportant; 10 = critical), please indicate the level of the following characteristic:

- (1) Which is the importance of flexibility in the sourcing strategy of your business unit?

A.7. Supplier searching and switching costs

In the supplier selection stage:

Using a 10-point scale (1 = very simple; 10 = very complicated), please indicate the level of difficulty of each item:

- (1) Identifying a supplier capable of delivering this material is:
- (2) Establishing the contractual details of the relationship is:

After supplier selection:

Using a 10-point scale (1 = never; 10 = very frequently), please indicate the frequency of each activity:

- (3) We adapt our products/tools/processes to use the material from each supplier

Using a 10-point scale (1 = low; 10 = very high), evaluate the level of each characteristic:

(4) The time/effort dedicated to learn the specific processes of each supplier (commercial procedures, logistical processes).

(5) The time/effort dedicated to develop the relationship with each supplier (visits, dedicated buyers, etc).

A.8. Annual revenue (million euros)

(1) Less than 1 (2) Between 1 and 49 (3) Between 50 and 99

(4) Between 100 and 499 (5) More than 500

Appendix B. The matrix of the correlation coefficients

	SRC1	SRC2	SRC3	SRC4	SRC5	SRC6	SRC7	SRC8	SRC9	SRC10	SRC11	SRC12
Multiple sourcing (SRC1)	-											
Domestic sourcing (SRC2)	-0,10	-										
Supplier integration (SRC3)	-0,01	0,26*	-									
Joint product development with suppliers (SRC4)	-0,20	0,31**	0,66**	-								
Supplier selection (SRC5)	0,05	0,35**	0,23*	0,27*	-							
Flexible supply contracts (SRC6)	-0,03	0,17	0,23*	0,25*	0,31**	-						
Long-term relationships with suppliers (SRC7)	-0,05	0,23*	0,20	0,29**	0,12	0,24*	-					
Third-party logistics providers (SRC8)	0,06	-0,03	0,19	0,05	0,04	0,25*	0,03	-				
Alternative transportation modes (SRC9)	0,22*	-0,19	0,02	-0,15	0,02	0,23*	-0,26 *	0,30**	-			
E-marketplaces (SRC10)	0,16	-0,17	0,09	-0,10	-0,03	0,19	-0,21	0,09	0,29**	-		
Internal integration (SRC11)	-0,11	0,29**	0,43**	0,44**	0,14	0,27*	0,12	0,18	-0,08	0,03	-	
Electronic integration (SRC12)	-0,12	-0,03	0,18	0,11	-0,05	0,28**	0,08	0,23*	-0,10	0,01	0,14	-
Inventory buffers (SRC13)	0,15	-0,02	0,15	0,13	0,16	0,03	0,17	-0,06	0,07	0,04	0,01	-0,06

*Signif. 0.05; **Signif. 0.01 (2-tailed)

**CHAPTER 4: ASSESSING THE EFFECTIVENESS OF SUPPLY FLEXIBILITY
SOURCES**

Submitted to the *International Journal of Production Research*²

² Edited version

4.1 Introduction

The flexibility in the upstream side of supply chains has attracted the interest of many researchers in recent years. 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). From an academic perspective, the study of flexibility across supply chains complements the vast research on manufacturing flexibility.

There are several studies related to supply flexibility (e.g. Porter, 1985; Zhang *et al.*, 2002; Duclos *et al.*, 2003; Swafford *et al.*, 2006; Pujawan, 2004). However, most frameworks present drawbacks and limitations in common. Essentially, there is an overlap between flexibility assessment items and sourcing practices (e.g. the use of multiple sourcing could be either a flexibility item or a sourcing practice, according to these frameworks). Moreover, the scope of analysis in each firm includes the whole list of purchased components, rather than specific purchased items.

In order to overcome these limitations, considerable efforts were dedicated in the present study to the elaboration of the data collection instrument. 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*. It was measured at a specific component’s level (i.e. not at a firm’s level). Moreover, special care was taken in the design of the assessment items to avoid overlaps with sourcing practices.

After the definition of a performance dimension (i.e. supply flexibility), research is naturally driven to analyse how it can be improved. Different management practices are applied to increase supply flexibility. 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). The list is large and includes actions in several elements of the supply chain (e.g. suppliers, logistics providers, transportation modes, IT systems, etc), with heterogeneous results in terms of supply flexibility.

Nonetheless, there are few empirical studies that compare the *effectiveness* 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 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.

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?

The contribution to the literature is to provide a quantitative study analysing jointly the effectiveness of different flexibility sources. Accordingly, the effectiveness of different sourcing practices can be assessed more precisely and objectively than using qualitative methods. The moderating effect of other variables (i.e. flexibility focus and revenue) on this relationship can also be checked, in order to better understand the influence of purchasing strategic orientation on the effectiveness of sourcing practices.

4.2 Literature review

4.2.1 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 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 (e.g. flexible contracts).

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

4.2.2 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.

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

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. Moreover, the presence of multiple sources enables the pooling of demand among several categories of suppliers. For example, assigning a percentage of forecasted demand to offshore suppliers and reserve capacity at domestic, quick-response suppliers can increase the supply flexibility (Stratton and Warburton, 2003).

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).

Supplier integration: Numerous studies suggest that integrative practices have a positive effect on supply flexibility (Das *et al.*, 2006; Swafford *et al.*, 2006). The sharing of critical data (e.g. sales forecasts, buyer's future production schedule, future shipping requirements, etc) improves the supplier's ability to plan his production and inventory levels more efficiently (Christopher, 2000; Krajewski *et al.*, 2005). 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).

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).

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). Several empirical studies confirm this argument: for instance, in a study about the Italian eyewear district, Nassimbeni (2003) concluded that volume elasticity and reliability of deliveries were crucial supplier selection criteria, rather than price or terms of payment. In addition, Choi and Hartley (1996) found that the capability of suppliers to make volume changes is an important supplier selection criterion in the automotive industry. Furthermore, an adequate supplier selection can compensate a limited level of information sharing, when suppliers do not have adequate visibility to anticipate change (Swafford *et al.*, 2006).

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, supply contracts with quantity flexibility clauses are an important coordination mechanism between buyers and suppliers (Van der Vaart and Van Donk, 2004). 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. In another example, Eppen and Iyer (1997) suggest that flexible contracts such as backup

agreements can increase supply flexibility in fashion buying by adjusting purchase order quantities after observing early demand.

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).

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)). Another typical example of strategic agreement is found in automotive supplier parks, where inbound logistics providers often handle the delivery sequence for the suppliers (Howard *et al.*, 2006).

Alternative modes of transportation: Having alternative inbound modes of transportation (e.g. maritime, aerial, rail, etc) is acknowledged as a source of supply flexibility (Pujawan, 2004; Zhang *et al.*, 2002). The varied operational features (i.e. in-transit time, cost, capacity, frequency of delivery, etc) of the different transportation modes increase the range of options available to meet the changing customer needs (Zhang *et al.*, 2002).

E-marketplaces: Saeed *et al.* (2005) and Swafford *et al.* (2006b) argue that the use of inter-organizational systems in supply chains can be divided into two categories: electronic integration and electronic brokerage. Electronic integration will be explained in the next paragraph, and electronic brokerage corresponds to the use of e-marketplaces. Online searching for suppliers offers access to a larger number of potential suppliers (Peleg *et al.*, 2002; Lee, 2002), allowing the prompt scaling up and down of operations (Kaplan and Sawhney, 2000). This is especially important in fragmented industries (e.g. electronic components), where, without e-marketplaces, buyers can have great difficulty in searching alternative sources (Kerrigan *et al.*, 2001).

Electronic integration: In this study, electronic integration is the use of information technology (IT) tools (e.g. Electronic Data Interchange (EDI), supply chain planning software, Internet, etc) to integrate with supply chain partners (Saeed *et al.*, 2005). Many authors consider electronic integration with suppliers as an important

source of responsiveness in the upstream side of the supply chain (Wei and Krajewski, 2000; Stratton and Warburton, 2003; Bruce *et al.*, 2004). For example, researchers argue that the sharing of real-time information through EDI or Internet enables organizations to respond to dynamic environments. Additionally, the use of supply chain planning tools (to change volume assignments among suppliers, reschedule deliveries, check suppliers capacity, etc) is an effective way of increasing supply flexibility (Saeed *et al.*, 2005; Chung *et al.*, 2004).

Internal Integration: Stevens (1989) considered internal integration as a removal of the intra-organizational barriers between departments. This sort of integration (e.g. between Purchasing and Logistics) permits an increase in the responsiveness to changing materials requirements (Swafford *et al.*, 2006; Narasimhan *et al.*, 2006). Moreover, prior to an external integration initiative, purchasing executives must explicitly resort to internal integration strategies (e.g. integrated database, joint establishment of objectives, cross-functional teams, etc) to ensure the strategic relevance of the purchasing actions within the supply-base (Das *et al.*, 2006).

Inventory buffers: Buffer stocks of critical items are commonly used to hedge against uncertainty (Lee, 2002; Fisher, 1997). Some studies suggest that they can partly compensate a lack of supplier integration, specifically when there is high volume uncertainty and low mix uncertainty (Van Donk and Van der Vaart, 2005). Similarly, the literature on agility supports the use of inventory buffers to increase responsiveness across the supply chain (Wei and Krajewski, 2000; Stratton and Warburton, 2003).

In this study, the moderating effect of flexibility focus on the effectiveness of the distinct supply flexibility sources is also analysed. In the next section, we revise briefly some studies concerning flexibility focus.

4.2.3 Flexibility focus

The deployment of flexibility sources depends on the firm strategy and, more specifically, on its flexibility focus. Some empirical studies on flexibility have proposed 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.

4.3 Model development

The objective of this paper is to analyse the effectiveness of several sourcing practices concerning the achievement of supply flexibility. Therefore, the research questions are:

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?

Figure 1 depicts the research framework of this study.

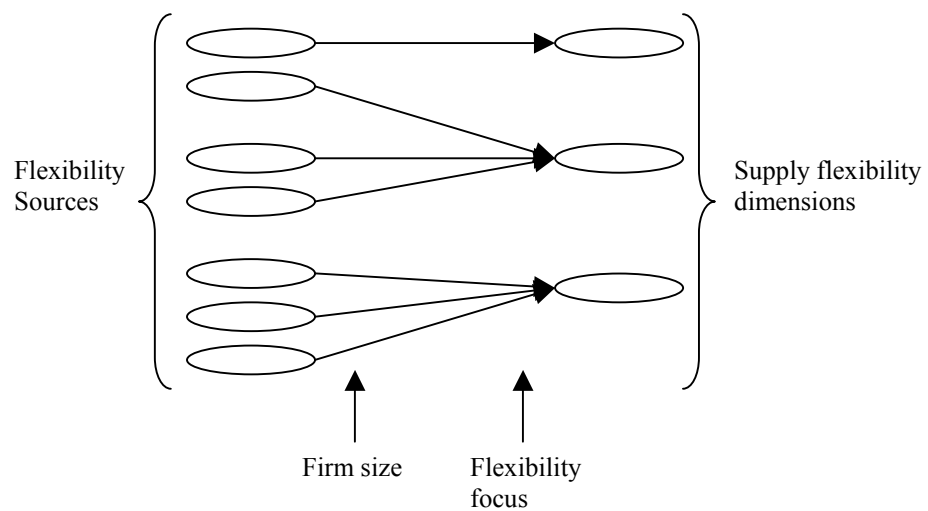


Figure 1. Research Framework

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). 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 small ones). 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.

4.4 Methodology

4.4.1 The instrument

In order to assure *content validity* (i.e. the extent to which it assures adequate coverage for the construct domain being measured (Churchill, 1979)), questionnaire items were based on previous studies. 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 (the questions can be seen in the Appendix A).

Finally, we have to make a methodological comment on the conversion of the questionnaire items into the variables scores. For most questionnaire items, a standard coding was used (e.g. the option on the left corresponded to a score of 1, and the option on the right to a score of 10). However, for some items (from FLEX5 to FLEX9) a reverse coding was used (i.e. the option on the left corresponded to 10, and the option on the right corresponded to 1). For example: in the item FLEX5, the *higher* the “cost/time associated with engaging in changing quantity of supplier’s order”, the *lower* the supply flexibility, and therefore the code had to be reversed.

4.4.2 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 5) 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 5.1%. This slightly low response rate should be analyzed 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 may assume that the 77 usable responses provide enough data to attain the research objectives.

The industry and size distribution of the sample can be appreciated in Table 2.

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		

4.5 Data analysis and discussion

4.5.1 Factor analysis

Exploratory factor analysis with varimax rotation was conducted in order to explore the underlying supply flexibility dimensions. In the interest of convergent and discriminant validity, we only considered items that had a factor loading higher than 0.50 and did not have a loading in excess of 0.40 on a second factor (Bagozzi and Yi, 1988).

Cronbach's alpha was used to evaluate *reliability* (i.e. how well a set of items measures a single one-dimensional latent construct values). In general, reliability coefficients of 0.70 are considered satisfactory, but some researchers consider 0.60 as a practical cut-off (Swafford *et al.*, 2006; Chen and Paulraj, 2004).

The final factor loadings of the supply flexibility retained items, as well as their underlying factors, can be appreciated in Table 3. The Kaiser-Meyer-Olkin test of sampling adequacy (KMO = 0.531) and the Bartlett's test of sphericity (significance = 0.000) were within the generally accepted limits, suggesting that factor analysis could

be applied (Malhotra, 1996). Cronbach's alpha was at least 0.608 for all dimensions of supply flexibility (see Table 3), indicating that construct reliabilities were adequate.

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. χ^2	99.537	
	d.f.	21	
	Sig.	0.000	
Supply flexibility items	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) ^a			
Cost / time needed to change the quantity ordered (FLEX8) ^a			
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.

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

Results of the factor analysis suggested the existence of three underlying dimensions of supply flexibility: delivery policy (FLEX1 and FLEX2), supplier responsiveness (FLEX3 and FLEX4) and adaptability (FLEX6, FLEX7 and FLEX9). The *delivery policy* dimension measures the capacity of varying delivery lot sizes and frequencies. Lot size and frequency are variables usually associated. For example, JIT studies often support the combination of small supplier lot sizes and frequent deliveries (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”. It is also analogous to the concept of supplier short-term process flexibility (Krajewski *et al.*, 2005), which includes supplier capacity slack and expediting efficiency (i.e. the capability to speed up batches of product at low cost). *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).

4.5.2 Regression analysis

According to the research framework presented in section 3, 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.

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, which can be seen in the Appendix B. 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. 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 variance inflation factors (VIF), which 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.

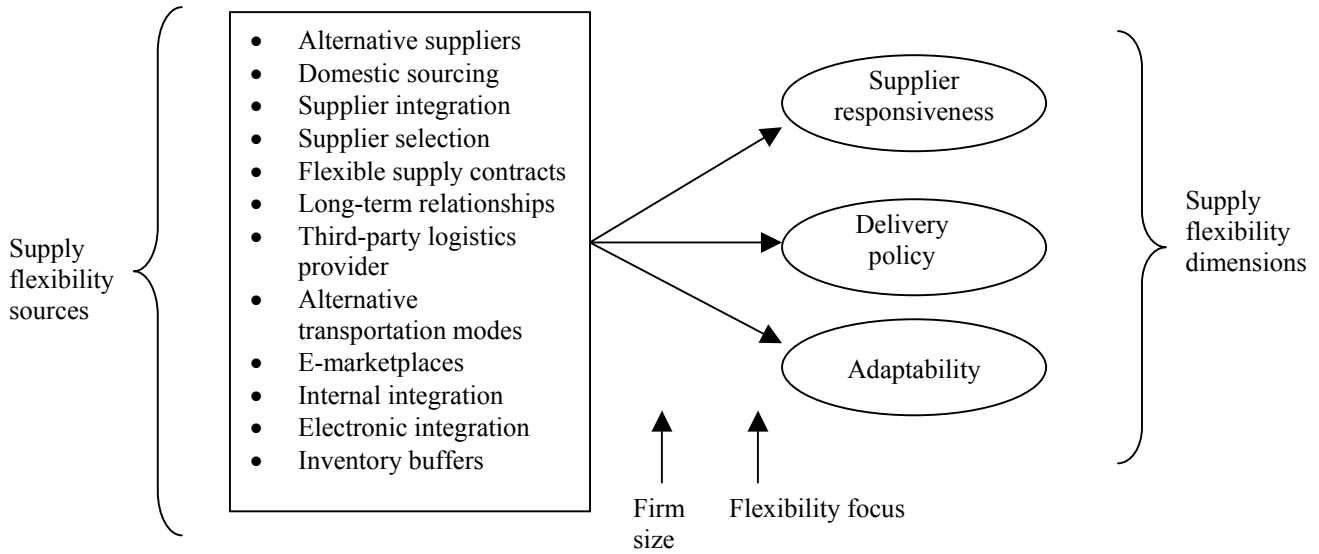


Figure 2. Research model

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). As a second step, two control variables were added: REV (revenue) and IMP (flexibility focus). The results can be appreciated in Table 4.

Table 4. Regression results (supplier responsiveness)

Model	Adjusted R ²	F-value	Significance F	Variables	Standardized β	T-value	Significance
(1) Base model	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
(2) Hypothesized model	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

Dependent variable: SR.

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, REV (revenue) and IMP (flexibility focus) have no significant effect on the dependent variable.

Potential outliers and influential cases were examined. Univariate outliers were verified using the cut-off 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.

The relationship between integration and flexibility is somewhat controversial. Although some researchers claim that integration increases supplier responsiveness (e.g. Choi and Krause, 2006; Swafford *et al.*, 2006) and manufacturing flexibility (e.g. Suarez *et al.*, 1996; Narasimhan and Das, 2000; Jack and Raturi, 2002), 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). Moreover, previous studies did not analyse several dimensions of integration (i.e. internal, external, etc) simultaneously. Therefore, the relationship between integration and supplier responsiveness is still unclear, and may depend on the type of integration practice, or context variables (e.g. firm revenue).

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).

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). In addition, REV (firm revenue) and IMP (flexibility focus) were included as control variables (see Table 5). The basic assumptions of regression (homoscedasticity, absence of multicollinearity, normality or linearity) were satisfied. 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, REV (revenue) and IMP (flexibility focus) have no significant effect on the dependent variable.

Table 5. Regression results (delivery policy)

Model	Adjusted R ²	F-value	Significance F	Variables	Standardized β	T-value	Significance
(1) Base model	0.080	7.645	0.007	Constant		3.343	0.001
				SRC5	0.304	2.765	0.007
(2) Hypothesized model	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

Dependent variable: DP.

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). Likewise, Van der Vaart *et al.* (1996) argue that the logistical profile of a particular material (e.g. the delivery frequency and the lot size variability) should be used as a starting point in supply negotiations.

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). Very often, suppliers tend to force a “big-lots policy” to achieve economies of scale, with negative effects on supply flexibility. This is especially dramatic in a condition of low volume uncertainty and high mix uncertainty (e.g. in the automotive sector), when stocks are not feasible options (Van Donk and Van der Vaart, 2005). Accordingly, a possible solution is to select suppliers that can better adjust their delivery policy to the buyers’ changing manufacturing needs. Indeed, the alignment of buyer and supplier flexibility has been the main issue in some recent studies about flexibility (e.g. Sawhney, 2006).

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). The basic assumptions of regression (homoscedasticity, absence of multicollinearity, normality and linearity) were satisfied.

We also included REV (revenue) and IMP (flexibility focus) as control variables (see Table 6). 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 = 0.033), SRC9 (p = 0.035) and SRC12 (p = 0.003). Regarding the control variables, “revenue” and “flexibility focus” have no significant effect on the dependent variable.

Table 6. Regression results (adaptability)

Model	Adjusted R ²	F-value	Significance F	Variables	Standardized β	T-value	Significance
(1) Base model	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
(2) Hypothesized model	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

Dependent variable: A.

The positive relationship between electronic integration and adaptability (standardized beta = 0.348, $p = 0.003$) is somewhat different than the results from Swafford *et al.* (2006), who did not find a significant correlation between procurement IT capabilities and adaptability. Nevertheless, results coincide with most of the studies on supply chain agility, which support the effect of procurement IT on supply chain responsiveness (Christopher, 2000; Bruce *et al.*, 2004; Chung *et al.*, 2004; Saeed *et al.*, 2005). Indeed, most of the literature on supply chain agility emphasizes the crucial effect of IT investments on responsiveness across the supply chain. Additionally, electronic integration between buyers and suppliers can reduce process uncertainties caused by human mistakes (e.g. by avoiding typing errors). At the same time, when process uncertainties do arise, IT facilitates making adjustments to handle them (Gerwin, 1993). Further research with a broader sample of firms and industrial sectors should be conducted to confirm these results and to contrast them with previous studies.

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

Interestingly, a negative association between logistics provider integration and adaptability (standardized beta = -0.259, $p = 0.033$) was found. This result departs from previous studies, which associate third-party logistics provider integration with

flexibility (Anderson *et al.*, 1997). A plausible reason for such a finding could be due to potential negative effects of integration on flexibility. Das *et al.* (2006) argue that some causes for this phenomenon could be: excessive caution among inexperienced team members, need for consultations in decision-making, communication delays and coordination needs. Anyway, the discrepancy of results suggests the need for further studies and replication of analysis using a broader sample of firms. Further research should also incorporate other variables (such as length of relationship, type of product/service bought, etc) that could explain why integration with the supplier increases supply flexibility while integration with the logistics provider does not.

4.6 Conclusion

This study aimed to analyse the effects of supply flexibility sources on the different dimensions of supply flexibility. It adds to previous literature on 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). First, “integration” variables (domestic sourcing, supplier and internal integration) are important to achieve supplier responsiveness (i.e. the ability of influencing suppliers’ short-term capacity and delivery lead-time). Second, supplier selection affects positively delivery policy (i.e. the capacity of varying delivery lot sizes and frequencies). Lastly, alternative transportation modes and electronic integration are positively associated to adaptability (i.e. the time or cost necessary to change the specification of components, implement supplier engineering change orders or alter short-term capacity of suppliers).

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. In this study, this relationship was positive, not significant, or even negative, depending on the flexibility source and the dimension of flexibility. This suggests the existence of countervailing forces at work, implying the existence of trade-offs among sourcing practices (considering the strategic objective of achieving flexibility). Further studies should confirm those findings in different contexts (e.g. different countries or industrial sectors) and expand the range of flexibility sources studied (e.g. “buyer-focused” operations). Second, this study provides researchers with a framework that can be used to investigate quantitatively the effects of managerial

practices on supply flexibility. As discussed in the literature review, previous studies on supply flexibility were largely based on anecdotal evidence. 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, etc), integrate purchasing with other internal functions (e.g. production, logistics, etc) and adopt domestic sourcing have higher supplier 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, since firms profile can vary significantly across countries. Second, although the statistical procedures suggest sufficient validity, the sample size should be larger in further studies, to increase the generalizability of the results. This would permit the use of more sophisticated statistical confirmatory techniques, such as Structural Equation Modelling (SEM). 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.

References

- Anderson, D.L., Britt, F.E. and Favre, D.J. (1997), "The seven principles of supply chain management", *Supply Chain Management Review*, Vol.1 No. 1, pp. 1-12.
- Babbie, E. (1990), *Survey Research Methods*, Wadsworth Publishing Company, Belmont, CA.
- Bagozzi, R.P. and Yi, Y. (1988), "On the evaluation of structural equation models", *Journal of Academy of Marketing Science*, Vol. 16 No. 1, pp. 74-94.
- Belsley, D.A., Kuh, E. and Welsh, R.E. (1980), *Regression Diagnostics – Identifying Influential Data and Sources of Collinearity*, John Wiley & Sons, New York.
- Braunsberger, K., Wybenga, H. and Gates, R. (2007), "A comparison of reliability between telephone and web-based surveys", *Journal of Business Research*, Vol.60 No.7, pp.758-764.
- Bruce, M., Daly, L. and Towers, N. (2004), "Lean or agile: a solution for supply chain management in the textiles and clothing industry?", *International Journal of Operations and Production Management*, Vol. 24 No. 2, pp. 151-170.
- Caniels, M.C.J and Gelderman, C.J. (2005), "Purchasing strategies in the Kraljic matrix – A power and dependence perspective", *Journal of Purchasing and Supply Management*, Vol. 11 pp. 141-155.
- Chen, I.J. and Paulraj, A. (2004), "Towards a theory of supply chain management: The constructs and measurements", *Journal of Operations Management*, Vol. 22 No. 2, pp. 119-150.
- Choi, T. and Hartley, J. (1996), "An exploration of supplier-selection practices across the supply chain", *Journal of Operations Management*, Vol. 14 No. 4, pp. 333-343.
- Choi, T. and Krause, D.R. (2006), "The supply base and its complexity: Implications for transaction costs, risks, responsiveness, and innovation", *Journal of Operations Management*, Vol. 24 No. 5, pp. 637-652.
- Christopher, M. (2000), "The agile supply chain: Competing in volatile markets", *Industrial Marketing Management*, Vol. 29 No. 1, pp. 37-44.

- Chung, W.W.C., Yam, A.Y.K. and Chan, M.F.S. (2004), "Networked enterprise: A new business model for global sourcing", *International Journal of Production Economics*, Vol. 87 No. 3, pp. 267-280.
- Churchill, G.A. (1979), "A paradigm for developing better measures of marketing constructs", *Journal of Marketing Research*, Vol. 16 No. 2, pp. 64-73.
- Das, A., Narasimhan, R. and Talluri, S. (2006), "Supplier integration – Finding an optimal configuration", *Journal of Operations Management*, Vol. 24 No. 5, pp. 563-582.
- De Toni, A. and Nassimbeni, G. (1999), "Buyer-supplier operational practices, sourcing policies and plant performances: results of an empirical research", *International Journal of Production Research*, Vol. 37 No. 3, pp. 597-619.
- Duclos, L.K., Vokurka, R.J. and Lummus, R.R. (2003), "A conceptual model of supply chain flexibility", *Industrial Management & Data Systems*, Vol. 103 No. 6, pp. 446-456.
- Eppen, G.D and Iyer, A.V. (1997), "Backup agreements in fashion buying: The value of upstream flexibility", *Management Science*, Vol. 43 No. 11, pp. 1469-1484.
- Fisher, M.L. (1997), "What is the right supply chain for your product?", *Harvard Business Review*, Vol. 75 No. 2, pp. 105-116.
- Fisher, M., Hammond, J., Obermeyer, W. and Raman, A. (1997), "Configuring a supply chain to reduce the cost of demand uncertainty", *Production and Operations Management*, Vol.6 No. 3, pp. 211-225.
- Flynn, B.B., Saladyn, B. (2005), "Relevance of Baldrige constructs in an international context: A study of national culture", *Journal of Operations Management*, Vol. 24 No. 5, pp. 583-683.
- Gerwin, D. (1993), "Manufacturing flexibility: A strategic perspective", *Management Science*, Vol. 39 No. 4, pp. 395-410.
- Giunipero, L.C., Denslow, D. and Eltantawy, R. (2005), "Purchasing/supply chain management flexibility: Moving to an entrepreneurial skill set", *Industrial Marketing Management*, Vol. 34, pp. 602-613.
- Gonzalez-Benito, J., Martínez-Lorente, A.R. and Dale, B.G. (2003), "A study of the purchasing management system with respect to total quality management" *Industrial Marketing Management*, Vol. 32 No. 6, pp. 443-454.
- Hair, J.F., Tatham, R.L., Anderson, R.E. and Black, W. (1998), *Multivariate Data Analysis*, Prentice-Hall, 5th edition, New York.

- Hamilton, L.C. (1992), *Regression with graphics: A second course in applied statistics*, Pacific Grove, California.
- Howard, M., Miemczyk, J. and Graves, A. (2006), "Automotive supplier parks: An imperative for build-to-order?", *Journal of Purchasing and Supply Management*, Vol. 12 No. 2, pp. 91-104.
- Jack, E.P. and Raturi, A. (2002), "Sources of volume flexibility and their impact on performance", *Journal of Operations Management*, Vol. 20 No. 5, pp. 519-548.
- Jin, B. (2004), "Achieving an optimal global versus domestic sourcing balance under demand uncertainty", *International Journal of Operations and Production Management*, Vol. 24 No. 12, pp. 1292-1305.
- Johnson, D. (2002), "Empirical study of second-tier automotive suppliers achieving QS-9000", *International Journal of Operations and Production Management*, Vol. 22 No. 8, pp. 902-928.
- Kaplan, S. and Sawhney, M. (2000), "E-hubs: The new B2B marketplaces", *Harvard Business Review*, Vol. 78 No. 3, pp. 97-102.
- Kerrigan, R., Roegner, E., Swinford, D., Dennis, D. and Zawada, C. (2001), "B2B basics", *McKinsey Quarterly*, No. 1; pp. 44-54.
- Krajewski, L., Wei, J. and Tang, L.L. (2005), "Responding to schedule changes in build-to-order supply chains", *Journal of Operations Management*, Vol. 23, No. 5, pp. 452-469.
- Krause, D.R., Pagell, M. and Curkovic, S. (2001), "Toward a measure of competitive priorities for purchasing", *Journal of Operations Management*, Vol. 19 No. 4, pp. 497-512.
- Lee, H.L. (2002), "Aligning supply chain strategies with product uncertainties", *California Management Review*, Vol. 44 No. 3, pp. 105-119.
- Lee, H.L. (2004), "The triple-A supply chain", *Harvard Business Review*, Vol. 82 No. 10, pp. 102-112.
- Lummus, R.R. and Vokurka, R.J. (1999), "Defining supply chain management: a historical perspective and practical guidelines", *Industrial Management and Data Systems*, Vol. 99 No. 1, pp. 11-17.
- Magretta, J. (1998), "The power of virtual integration: An interview with Dell Computer's Michael Dell", *Harvard Business Review*, Vol. 76, No. 2, pp. 72-84.

- Malhotra, N.K. (1996), *Marketing Research: An applied orientation*, 2nd edition, Englewood Cliffs, Prentice-Hall, New Jersey.
- Mason, C.H. and Perrault, W.D. (1991), “Collinearity, power and interpretation of multiple regression analysis”, *Journal of Marketing Research*, Vol. 28 No. 3, pp. 268-280.
- Minner, S. (2003), “Multiple-supplier inventory models in supply chain management: A review”, *International Journal of Production Economics*, Vol. 81-82 No. 11, pp. 265-279.
- Narasimhan, R. and Das, J. (2000), “An empirical examination of sourcing’s role in developing manufacturing flexibilities”, *International Journal of Production Research*, Vol. 38 No. 4, pp. 875-893.
- Narasimhan, R., Swink, M. and Kim, S.W. (2006), “Disentangling leanness and agility: An empirical investigation”, *Journal of Operations Management*, Vol. 24 No. 5, pp. 440-457.
- Nassimbeni, G. (2003), “Local manufacturing systems and global economy: Are they compatible? The case of the Italian eyewear district”, *Journal of Operations Management*, Vol. 21 No. 2, pp. 151-171.
- Peleg, B., Lee, H.L. and Haussman, W.H. (2002), “Short-term e-procurement strategies versus long-term contracts”, *Production and Operations Management*, Vol. 11 No. 4, pp. 458-479.
- Ponce, E. and Prida, B. (2004), *La logística de aprovisionamientos para la integración de la cadena de suministros*, Pearson Educación, Madrid.
- Porter, M.E. (1985), *Competitive advantage*, Free Press, New York.
- Prater, E., Biehl and M., Smith, M.A. (2001), “International supply chain agility: Tradeoffs between flexibility and uncertainty”, *International Journal of Operations and Production Management*, Vol. 21, No. 5/6, pp. 823-839.
- Pujawan, N. (2004), “Assessing supply chain flexibility: a conceptual framework and a case study”, *International Journal of Integrated Supply Management*, Vol. 1 No. 1, pp. 79-97.
- Quayle, M. (1998), “Industrial procurement: Factors affecting sourcing decisions”, *European Journal of Purchasing and Supply Management*, Vol.4 No. 1, pp. 199-205.

- Saeed, K.A., Malhotra, M.K. and Grover, V. (2005), "Examining the impact of interorganizational systems on process efficiency and sourcing leverage in buyer-supplier dyads", *Decision Sciences*, Vol. 36 No. 3, pp. 365-396.
- Sawhney, R. (2006), "Interplay between uncertainty and flexibility across the value-chain: Towards a transformation model of manufacturing flexibility", *Journal of Operations Management*, Vol. 24 No. 5, pp. 476-493.
- Smith, J.M. (1999), "Item selection for global purchasing", *European Journal of Purchasing and Supply Management*, Vol. 5 No. 1, pp. 117-127.
- Stevens, G.C. (1989), "Integrating the supply chain", *International Journal of Physical Distribution and Materials Management*, Vol. 19 No .8, pp. 3-8.
- Stratton, R. and Warburton, R.D.H. (2003), "The strategic integration of agile and lean supply", *International Journal of Production Economics*, Vol. 85 No. 2, pp. 183-198.
- Suarez, F., Cusumano, M.A. and Fine, C.H., (1996), "An empirical study of manufacturing flexibility in printed circuit board assembly", *Operations Research*, Vol. 44 No. 1, pp. 223-241.
- Swafford, P., Ghosh, S. and Murthy, N. (2006), "The antecedents of supply chain agility of a firm: Scale development and model testing", *Journal of Operations Management*, Vol. 24 No. 2, pp. 170-188.
- Swafford, P., Ghosh, S. and Murthy, N. (2006), "A framework for assessing value chain agility", *International Journal of Operations and Production Management*, Vol. 26 No. 2, pp. 118-140.
- Upton, D.M. (1994), "The management of manufacturing flexibility", *California Management Review*, Vol. 36, No. 2, pp. 72-89.
- Upton, D.M. (1997), "Process range in manufacturing", *Management Science*, Vol. 43 No. 8, pp. 1079-1092.
- Van Der Vaart, J.T., De Vries, J. and Wijngaard, J. (1996), "Complexity and uncertainty of materials procurement in assembly situations", *International Journal of Production Economics*, Vol. 46-47, pp. 137-152.
- Van der Vaart, T. and Van Donk, D.P. (2004), "Buyer focus: Evaluation of a new concept for supply chain integration". *International Journal of Production Economics*, Vol. 92 No. 1, pp. 21-30.

- Van Donk, D.P. and Van der Vaart, T. (2005), "A case of shared resources, uncertainty and supply chain integration in the process industry", *International Journal of Production Economics*, Vol. 96 No. 1, pp. 97-108.
- Vickery, S., Calantone, R. and Dröge, C. (1999), "Supply chain flexibility: an empirical study", *The Journal of Supply Chain Management*, Vol. 35 No. 1, pp. 16-24.
- Wei, J. and Krajewski, L. (2000), "A model for comparing supply chain schedule integration approaches", *International Journal of Production Research*, Vol. 38 No. 9, pp. 2099-2123.
- Womack, J.P., Jones and D.T., Roos, D. (1990), *The Machine that Changed the World*, Macmillan Publishing Company, New York, NY.
- Zeng, A.Z. (2000), "A synthetic study of sourcing strategies", *Industrial Management & Data Systems*, Vol. 100 No. 5, pp. 219-226.
- Zhang, Q., Vonderembse, M.A. and Lim, J. (2002), "Value chain flexibility: a dichotomy of competence and capability", *International Journal of Production Research*, Vol. 40 No. 3, pp. 561-583.

Appendix A. 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.

A.1. Flexibility sources

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

- (15) We use multiple suppliers.
- (16) We use local (i.e. same country) suppliers.
- (17) We collaborate intensely with the suppliers (sharing information, forming cross-functional teams, joint planning, etc).
- (18) We involve the suppliers in joint product development activities.
- (19) We select the suppliers based on their flexibility (slack capacity, responsiveness, etc).
- (20) We use flexible contracts (backup agreements, quantity-flexible contracts).
- (21) We use long-term relationships with suppliers.
- (22) We collaborate with the inbound logistics provider.
- (23) We use alternative transportation modes.
- (24) We use e-marketplaces to search alternative suppliers.
- (25) We collaborate intensely with other areas within our firm (production, logistics, etc).
- (26) We use Information Technology planning tools (Supply Chain Planning, Suppliers Relationship Management, etc) and/or Electronic Data Interchange (EDI) with the suppliers.
- (27) We use inventory buffers.

- (28) We use other sources of supply flexibility. Which one (s)?

A.2. Supply uncertainty

Use a 10-point scale for each (1 = never; 10 = very frequently).

- (4) The suppliers deliver the required quantity.
- (5) The suppliers deliver in the required date.
- (6) The suppliers deliver the required specification/configuration.

A.3. Demand uncertainty

Use a 10-point scale for each (1 = never; 10 = very frequently).

- (4) The required quantities fluctuate drastically from week to week (for example: to change orders from 10 to 100 units)- *Volume uncertainty*.
- (5) The required specification/configuration fluctuates drastically from week to week (for example: to change order specification from “blue” to “red”) - *Mix uncertainty*.
- (6) The required lead-times vary drastically from week to week (for example: to anticipate an order) - *Delivery uncertainty*.

A.4. Technology uncertainty

Use a 10-point scale for each (1 = never; 10 = very frequently).

- (4) Our sector is characterized by rapidly changing technologies.
- (5) Technological changes provide big opportunities in our industry.
- (6) It is very difficult to predict where technology in our industry will be in 3-5 years.

A.5. 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:

- (5) Range of supplier delivery frequencies (daily, weekly, etc).

- (6) Range of possible order sizes from suppliers.
- (7) Extent to which supplier lead-time can be expedited/changed.
- (8) Extent to which supplier short-term capacity can be influenced.

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:

- (6) Change quantity of supplier's order.
- (7) Change specification/configuration of supplier's order.
- (8) Influence supplier's ability to implement engineering change orders.
- (9) Change delivery times of orders placed with suppliers.
- (10) Influence supplier's short-term capacity.

A.6. Flexibility focus

Using a 10-point scale (1 = unimportant; 10 = critical), please indicate the level of the following characteristic:

- (1) Which is the importance of flexibility in the sourcing strategy of your business unit?

A.7. Supplier searching and switching costs

In the supplier selection stage:

Using a 10-point scale (1 = very simple; 10 = very complicated), please indicate the level of difficulty of each item:

- (6) Identifying a supplier capable of delivering this material is:
- (7) Establishing the contractual details of the relationship is:

After supplier selection:

Using a 10-point scale (1 = never; 10 = very frequently), please indicate the frequency of each activity:

- (8) We adapt our products/tools/processes to use the material from each supplier

Using a 10-point scale (1 = low; 10 = very high), evaluate the level of each characteristic:

(9) The time/effort dedicated to learn the specific processes of each supplier (commercial procedures, logistical processes).

(10) The time/effort dedicated to develop the relationship with each supplier (visits, dedicated buyers, etc).

A.8. Annual revenue (million euros)

- (1) Less than 1 (2) Between 1 and 49 (3) Between 50 and 99
(4) Between 100 and 499 (5) More than 500

Appendix B. The matrix of correlation coefficients

Supply flexibility sources

	SRC1	SRC2	SRC3	SRC4	SRC5	SRC6	SRC7	SRC8	SRC9	SRC10	SRC11	SRC12
Multiple sourcing (SRC1)	-											
Domestic sourcing (SRC2)	-0,10	-										
Supplier integration (SRC3)	-0,01	0,26*	-									
Joint product development with suppliers (SRC4)	-0,20	0,31**	0,66**	-								
Supplier selection (SRC5)	0,05	0,35**	0,23*	0,27*	-							
Flexible supply contracts (SRC6)	-0,03	0,17	0,23*	0,25*	0,31**	-						
Long-term relationships with suppliers (SRC7)	-0,05	0,23*	0,20	0,29**	0,12	0,24*	-					
Third-party logistics providers (SRC8)	0,06	-0,03	0,19	0,05	0,04	0,25*	0,03	-				
Alternative transportation modes (SRC9)	0,22*	-0,19	0,02	-0,15	0,02	0,23*	-0,26 *	0,30**	-			
E-marketplaces (SRC10)	0,16	-0,17	0,09	-0,10	-0,03	0,19	-0,21	0,09	0,29**	-		
Internal integration (SRC11)	-0,11	0,29**	0,43**	0,44**	0,14	0,27*	0,12	0,18	-0,08	0,03	-	
Electronic integration (SRC12)	-0,12	-0,03	0,18	0,11	-0,05	0,28**	0,08	0,23*	-0,10	0,01	0,14	-
Inventory buffers (SRC13)	0,15	-0,02	0,15	0,13	0,16	0,03	0,17	-0,06	0,07	0,04	0,01	-0,06

*Signif. 0.05; **Signif. 0.01 (2-tailed)

CHAPTER 5: CONCLUSION

This thesis aimed to contribute to the empirical research on flexibility in supply chains. In particular, the main theme of this thesis was the relationship between uncertainty, integration and supply flexibility. The thesis was divided into three main parts. In the *first paper*, a multiple case study was performed, in order to investigate the inter-play between the drivers and sources of supply flexibility. The *second paper* of the thesis provided a taxonomy of supply flexibility strategies, through a cluster analysis. Finally, in the *third paper* we assessed the effectiveness of sourcing practices with respect to supply flexibility.

In the **first paper**, an exploratory multiple case study was conducted, in order to better understand the supply flexibility construct. In particular, we aimed to identify empirically the drivers and sources of supply flexibility, i.e. the *whys* and *hows* of supply flexibility. Moreover, the relationship between drivers and sources was identified. An important result of the paper was the identification of two patterns of sources: firms may seek supply flexibility by “improving supplier responsiveness” (single sourcing, a high level of internal and external integration, co-location of suppliers and supplier selection), or by adopting a “flexible sourcing” (a larger supply base, lower levels of supplier responsiveness and faster supply network redesign). In addition, some managerial practices were adopted by firms in both groups. We also noted that the supplier switching costs could be a significant variable to explain why a firm follows a particular strategy.

The results of the first paper, although promising, called for more exhaustive empirical evidence. Accordingly, the next step in our research was to gather quantitative data with a larger sample of firms to achieve more general conclusions. The instrument for quantitative data gathering was an online survey, submitted to the members of the Spanish Association of Purchasing Managers (AERCE). The dataset obtained was used to conduct the analysis presented in the second and third paper of the thesis. In the preliminary analysis of the dataset, an exploratory factor analysis was conducted. The objective was to identify the underlying dimensions of the constructs involved in the study. Three dimensions of supply flexibility were identified: adaptability, delivery policy and supplier responsiveness. These dimensions coincide partially with previous studies (Swafford *et al.*, 2006). Another exploratory factor analysis was conducted for the environmental variables. Four dimensions were identified: demand uncertainty, supply uncertainty, technology uncertainty and supplier switching costs.

The aim of the **second paper** was to elaborate a taxonomy of supply flexibility strategies. These strategies are depicted in terms of sets of flexibility sources used jointly by the firms in the sample. To identify these strategies a cluster analysis was conducted. The results show that three clusters can be identified: “integrated”, “domestic” and “offshore”. The “integrated” cluster applied domestic sourcing, supplier integration, supplier selection, flexible contracts, long-term relationships, internal integration and electronic integration. The “domestic” cluster used domestic sourcing and supplier selection. The “offshore” cluster relied on integration with third-party logistics providers and alternative modes of transportation. Another conclusion was that all groups employ some sort of external or internal integration to achieve supply flexibility. Similarly to the first paper, some sourcing practices were used by members of all groups. Furthermore, we verified that the “integrated” cluster presented superior supply flexibility with respect to the “domestic” and “offshore” clusters, but also a greater investment in integration initiatives. The results added to the literature on supply chain integration by suggesting that there could be a trade-off between the costs of integration and supply flexibility, corroborating previous studies that posit an “optimal” level of integration (Das *et al.*, 2006).

The **third paper** analysed the effectiveness of the supply flexibility sources, i.e. the relationship between the utilization of supply flexibility sources and the level of supply flexibility obtained. Although some sources are used jointly (as described in the second paper), the objective of the third paper was to identify which sources are more effective to achieve the different dimensions of supply flexibility. The multiple regression results suggested a complex relationship, depending on which supply flexibility source and dimension of supply flexibility were considered. For example, the first supply flexibility dimension (supplier responsiveness) had a positive relationship with domestic sourcing, internal integration and supplier integration. Furthermore, the second supply flexibility dimension (delivery policy) was positively associated with the use of flexibility-based supplier selection criteria. Nevertheless, the relationship between the flexibility sources and the third dimension of supply flexibility (adaptability) was more intricate. Although being positively associated with electronic integration (i.e. EDI, supply chain planning software, etc) and alternative means of transportation (i.e. aerial, maritime, etc), adaptability was negatively associated with the integration with the logistics provider. In the paper, some reasons were provided to explain these relationships. This paper also contributed to the ongoing debate about the

effects of integration on flexibility (Jack and Raturi, 2002; Das *et al.*, 2006), by decomposing the effects of different types of integration on each dimension of supply flexibility. In particular, we observed a significant effect of several dimensions of integration (supplier, internal or physical) on the first dimension of supply flexibility (supplier responsiveness), and a significant effect of electronic integration on the third dimension of supply flexibility (adaptability). However, no significant effect was detected on the second dimension of supply flexibility (delivery policy).

When comparing these results with the second paper, we note that they are complementary. Whereas the second paper identifies three ways to combine the sources, the third paper analyses the effects of each source on supply flexibility. Therefore, while the second paper considers the “integrated” strategy as generating a higher level of supply flexibility, the third paper recognizes the sources “domestic sourcing”, “internal integration”, “supplier selection”, “alternative modes of transportation” and “electronic integration” as more effective in achieving supply flexibility.

There are some **common results** among the papers of the thesis. First, there is not a single approach to increase supply flexibility. The different sourcing practices have different effects on different dimensions of supply flexibility, and firms apparently combine those practices to form supply flexibility strategies. Second, there are evidences that integration is positively associated with supply flexibility. However, the significance and level of this relationship depends on the dimension of the integration considered (e.g. physical, supplier, internal, etc). Lastly, long-term relationships and inventory buffers seem to have a positive effect on supply flexibility, for all firms studied.

Moreover, we can contrast the results of the first and second paper of the thesis. In particular, there seems to be a correspondence between the strategies suggested by both. For example, the “improved supplier responsiveness” strategy identified in the first paper resembles the “integrated” strategy of the second paper (supplier and internal integration, domestic sourcing). Similarly, the “flexible sourcing” strategy of the first paper presents some points in common with the “offshore” strategy of the second paper (lower supplier responsiveness and less domestic sourcing). The “domestic” strategy had some characteristics of the “improved supplier responsiveness” strategy (e.g. domestic sourcing and supplier selection), but missed others (e.g. supplier integration). In that sense, it could be considered as an “alternative version” of the “improved supplier responsiveness” strategy.

Some **limitations and further lines of research** were shared among the papers of this thesis. First, there could be a context bias, since firm samples presented a limited environment differentiation (i.e. industries, countries, etc). Second, although the statistical procedures suggest sufficient validity, the sample size should be larger in further studies, to increase the generalizability of the results. This would permit the use of more sophisticated statistical confirmatory techniques, such as Structural Equation Modelling (SEM). Third, the use of single-informants is a potential source of bias. Accordingly, further studies considering multiple informants would be an interesting extension to be addressed. Fourth, the study of the dyadic relationship buyer-supplier would permit the analysis of a wider range of managerial practices, e.g. buyer-focused operations (Van der Vaart and Van Donk, 2004). Lastly, researchers should explore other variables that could explain how firms select their supply flexibility approaches, e.g. power and dependency (Caniels and Gelderman, 2005).

Furthermore, some limitations are specific to the third paper. First, an interesting extension would be to perform separate regressions for each flexibility cluster. In this study, we did not perform this analysis because of the reduced sample size for each cluster. Second, cross-sectional studies may assume causal relationships among variables that may not correspond to reality. Thus, causal relationships should be further confirmed using longitudinal studies.

From a managerial viewpoint, supply flexibility has significant implications. The flexibility of supply chains has been tested in the past years by major disruptions including wars, terrorist attacks and natural disasters. During such events, some manufacturers have been able to continue operations with minimal impact on their processes while other companies have experienced delays or complete shutdowns. Indeed, from a macro level, supply chain flexibility is a source of country economic resilience. Fred Smith, the founder of FedEx, said economic corrections had become shallower and less prolonged during the past century (Freeland and Ward, 2006). And one of the reasons has been the capacity of modern supply chains to respond in a timely and cost effective manner to changing requirements of purchased components.

Additional references

- Caniels, M.C.J and Gelderman, C.J. (2005), "Purchasing strategies in the Kraljic matrix – A power and dependence perspective", *Journal of Purchasing and Supply Management*, Vol. 11 pp. 141-155.
- Chen, I.J. and Paulraj, A. (2004), "Towards a theory of supply chain management: The constructs and measurements", *Journal of Operations Management*, Vol. 22 No. 2, pp. 119-150.
- Christopher, M., 1998. *Logistics and Supply Chain Management: Strategies for Reducing Costs and Improving Service*, 2nd Ed. Financial Times /Pitman Publishing, London.
- Das, A., Narasimhan, R. and Talluri, S. (2006), "Supplier integration – Finding an optimal configuration", *Journal of Operations Management*, Vol. 24 No. 5, pp. 563-582.
- Duclos, L.K., Vokurka, R.J. and Lummus, R.R. (2003), "A conceptual model of supply chain flexibility", *Industrial Management & Data Systems*, Vol. 103 No. 6, pp. 446-456.
- Eisenhardt, K.M. (1989), "Building theories from case study research", *Academy of Management Review*, Vol. 14 No. 4, pp. 532-550.
- Freeland, C. and Ward, A. (2006), "FedEx founder credits supply-chain flexibility parcel freight", *Financial Times*, November, pp.23-23.
- Frohlich, T. and Westbrook, R. (2001), "Arcs of integration: an international study of supply chain strategies". *Journal of Operations Management*, Vol. 19 No. 2, pp. 185-200.
- Gimenez, C. and Ventura, E. (2005), "Logistics-production, logistics-marketing and internal integration", *International Journal of Operations and Production Management*, Vol. 25 No. 1, pp. 20-38.
- Gingsberg, A. and Venkatraman, N. (1985), "Contingency perspectives of organizational strategy: a critical review of the empirical research", *Academy of Management Review*, Vol. 10 No. 3, pp. 421-434.
- Hayes, R.H. and Wheelwright, S.C. (1984), *Restoring our competitive edge: Competing through manufacturing*, John Wiley & Sons, New York, NY.
- Jack, E.P. and Raturi, A. (2002), "Sources of volume flexibility and their impact on performance", *Journal of Operations Management*, Vol. 20 No. 5, pp. 519-548.

- Mentzer, J.T. and Flint, D.J. (1997), "Validity in Logistics Research", *Journal of Business Logistics*, Vol. 18 No. 1, pp. 199-216.
- Miles, M.B. and Huberman, A.M. (1994), *Qualitative Data Analysis*, 2nd Ed., Sage, Newbury Park, CA.
- Milliken, F.J. (1987), "Three types of perceived uncertainty about the environment: state, effect and response uncertainty", *Academy of Management Review*, Vol. 12 No. 1, pp. 133-143.
- Slack, N. (1983), "Flexibility as a manufacturing objective", *International Journal of Operations and Production Management*, Vol. 7 No. 4, pp. 35-45.
- Stank, T.P., Keller, S.B. and Daugherty, P.J. (2001), "Supply chain collaboration and logistical service performance", *Journal of Business Logistics*, Vol. 22 No. 1, pp. 29-48.
- Swafford, P., Ghosh, S. and Murthy, N. (2006), "The antecedents of supply chain agility of a firm: Scale development and model testing", *Journal of Operations Management*, Vol. 24 No. 2, pp. 170-188.
- Swamidass, P.M. and Newell, W.E. (1987), "Manufacturing strategy, environmental uncertainty and performance: A path analytic model", *Management Science*, Vol. 33 No. 4, pp. 509-524.
- Upton, D.M. (1994), "The management of manufacturing flexibility", *California Management Review*, Vol. 36, No. 2, pp. 72-89.
- Van der Vaart, T. and Van Donk, D.P. (2004), "Buyer focus: Evaluation of a new concept for supply chain integration". *International Journal of Production Economics*, Vol. 92 No. 1, pp. 21-30.
- Voss, C., Tsikriktsis, N. and Frohlich, M. (2002), "Case research in operations management", *International Journal of Operations and Production Management*, Vol. 22 No. 2, pp. 195-219.