Risk Uncertainty and Supply Chain Decisions: A Real Options Perspective

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ABSTRACT

Supply chain risk uncertainty can create severe repercussions, thus it is not surprising that research interest in supply chain risk has been growing. While extant inquiry is informative, there is a lack of investigations that center on supply chain investment decisions when facing high levels of risk uncertainty. Given the potential dollar value involved in these decisions, an understanding of how these supply chain decisions are made is of significant theoretical and practical importance. Real options theory, with its focus on decision making under conditions of uncertainty, is an appealing theoretical lens for this endeavor. In essence, real options theory asserts that managerial decisions center on creating and then exercising or not exercising certain opportunities. To date, theorizing about and investigations of real options have used firms as their focus. Not yet examined are real options within supply chains that cross firm boundaries and drive much of the competitive activity in the modern economy. Accordingly, we extend real options theory to the supply chain context by examining how different types of options are approached relative to supply chain project investments. Specifically, we theorize how the options will be related to perceived value under conditions of high supply chain risk uncertainty. Overall, our investigation builds knowledge by extending real options theory to the supply chain context and by providing evidence suggesting some options operate differently in supply chains than they do in firms.

Subject Areas: Postponement, Projects, Real Options Theory, Supply Chain Risk, Supply Chain Uncertainty, and Survey Research.

INTRODUCTION

Huge stakes are often involved in supply chain decisions. Bad supply chain decisions led Cisco, for example, to write off $2.25 billion in inventory in 2001 (Lee, 2004). Similarly, poor design and manufacturing decisions created a $2.8

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billion loss for Pfizer (Johnson, 2007). In an effort to cut costs, Boeing outsourced the design and manufacture of major sections of a new aircraft that ultimately culminated in defective aircraft components; severe product delivery delays; and additional, unplanned expenditures in excess of $2 billion (Lunsford, 2007). Ironically, this global outsourcing strategy was used as a selling point to its investors (Lunsford, 2007)—investors who normally experience the negative repercussions of these types of situations. Announcements of supply chain problems, on average, decrease shareholder value by 10.28% (Hendricks & Singhal, 2003) and can, in the longer term, result in a mean abnormal return of nearly −40% coupled with significant increases in equity risk (Hendricks & Singhal, 2005).

Given these potential negative repercussions, it is not surprising that there is a growing interest in supply chain decisions and the accompanying risk and uncertainty (e.g., Blackhurst, Craighead, Elkins, & Handfield, 2005; Swink & Zsidisin, 2006; Craighead, Blackhurst, Rungtusanatham, & Handfield, 2007; Hendricks, Singhal, & Zhang, 2009). However, while there has been significant effort to assess supply chain risk (e.g., Zsidisin, 2003; Zsidisin, Ellram, Carter, & Cavinato, 2004), there has been a lack of studies that capture managerial thinking when faced with high levels of supply risk. Thus, we believe that understanding how such supply chain decisions are made is of significant theoretical and practical importance.

Real options theory with its focus on risk uncertainty appears to be a valuable theoretical lens for this endeavor. The central premise of real options theory is that managerial decisions revolve around creating and then exercising or not exercising certain options. Having the flexibility provided by options is advantageous when facing uncertainty (i.e., unpredictability of environmental or organizational variables; Thompson, 1967). To the extent that uncertainty surrounds a decision, managers prefer to postpone major investments while maintaining the potential to exercise the option by moving more boldly at some future point (Myers, 1977). In recent years, researchers have used real options to analyze firms' investments in areas such as research and development (Oriani & Sobrero, 2008), knowledge (Wang & Lim, 2008), and technology (McGrath & Nerkar, 2004).

Despite its popularity, Tiwana, Wang, Keil, and Ahluwalia (2007) noted that empirical investigations of real options at the firm level are scarce. In the context of supply chains, there appear to be none. This is surprising because uncertainty is commonplace in contemporary supply chains (e.g., Geary, Childerhouse, & Towill, 2002), and there is anecdotal evidence that at least some managers behave consistent with the central premise of real options theory when making supply chain decisions. Consider the examples of Benetton, Whirlpool, and Hewlett Packard (HP). Benetton redesigned its supply chain to delay the dyeing of its garments until demand uncertainty was reduced—the delaying of this activity resulted in enhanced customer responsiveness and reduced costs (Dapiran, 1992). Whirlpool redesigned its distribution process to delay the shipments of appliances until customer orders were received—this redesign resulted in significant reductions in inventory and transportation costs (Waller, Dabholkar, & Gentry, 2000). HP moved the final assembly of its DeskJet printers to a later stage in the supply chain, which reduced uncertainties associated with demand and distribution; this redesign initiative reduced various supply chain costs (Feitzinger & Lee, 1997). In each of

these examples, supply chain uncertainty was present, and managers responded by delaying a key supply chain activity. This is often referred to as "postponement" (Bucklin, 1965; Van Hoek, 2001).

Postponement may take many forms, including price postponement (Van Mieghem & Dada, 1999), production postponement (Bucklin, 1965), purchasing postponement (Yang, Burns, & Backhouse, 2004), packaging postponement (Zinn & Bowersox, 1988), and distribution postponement (Waller et al., 2000). Regardless of the form, the key motivation behind postponement is to enable better informed decisions by delaying supply chain investments or activities in the hope of reducing uncertainty (Bucklin, 1965; Boone, Craighead, & Hanna, 2007). The extant research on postponement is informative, yet opportunities exist to further its maturation (see Van Hoek, 2001 and Boone et al., 2007 for reviews of the postponement research). One of the key research needs is to empirically link postponement with uncertainty (Boone et al., 2007). Additionally, Van Hoek (2001) called for the expansion of postponement to other aspects of the supply chain. For example, there is a notable absence of studies that have analyzed the postponement of investments in various supply chain projects. Further, the postponement of investments may take on various forms, or options, each of which may offer value. Yet, how these different types of options operate within supply chains in general remains unknown.

Accordingly, our article is aimed at helping close the gap between what we know and what we need to know about the implications of supply chain uncertainty for delayed supply chain project investments. Specifically, we attempt to build knowledge by examining how supply chain managers approach six important options—unlocking, stage, scale, switch use, deferral, and abandonment (Fichman, Keil, & Tiwana, 2005; Tiwana et al., 2007). We extend real options theory by adapting these six options to the supply chain context and then test the resulting predictions.

THEORY AND HYPOTHESES

Managers often must make decisions under uncertain conditions. This uncertainty may be derived from various sources. Endogenous uncertainty resides in the firm and may be mitigated by managerial responses (Dixit & Pindyck, 1994). On the other hand, exogenous uncertainty originates outside the firm. Exogenous uncertainty thus lies beyond the reach of managerial control (Dixit & Pindyck, 1994), although it may be reduced over time as events unfold. The portion of uncertainty that may reduce over time is referred to as risk uncertainty (a.k.a. Newtonian uncertainty) and not genuine uncertainty (Scherpereel, 2008). In this study, we center on risk uncertainty; however, for ease of discussion, we will often refer to it as simply "uncertainty."

Uncertainty inherent in the supply chain has an exogenous element for any given participant because the chain's functioning depends not only on that participant but also on others. These other participants share with our focal participant certain supply chain–level goals and motives, but they also each have their own goals and motives that may conflict with those of the chain as a whole (Hult, Ketchen, & Arrfelt, 2007). The mixed-motive nature of supply chain relationships

has been the catalyst for many strategic supply chain initiatives (e.g., various forms of postponement) wherein key supply chain activities are delayed until supply chain uncertainty is reduced. The delaying of an activity is consistent with the central premise of real options theory.

Real options theory contends that uncertainty may be reduced over time and therefore better-informed investment decisions may be made (Dixit & Pindyck, 1994). This motivates decision makers to delay making investments (McGrath, Ferrier, & Mendelow, 2004). There are six main options offered by the growing literature on real options: unlocking, stage, deferral, scale, switch use, and abandonment (Fichman et al., 2005; Tiwana et al., 2007). An *unlocking* option (extant research also refers to this option as a *growth* option; e.g., Tiwana et al., 2007) is present when an investment creates the opportunity for future opportunities or allows for the development of future capabilities (Kogut & Kulatilaka, 2001). A *stage* option allows an investment or project to be completed incrementally (Majd & Pindyck, 1987). A *deferral* option allows an investment to be postponed to a later point in time (Miller & Folta, 2002). A *scale* option allows for investments or projects to be expanded (Fichman et al., 2005) while a *switch use* option allows for investments to be redeployed (Trigeorgis, 1993). Finally, an *abandonment* option is present if the investment or project can be terminated and remaining funds used elsewhere (Hubbard, 1994).

According to real options theory, managers will look beyond the net present value (NPV) of an investment and consider the strategic value of the options offered by an investment or project. However, managers appear to be prone to exhibit systematic biases when evaluating options. Building on the work of Nobel Laureate Herbert Simon (e.g., March & Simon, 1958; Simon, 1979), Tiwana et al. (2007) found evidence that managers demonstrate a bounded rationality bias when making decisions. Bounded rationality in decision making involves satisficing, which denotes that managers will search for pertinent information until it is believed that they have enough data to make an acceptable decision, even if additional information is available that could lead to an optimized decision (Simon, 1979). In the context of real options, Tiwana et al. (2007) found evidence that managers, in some cases, will satisfice by not considering their options if a project's NPV is high, but they do consider options (i.e., continue to search) when a project has a low NPV.

Compared to past research, we theorize that some options will be perceived differently for supply chain decisions—we organized our hypotheses based on how we theorize the options will be perceived. However, managers are subject to satisficing regardless of the context (Simon, 1979), leading us to expect that supply chain managers will exhibit a bounded rationality bias when considering each of the options.

Unlocking Options

An unlocking option is present when a project creates the likelihood for future strategic opportunities or allows for the development of future capabilities (e.g., Kogut & Kulatilaka, 2001). In past research (e.g., Tiwana et al., 2007), the appeal of unlocking options was expected to be related to uncertainty. However, we contend

that unlocking options will be considered in supply chain projects regardless of the level of uncertainty. For firms to compete, they must invest in their supply chain, particularly to the extent that competition is evolving to be supply chain versus supply chain as opposed to firm versus firm (e.g., Slone, 2004; Hult et al., 2007). In many cases, supply chain projects are competitive necessities.

For example, consider the strategic initiative efficient consumer response found in the grocery industry. Firms had to invest in supply chain technology and distribution systems to reduce the substantial efficiencies found within grocery supply chains. Those firms that did not invest in their supply chains would not develop the capabilities of their counterparts and would, therefore, be less competitive. Supply chain projects do not necessarily have to be linked to industry initiatives. For example, electronic data interchange (EDI), a process wherein supply chain members share information digitally, became commonplace in many automotive companies. Those suppliers who wished to stay attractive to the big auto manufacturers needed to develop EDI capabilities to unlock future business.

Supply chain projects may also be required to foster a specific supply chain initiative. Consider a firm that wishes to pursue a global sourcing strategy from low-cost countries (LCC). For the firm to realize this effort, it may be necessary for it to invest in a distribution facility or even the infrastructure of LCC-based suppliers. Therefore, managers likely perceive projects with embedded unlocking options as valuable regardless of the level of uncertainty. However, we still theorize that a bounded rationality bias is present for unlocking options, leading NPV to be a key factor. Hence, we predict

> *H1:* *When supply chain projects are perceived to have a low NPV, embedded unlocking options will be positively related to the perceived value of a project.*

Staging and Deferral Options

In the presence of uncertainty, a staging option can be attractive as it allows a project to be funded or completed incrementally (e.g., Majd & Pindyck, 1987). If the project can be funded or completed incrementally, the supply chain manager has the option to continue to a subsequent stage if the project provides desirable interim outcomes (Huchzermeier & Loch, 2001; Tiwana et al., 2007). Conversely, if the initial stage does not offer desirable outcomes, investments could cease and losses would be limited to the initial outlay of funds (Fichman et al., 2005; Tiwana et al., 2007).

Consider a firm that is managing a large volume of product flow originating from overseas sources of supply. Because tracking items through the supply chain is a challenge in this situation, the firm may consider a supply chain project to implement radio frequency identification (RFID) tracking devices. This type of supply chain project would allow for staging in that RFID could be implemented in a portion of the supply chain and then evaluated for its effectiveness after uncertainty is reduced. Whereas staging allows the project to be completed incrementally, a deferral allows investment to be postponed to a later point in time (e.g., Miller & Folta, 2002). As long as the opportunity costs are not high (Folta & O'Brien, 2004), delaying investments in a project can be appealing as the delay

allows the manager to make better-informed decisions due to uncertainty reduction and thus better information (Bendoly & Swink, 2007). In both staging and deferral, we theorize that a bounded rationality bias is present, leading NPV to be a key consideration. Hence, we predict

> H2: *When supply chain projects are perceived to have a low NPV, there will be a significant interaction between supply chain risk uncertainty and embedded staging options. This interaction will be positively related to the perceived value of a project.*

> H3: *When supply chain projects are perceived to have a low NPV, there will be a significant interaction between supply chain risk uncertainty and embedded deferral options. This interaction will be positively related to the perceived value of a project.*

Scale, Switch Use, and Abandonment Options

A scale option allows for investments or projects to be expanded (Fichman et al., 2005); a switch use option allows for investments to be redeployed (Trigeorgis, 1993); and an abandonment option is present when the investment or project can be terminated, freeing up remaining funds to be used elsewhere (Hubbard, 1994). These three options are likely perceived to be valuable when NPV is low and uncertainty is high (Tiwana et al., 2007). However, in the context of supply chain projects, we theorize that, under the same conditions, the options would be *less* desirable.

First, a key characteristic of modern supply chains is long-term strategic alliances among supply chain participants (Handfield & Nichols, 1999). Firms engaged in such alliances surrender the ability to obtain optimal pricing in each transaction and instead work toward building trust and consistency with buyers and suppliers (Slone, 2004). Abandonment and switch use options involve taking away from supply chain partners. Exercising these options could harm relationships among supply chain partners, thereby undermining trust and consistency. As a result, we contend that supply chain managers will be reluctant to use these options. In particular, managers will be reluctant to exercise abandonment and switch use options when supply chain uncertainty is high because such uncertainty means supply chain partners are already in a vulnerable state.

A second reason for switch use, abandonment, and particularly the scale option being less desirable at the supply chain level is the uncertainty and the potential negative effects to the firm. Exogenous supply chain uncertainty is beyond the reach of managerial control (Dixit & Pindyck, 1994). Not surprisingly, negative supply chain events, stemming from uncertainty, are perceived as one of the biggest threats to a firm's revenue streams (Green, 2004). Therefore, when uncertainty is high, managers would be quite reluctant to invest additional money (scale) in the supply chain. Additionally, when uncertainty is high, there is also reluctance to exercise switch use and abandonment options as this would exacerbate supply chain uncertainty and could ultimately increase the threats to the firm.

In sum, we theorize that scale, switch use, and abandonment options will be negatively perceived when supply chain uncertainty is high. We theorize that a bounded rationality bias is again present and, hence, we predict

> *H4: When supply chain projects are perceived to have a low NPV, there will be a significant interaction between supply chain risk uncertainty and embedded scale options. This interaction will be negatively related to the perceived value of a project.*

> *H5: When supply chain projects are perceived to have a low NPV, there will be a significant interaction between supply chain risk uncertainty and embedded switch use options. This interaction will be negatively related to the perceived value of a project.*

> *H6: When supply chain projects are perceived to have a low NPV, there will be a significant interaction between supply chain risk uncertainty and embedded abandonment options. This interaction will be negatively related to the perceived value of a project.*

METHOD

Data Collection Process and Study Sample

We constructed a survey to assess supply chain risk uncertainties, supply chain options, aspects of performance, and certain demographics. The mailing list was purchased from a commercial vendor. Given our focus on supply chain issues, we targeted supply chain executives as potential respondents. Through a qualifying survey sent via e-mail to the 3,912 firms in the database, we identified 823 firms that were considering or had recently considered implementing a major supply chain project (Tiwana et al., 2007). The supply chain managers in the sampling frame had titles such as vice president of distribution services, vice president of logistics, vice president of operations, vice president for transportation, vice president of worldwide supply chain, and national warehouse operations manager. The firms represented a broad cross-section of industries, such as computers, express delivery, food, retail, automotive, and defense.

Each respondent was asked to identify a recent major supply chain project to use as the reference while answering the survey. Projects could be from the areas of logistics management (e.g., distribution network analysis, transportation systems assessment), supply management (e.g., supply base rationalization, development of the supplier base), operations management (e.g., lean manufacturing, insourcing/outsourcing analysis), information technology (IT; e.g., system implementation, integration of IT systems with supply chain members), or any other supply chain projects of a major nature (e.g., implementing performance systems, integrating supply chain management into corporate strategy). A major supply chain project was defined as a project that significantly altered current supply chain practices and/or could be considered a disruptive supply chain innovation.

Prior to collecting the data, we pretested the scale items with five experts in supply chain management practices and literature. The pretest resulted in some changes being made, mainly to the instructions to the respondents. The results of the pretest also highlighted the need to keep the responses anonymous to secure high-quality study participation. As such, we opted not to code the surveys for identification purposes. We followed Huber and Power's (1985) guidelines on how

to get quality data from key informants. The survey was developed using Dillman's (2000) method and administered to supply chain executives via e-mail.

The surveys were sent to the identified supply chain manager of each of the 823 firms in the fall of 2007. Two waves of survey mailings were conducted, with 192 responding after the first wave and 81 responding after the second wave. The total responses included data from key informants from 273 firms from the sampling frame of 823 firms for an effective yielded response rate of 33.2%. Procedures recommended by Armstrong and Overton (1977) revealed no evidence of nonresponse bias. Our sampling method follows supply chain studies investigating similar phenomena and the response rate compares favorably with other strategically oriented studies of supply chain managers (e.g., Hult et al., 2007) as well as studies focused on logistics executives (e.g., Autry, Skinner, & Lamb, 2008), supply management executives (e.g., Rossetti & Choi, 2008), and operations management executives (e.g., Krause, Handfield, & Tyler, 2007).

The responding firms selected major supply chain projects in the areas of logistics management ($n = 136$, 49.8%), supply management ($n = 21$, 7.7%), operations management ($n = 22$, 8.1%), IT ($n = 44$, 16.1%), or another project ($n = 50$, 18.3%) as the focus of their survey responses. These firms had existed an average of 55.0 years (standard deviation $= 53.9$) and employed an average of 23,372 people (standard deviation $= 69,475$). The firms are primarily service oriented ($n = 157$, 57.5%) as opposed to manufacturing oriented ($n = 116$, 42.5%), with an average of 40.1% (standard deviation $= 30.1\%$) of their supply chain activities being international in scope. In terms of the respondents acting as key informants, they averaged a score of 4.26 (standard deviation $= 1.0$) on their "knowledge of the supply chain activities" involving their firms on a scale ranging from $1 = $ *strongly disagree* to $5 = $ *strongly agree* and viewed the "importance of the supply chain projected selected" as a score of 4.08 (standard deviation $= .8$) on a scale ranging from $1 = $ *not important at all* to $5 = $ *essential*.

Measures and Measurement Analysis

The Appendix includes all of the measurement items. The scales to measure supply chain options (i.e., unlocking, stage, deferral, scale, switch, and abandonment) are newly developed based on real options theory, past surveys about real options (e.g., Tiwana et al., 2007), and work in supply chain management. The supply chain risk uncertainty scale is based on work by Jaworski and Kohli (1993). Rooted in real options theory, NPV was measured as a multiplicative effect of the "relative NPV" with referent to cost versus benefits of the supply chain project times the "importance" placed on the project selected by the participants. Perceived value was measured as return on investment (ROI) for the specific supply chain project. We also included a series of four control variables that could affect our focal relationships (e.g., Amburgey & Rao, 1996) to better understand the true effects of the hypothesized relationships within the context of the firms studied (i.e., age of the firm, size of the firm in number of employees, percentage of supply chain activities that are international in scope, and if the firm was primarily service oriented or product oriented).

Table 1 reports the correlation matrix for the study constructs. Table 2 summarizes the measurement analysis and basic statistics (i.e., means, standard deviations, composite reliabilities, average variances extracted, factor loadings, and fit statistics for the confirmatory measurement analysis). All perceptual measures were subjected to assessments of reliability and validity. As such, the psychometric properties of the seven latent constructs using 21 reflective measures were evaluated simultaneously in one confirmatory factor analysis (CFA) using LISREL 8.80 (Joreskog, Sorbom, Du Toit, & Du Toit, 2000).

Fit statistics

The CFA model fit was evaluated using a series of fit indices recommended by Gerbing and Anderson (1992) and Hu and Bentler (1999)—the normed fit index (NFI), DELTA2, comparative fit index (CFI), and root mean square error of approximation (RMSEA)—along with the reporting of chi square (χ^2) and degrees of freedom (df). Using these fit indices, an excellent fit to the data was achieved in the CFA. The NFI = .91, DELTA2 = .96, CFI = .96, and RMSEA = .05 (χ^2 = 283.73, df = 168).

Composite reliability

We assessed the latent factors' reliabilities by calculating the composite reliability and their reflective measurement items along with the average variances extracted for each construct (Fornell & Larcker, 1981). We also examined the factor loadings and their *t* values (Anderson & Gerbing, 1988). The scales' reliabilities ranged from .78 to .88 with average variance extracted ranging from 54.00% to 70.67%. The factor loadings ranged from .64 to .91 ($p < .01$). Table 2 reports the complete CFA results.

Discriminant validity

The scales were also found to have good discriminant validity in that the shared variances between any pairs of constructs did not exceed 12.25% while the average variances extracted for the constructs ranged from 54.00% to 70.67%. To verify the discriminant validity obtained in comparing shared variances with average variances extracted, we employed the technique suggested by Bagozzi and Phillips (1982). This entails examining pairs of constructs in a series of two-factor CFA models using LISREL 8.80 (Joreskog et al., 2000). Specifically, each pairwise CFA model was run twice. In the first analysis, the φ coefficient was constrained to unity. In the second analysis, the φ coefficient was allowed to vary freely. Based on the results of a chi-square difference test between pairs of constructs, the unconstrained models were better than the associated constrained models (i.e., $\chi^2_{(1)} > 3.84$ was exceeded in all cases).

Common method variance

To examine the potential that common method variance would affect the results of the hypothesis testing, we employed the one-factor test presented by Podsakoff, MacKenzie, Lee, and Podsakoff (2003) within the CFA setting. The logic behind this test is that if common method variance poses a serious threat, a single latent

Table 1: Correlations and shared variances ($n = 273$).

	Unlocking	Stage	Deferral	Scale	Switch	Abandon	Uncertainty	Return on Investment (ROI)	Net Present Value (NPV)	Age	Size	Intl
Unlocking	1.00	.06	.01	.00	.00	.00	.04	.06	.09	.01	.00	.01
Stage	.25	1.00	.00	.04	.00	.02	.01	.02	.00	.00	.01	.02
Deferral	−.12	−.01	1.00	.06	.00	.12	.00	.03	.08	.01	.00	.01
Scale	.04	.20	.00	1.00	.00	.03	.01	.01	.00	.01	.00	.00
Switch	.07	.07	.05	.04	1.00	.06	.01	.00	.00	.01	.00	.01
Abandon	−.04	.14	.35	−.18	.25	1.00	.00	.00	.01	.00	.00	.00
Uncertainty	.19	.10	.06	.09	.09	.05	1.00	.00	.02	.06	.01	.01
ROI	.24	.13	−.16	−.10	.02	−.02	.07	1.00	.10	.00	.02	.02
NPV	.30	.04	−.28	−.06	.03	−.10	.13	.31	1.00	.01	.00	.00
Age	−.12	.01	−.11	−.10	.09	−.02	−.24	−.06	−.08	1.00	.04	.01
Size	.06	.08	−.06	−.02	.04	.06	.11	.13	.05	.21	1.00	.00
Intl	−.11	.14	.08	.05	.12	.01	−.10	.13	.00	.08	.06	1.00

Correlations are included below the diagonal. All correlations at .12 or above are significant at $p < .05$. Shared variances are included above the diagonal. Along with *Age* and *Size*, and *Intl*, organizational *Type* was included as a dummy variable (coded as *primarily a service organization* = 1 or *primarily a manufacturing organization* = 2).

Table 2: Means, standard deviations, composite reliabilities, variances extracted, factor loadings, and fit statistics.

Construct	Mean	Standard Deviation	Composite Reliability	Variance Extracted (Percent)	Factor Loading
Perceptual measures in CFA model					
Unlocking	4.41	.67	.85	64.67	.76–.87
Stage	3.56	.86	.78	54.00	.64–.83
Deferral	2.22	.77	.85	64.67	.77–.86
Scale	3.06	.93	.86	67.00	.70–.88
Switch	3.64	.80	.85	65.33	.76–.88
Abandon	3.01	1.00	.88	70.67	.78–.91
Uncertainty	3.63	.79	.82	60.00	.74–.83
Performance and control measures					
Return on investment	43.59	34.79			
Net present value	13.94	5.61			
Age	54.95	53.91			
Size	23,372.09	69,475.29			
Intl	40.12	30.15			

Fit Statistics:
$\chi^2 = 283.73$.
Degrees of Freedom = 168.
Normed fit index = .91.
DELTA2 = .96.
Comparative fit index = .96.
Root mean square error of approximation = .05.

factor would account for all manifest variables. Given the data collected, this technique provides the most direct assessment of potentially problematic common method variance in our data set. The one-factor model resulted in a $\chi^2 = 2{,}347.6$ with df $= 189$ versus $\chi^2 = 283.73$ with df $= 168$ for the theoretically defined measurement model. Thus, we found no evidence that common method variance is a serious inhibiting element in testing and interpreting the hypotheses.

RESULTS

The hypotheses were tested using three-step hierarchical linear regression. In the first step, the four control variables were entered along with the variable of supply chain uncertainty (which forms one of the factors for the interaction terms in step three). In step two, the six types of real options were entered (unlocking, staging, deferral, scale, switch, and abandon). In step three, the interaction effects composed of supply chain uncertainty and each of the real options were entered. Overall, as shown in Table 3, the predictions made in H1 (unlocking), H3 (deferral), H4 (scale), and H6 (abandon) are supported in the analysis while the predictions made in H2 (stage) and H5 (switch) are not.

The analyses were conducted for the two subgroups of "low NPV" ($n = 130$) and "high NPV" ($n = 139$) to be able to examine the hypotheses directly.

Table 3: Standardized hierarchical regression results with return on investment as criterion variable.

	Low Net Present Value (n = 130)			High Net Present Value (n = 139)		
	Step 1: Controls	Step 2: Main Effects	Step 3: Interactions	Step 1: Controls	Step 2: Main Effects	Step 3: Interactions
Age	−.09	−.13	−.08	−.11	−.32	−.01
Size	.19*	.14*	.12	−.04	−.18	−.26
Intl	−.06	−.01	−.01	.25	.31	.31
Type	−.03	−.03	−.01	.06	.34	.37
Uncertainty	−.04	−.05	−.07	.09	.05	−.34
Unlocking option	H1 →	.19*	.18*		.19	.58
Staging option		.15	.17*		−.18	.03
Deferral option		−.14	−.20*		−.23	−.04
Scale option		−.14	−.09		.06	−.36
Switch use option		.11	.10		.15	.27
Abandon option		−.02	−.08		.36	.09
(Unlocking) × (Uncertainty)		H2 →	.06			−.51
(Stage) × (Uncertainty)		H3 →	−.10			.17
(Deferral) × (Uncertainty)		H4 →	.32**			−.39
(Scale) × (Uncertainty)		H5 →	−.21**			−.35
(Switch) × (Uncertainty)		H6 →	−.01			.69*
(Abandon) × (Uncertainty)			−.37**			−.45
R^2	19.5%	37.9%	54.0%	31.5%	44.9%	70.9%
ΔR^2		14.4%	29.1%		20.2%	50.2%
F change (ΔR^2)		2.12**	3.37**		.37	1.10

* $= p < .10.$ ** $= p < .05.$

This subgrouping was based on a median split on the multiplicative effect of the "relative NPV" with referent to cost versus benefits of the supply chain project times "importance" placed on the project selected by the participants. A median split was selected for two reasons (e.g., Tiwana et al., 2007). First, supply chain managers are likely to use their prior experience with similar projects as a frame of reference in evaluating a project's potential value (Kahneman & Tversky, 1984). As such, a median split accounts for supply chain managers' relative benchmarks instead of using an absolute negative or positive NPV as the cutoff. Second, a median split allows for maximum power in each subgroup (e.g., Cohen, 1988).

Consistent with our theorizing, the statistical significance of H1 was assessed via the direct effect of the unlocking option in the low NPV subgroup (step two of the model) while H2–H6 were assessed in step three via the interaction effects of supply chain uncertainty and each of the real options of stage, deferral, scale, switch, and abandon. As shown in Table 3, under high parametric uncertainty (low NPV), the unlocking option has a direct effect on ROI (.18, $p < .10$). Also, the real options of deferral (.32, $p < .05$), scale ($-.21$, $p < .05$), and abandonment ($-.37$, $p < .05$) were significant predictors of ROI in the low NPV analysis. The real option of switching (.69, $p < .10$) was significant in the high NPV analysis.

Within the low NPV group, the direct effects of the six real options explain 14.4% of the variance beyond that explained by the control variables. The interaction effects explain 29.1% of the variance beyond the combined effect of the step one and step two variables. The full low NPV model explains 54.0% of the variance in ROI. In the high NPV analysis, the step three variables (driven by the interaction between switching and uncertainty) explain a significantly greater portion of the variance than the step one and step two variables (no statistically significant difference exist between the step one control variables and the step two real option direct effects). The full high NPV model explains 70.9% of ROI.

DISCUSSION

The study's findings need to be considered in light of its limitations. By allowing supply chain executives to complete the survey based on a project of their choice, the results may be biased toward (or away from) certain types of projects. Also, we did not have access to archival project NPV information or other project performance data (Swink, Talluri, & Pandejpong, 2006) and thus we relied on executives to report this information. Finally, the cross-sectional design of our study did not allow us to analyze the various options over time or to make causal inferences. Despite these limitations, our study offers a potential contribution by extending real options theory to the supply chain context and testing the resultant predictions.

Our results provide evidence that supply chain managers use real options thinking when encountering risk uncertainty. The overall pattern in our results also suggests that managers operate under a bounded rationality bias when making supply chain investment decisions. When a supply chain project's NPV was high, managers appeared to exhibit satisficing behavior (Simon, 1979) by not relating the options (the switch use option was the exception) to perceived value. In contrast, when a supply chain project's NPV was low, managers related the options to

Table 4: Contrasting how real options are addressed for firm and supply chain decisions.

Type of Option	Previous Findings	Current Supply Chain Findings
Unlocking	Positively related to the perceived value of a project under conditions of high uncertainty	Positively related to the perceived value of a project regardless of the level of uncertainty
Staging	Not significant	Not significant
Deferral	Not significant	Positively related to the perceived value of a project under conditions of high uncertainty
Scale	Positively related to the perceived value of a project under conditions of high uncertainty	Negatively related to the perceived value of a project under conditions of high uncertainty
Switch use	Positively related to the perceived value of a project under conditions of high uncertainty	Not significant
Abandonment	Positively related to the perceived value of a project under conditions of high uncertainty	Negatively related to the perceived value of a project under conditions of high uncertainty

perceived value and thus exhibited more thorough searching behavior (Simon, 1979).

Our key overarching finding, however, is that how options are considered within the context of supply chain decisions differ from how they were found to be considered by past research. Recent studies (e.g., Craighead, Hult, & Ketchen, 2009; Flynn, Huo, & Zhao, 2009; Fugate, Stank, & Mentzer, 2009; Hendricks et al., 2009) continue to provide evidence that supply chain decisions affect important outcomes. Meanwhile, the findings of Tiwana et al. (2007) suggest that real options thinking is used in firm-level decisions. Our study helps fill a gap left by the recent supply chain studies by shedding new light on how supply chain decisions are made when faced with high levels of risk uncertainty—uncertainty that can culminate in severe repercussions for performance (e.g., Hendricks & Singhal, 2003; Craighead et al., 2007). Table 4 summarizes the differences between our findings for real options in supply chains and Tiwana et al.'s (2007) findings for firm decisions. These differences are elaborated upon below.

Unlocking Options

Tiwana et al. (2007) found that managers perceive more value in holding unlocking options when uncertainty is high than when uncertainty is low. These authors suggested that the reason is that, under highly uncertain conditions, the passage of time is needed to learn the value of an option. This leads managers to wish to maintain the ability to grow in case events reveal unlocking to be valuable. In contrast to Tiwana et al.'s (2007) theorizing and findings, we predicted in H1 that supply chain managers would consider unlocking options regardless of the level of uncertainty present. Our results support this contention, indicating that managers

facing different levels of uncertainty are willing to invest in their supply chains to maintain access to future opportunities (e.g., Kogut & Kulatilaka, 2001).

This does not imply that the level of uncertainty is irrelevant to unlocking options in supply chains. Our results could indicate, however, that concern for today's level of uncertainty (Green, 2004) is suppressed in favor of recognition that competition is evolving to be supply chain versus supply chain as opposed to firm versus firm (e.g., Slone, 2004; Hult et al., 2007). To the extent that managers believe this transition is occurring, they may view supply chain investments that facilitate future unlocking as necessities to maintaining competitiveness with their rivals. The need to cope with uncertainty has long been a core tenet of organization theory (e.g., Thompson, 1967). To the extent that our findings for H1 are supported by future inquiry, our results shed new light on the conditions under which uncertainty is more or less important within supply chains.

Staging and Deferral Options

Consistent with prior real options research, we hypothesized (H2) that managers would perceive value in owning staging options when facing high supply chain uncertainty. We did not find support for this prediction. This is surprising given the flexibility the staging option affords. If a project can be funded or completed incrementally, a supply chain manager has the option to continue to the subsequent stage if the project provides desirable interim outcomes (Huchzermeier & Loch, 2001; Tiwana et al., 2007), while investments could cease if early stages' outcomes were less than desired (Fichman et al., 2005). Tiwana et al. (2007) theorized that their lack of findings for the staging option at the firm level could mean that the staging option is embedded in the other options. For example, staging can be viewed simply as a structured form of unlocking.

Another possibility relevant to the supply chain context is that managers avoid staging because of the implicit message it spreads across supply chain partners. Supply chains lack many of the sources of cohesiveness that firms enjoy, such as organizational culture (Hult, Ketchen, & Nichols, 2002). This helps make supply chain relations more fluid and precarious than those within a firm (Hult, Ketchen, & Slater, 2004). Although staging appears to be a logical approach in that it protects scarce resources, staging also could be interpreted as a sign of a lack of complete commitment to a supply chain project. Such signals can undermine the limited cohesiveness of a supply chain. Further, staging can be viewed by partners as a sign of an incremental and conservative approach to competition that is ill fitted to the hypercompetitive nature of most modern industries. These ideas suggest the need to possibly integrate signaling theory (Rindova, Williamson, Petkova, & Sever, 2005) into supply chain inquiry in general and into investigations of supply chain options in particular.

In H3, we examined the deferral option (Miller & Folta, 2002). The results supported our contention that supply chain managers, in the presence of high uncertainty, consider projects that offer the chance to delay investment to a later point in time. In contrast, Tiwana et al. (2007) did not find evidence that managers making firm-level decisions considered the deferral option. One possible explanation for the differences between supply chains and firms centers on the

degree to which uncertainty is endogenous versus exogenous. In comparison to the uncertainty surrounding firm decisions, supply chain uncertainty is more exogenous in nature (Dixit & Pindyck, 1994) and may be viewed as a serious threat to performance (Green, 2004). This lack of managerial control and influence appears likely to lead boundedly rational supply chain managers to postpone a project until external events unfold. Although the underlying philosophy of the deferral option has similarities to that of staging, deferral has important advantages over staging within the supply chain context. By postponing a supply chain project in its entirety, managers avoid the impression of partial and weak commitment that can beset a staging approach.

Scale, Switch Use, and Abandonment Options

Tiwana et al. (2007) found that managers relate (positively) possessing scale, switch use, and abandonment options to the perceived value of a project more under conditions of high uncertainty than under low uncertainty. In contrast, we predicted that supply chain managers would view scale (H4), switch use (H5), and abandonment (H6) options as unfavorable under conditions of high uncertainty. Our overall arguments stemmed from the presence and importance of long-term strategic alliances (Handfield & Nichols, 1999) and exogenous uncertainty (Dixit & Pindyck, 1994; Green, 2004) in the supply chain.

The results support our contention with regard to scale. As Fichman et al. (2005) note, scaling can carry intangible costs such as those related to credibility and morale. Within a supply chain, these intangible costs are exacerbated by high uncertainty. Supply chain members have mixed loyalties (Hult et al., 2002) in that they serve both their home organization and the chain. If a conflict arises between these interests, the interest of the home organization almost always wins (Slone, 2004). While risking credibility and morale is dangerous within a firm, the lack of cohesiveness across supply chain members increases this danger. Under high uncertainty, assessing the likelihood of such problems is particularly difficult. Moreover, building in scale options is costly (Fichman et al., 2005), which is inconsistent with the cost reductions traditionally sought through the integration of supply chain partners (Handfield & Nichols, 1999). Thus, overall, scale options appear to offer a better fit with firm-level projects than with supply chain projects, particularly under high uncertainty.

We did not find support for our prediction related to switch use, which is the option to redeploy investments (Trigeorgis, 1993). The switch use option introduces an unknown element into the supply chain equation. Each partner must be concerned that a potential switch will lead the chain toward an approach that it would not consider desirable, such as competing with one of the other supply chains within which it participates (Yang et al., 2004). Thus, switch use options may be undesirable because they have the potential to not only increase the level of uncertainty in the supply chain, but even to move the chain toward actions that are counterproductive from the perspective of some members.

The results support our contention with regard to abandonment—managers are less likely to consider this option under conditions of high uncertainty. We suspect this result is driven by at least two factors. First, supply chain managers

have a desire to avoid actions that can cause negative repercussions to their supply chain partners, especially when high levels of uncertainty have put them in a vulnerable state. Further, supply chain managers must be wary of the signals sent by abandonment. A partner that builds in the option to abandon a project can be seen as unreliable and unpredictable. Within the modern competitive arena, supply chain partnerships are essential to success, and the competition to ally with good partners is intense (Slone, 2004; Hult et al., 2007). With this context, managers dare not risk the competitive implications of being viewed negatively.

CONCLUSION

The introduction of a viable new theory about organizations is a relatively rare event. Rarer still is the emergence of a theory that reshapes how scholars and managers view firms. Because of its importation from the field of finance, real options theory has shed important new light on how firm-level decisions are made. Our study sought to extend real option theory by adapting it to the supply chain context, a context that drives much of the competitive activity within today's economy. Recent supply chain research (e.g., Craighead et al., 2009; Flynn et al., 2009; Fugate et al., 2009; Hendricks et al., 2009) continues to find that supply chain decisions shape important outcomes, but has left how these decisions are made unexamined empirically. In addressing this gap in the context of risk uncertainty, we found evidence that several options operate differently for supply chain decisions than they do for firm decisions. Looking to the future, it is important to recognize that, while supply chains appear to be increasingly vital to competition, firm decisions will remain of enormous importance. Thus, developing a more complete understanding of real options and their role in managerial decision making will require concurrent theorizing about and empirical assessment of supply chain and firm options—our study represents an important step in this direction.   [Received: January 2010. Accepted: April 2010.]

REFERENCES

Amburgey, T. L., & Rao, H. (1996). Organizational ecology: Past, present, and future directions. *Academy of Management Journal, 39*(5), 1265–1286.

Anderson, J. C., & Gerbing, D. W. (1988). Some methods for respecifying measurement models to obtain unidimensional construct measurement. *Journal of Marketing Research, 19*(November), 453–460.

Armstrong, J. S., & Overton, T. S. (1977). Estimating nonresponse bias in mail surveys. *Journal of Marketing Research, 14*(August), 396–402.

Autry, C. W., Skinner, L. R., & Lamb, C. W. (2008). Interorganizational citizenship behaviors: An empirical study. *Journal of Business Logistics, 29*(2), 53–74.

Bagozzi, R. P., & Phillips, L. W. (1982). Representing and testing organizational theories: A holistic construal. *Administrative Science Quarterly, 27*(September), 459–489.

Bendoly, E., & Swink, M. (2007). Moderating effects of information access on project management behavior, performance and perceptions. *Journal of Operations Management, 25*(3), 604–622.

Blackhurst, J., Craighead, C. W., Elkins, D., & Handfield, R. B. (2005). An empirically-derived agenda of critical research issues for managing supply chain disruptions. *International Journal of Production Research, 43*(19), 4067–4081.

Boone, C. A., Craighead, C. W., & Hanna, J. B. (2007). Postponement: An evolving supply chain concept. *International Journal of Physical Distribution and Logistics Management, 37*(8), 594–611.

Bucklin, L. P. (1965). Postponement, speculation and structure of distribution channels. *Journal of Marketing Research, 2*(1), 26–31.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. Hillsdale, NJ: Erlbaum.

Craighead, C. W., Blackhurst, J., Rungtusanatham, M. J., & Handfield, R. B. (2007). The severity of supply chain disruptions: Design characteristics and mitigation capabilities. *Decision Sciences, 38*(1), 131–156.

Craighead, C. W., Hult, G. T. M., & Ketchen, D. J., Jr. (2009). The effects of innovation-cost strategy, knowledge and action in the supply chain on firm performance. *Journal of Operations Management, 27*(5), 405–421.

Dapiran, P. (1992). Benetton—Global logistics in action. *International Journal of Physical Distribution and Logistics Management, 22*(6), 1–5.

Dillman, D. A. (2000). *Mail and Internet surveys: The tailored design method*. New York: Wiley.

Dixit, A., & Pindyck, R. (1994). *Investment under uncertainty*. Princeton, NJ: Princeton University Press.

Feitzinger, E., & Lee, H. L. (1997). Mass customization at Hewlett Packard: The power of postponement. *Harvard Business Review, 75*(1), 116–121.

Fichman, R. G., Keil, M., & Tiwana, A. (2005). Beyond valuation: Options thinking in IT project management. *California Management Review, 47*(2), 74–96.

Flynn, B. B., Huo, B., & Zhao, X. (2009). The impact of supply chain integration on performance: A contingency and configuration approach. *Journal of Operations Management, 28*(1), 58–71.

Folta, T. B., & O'Brien, J. P. (2004). Entry in the presence of dueling options. *Strategic Management Journal, 25*(2), 121–138.

Fornell, C., & Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research, 18*(1), 39–50.

Fugate, B. S., Stank, T. P., & Mentzer, J. T. (2009). Linking improved knowledge management to operational and organizational performance. *Journal of Operations Management, 27*(3), 247–264.

Geary, S., Childerhouse, P., & Towill, D. (2002). Uncertainty and the seamless supply chain. *Supply Chain Management Review, 6*(4), 52–61.

Gerbing, D. W., & Anderson, J. C. (1992). Monte Carlo evaluations of goodness of fit indices for structural equation models. *Sociological Methods and Research, 21*(2), 132–160.

Green, M. (2004). Loss/risk management notes: Survey: Executives rank fire, disruptions top threats. *Best's Review, 105*(5), 105.

Handfield, R. B., & Nichols, E. L. (1999). *Introduction to supply chain management*. Upper Saddle River, NJ: Prentice Hall.

Hendricks, K., & Singhal, V. (2003). The effect of supply chain glitches on shareholder wealth. *Journal of Operations Management, 21*(5), 501–522.

Hendricks, K. B., & Singhal, V. R. (2005). An empirical analysis of the effect of supply chain disruptions on long-run stock price performance and equity risk of the firm. *Production and Operations Management, 14*(1), 35–52.

Hendricks, K. B., Singhal, V. R., & Zhang, R. (2009). The effect of operational slack, diversification, and vertical relatedness on the stock market reaction to supply chain disruptions. *Journal of Operations Management, 27*(3), 233–246.

Hu, L.-T., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling, 6*(1), 1–55.

Hubbard, G. R. (1994). Investments under uncertainty: Keeping one's options open. *Journal of Economic Literature, 32*(4), 1816–1831.

Huber, G. P., & Power, D. J. (1985). Retrospective reports of strategic-level managers: Guidelines for increasing accuracy. *Strategic Management Journal, 6*(2), 171–180.

Huchzermeier, A., & Loch, C. H. (2001). Project management under risk: Using the real options approach to evaluate flexibility in R&D. *Management Science, 47*(1), 85–101.

Hult, G. T. M., Ketchen, D. J., & Arrfelt, M. (2007). Strategic supply chain management: Improving performance through a culture of competitiveness and knowledge management. *Strategic Management Journal, 28*(10), 1035–1052.

Hult, G. T. M., Ketchen, D. J., & Nichols, E. (2002). An examination of cultural competitiveness and order fulfillment cycle time within supply chains. *Academy of Management Journal, 45*(3), 577–586.

Hult, G. T. M., Ketchen, D. J., & Slater, S. F. (2004). Information processing, knowledge development, and strategic supply chain performance. *Academy of Management Journal, 47*(2), 241–253.

Jaworski, B. J., & Kohli, A. K. (1993). Market orientation: Antecedents and consequences. *Journal of Marketing, 57*(3), 53–70.

Johnson, A. (2007). Insulin flop costs Pfizer $2.8 billion. *Wall Street Journal*, October 19.

Joreskog, K. G., Sorbom, D., Du Toit, S., & Du Toit, M. (2000). *LISREL 8: New statistical features* (2nd ed.). Chicago: Scientific Software International.

Kahneman, D., & Tversky, A. (1984). Choices, values, and frames. *American Psychologist, 39*(4), 341–350.

Kogut, B., & Kulatilaka, N. (2001). Capabilities as real options. *Organizational Science, 12*(6), 744–758.

Krause, D. R., Handfield, R. B., & Tyler, B. B. (2007). The relationships between supplier development, commitment, social capital accumulation and performance improvement. *Journal of Operations Management, 25*(2), 528–545.

Lee, H. L. (2004). The triple-a supply chain. *Harvard Business Review, 83*(October), 102–112.

Lunsford, J. L. (2007). Jet blues: Boeing scrambles to repair problems with new plane: Layers of outsourcing slow 787 production; "Hostage to Suppliers." *Wall Street Journal*, December 7.

Majd, S., & Pindyck, R. (1987). Time to build, option value, and investment value. *Journal of Financial Economics, 18*(2), 7–27.

March, J. G., & Simon, H. A. (1958). *Organizations*. New York: Wiley.

McGrath, R. G., Ferrier, W. J., & Mendelow, A. L. (2004). Real options as engines of choice and heterogeneity. *Academy of Management Review, 29*, 86–101.

McGrath, R. G., & Nerkar, A. (2004). Real options reasoning and a new look at the R&D investment strategies for pharmaceutical firms. *Strategic Management Journal, 25*(1), 1–21.

Miller, K. D., & Folta, T. B. (2002). Option value and entry timing. *Strategic Management Journal, 23*(7), 655–665.

Myers, S. C. (1977). Determinants of corporate borrowing. *Journal of Financial Economics, 5*(2), 147–176.

Oriani, R., & Sobrero, M. (2008). Uncertainty and the market valuation of R&D within a real options logic. *Strategic Management Journal, 29*(4), 343–361.

Podsakoff, P. M., MacKenzie, S. B., Lee, J.-Y., & Podsakoff, N. P. (2003). Common method biases in behavioral research: A critical review of the literature and recommended remedies. *Journal of Applied Psychology, 88*(5), 879–903.

Rindova, V., Williamson, I., Petkova, A., & Sever, J. (2005). Being good or being known: An empirical examination of the dimensions, antecedents, and consequences of organizational reputation. *Academy of Management Journal, 48*(6), 103–1050.

Rossetti, C. L., & Choi, T. Y. (2008). Supply management under high goal incongruence: An empirical examination of disintermediation in the aerospace supply chain. *Decision Sciences, 39*(3), 507–540.

Scherpereel, C. M. (2008). The option-creating institution: A real options perspective on economic organization. *Strategic Management Journal, 29*(5), 455–470.

Simon, H. (1979). Rational decision making in business organizations. *American Economic Review, 69*(4), 493–513.

Slone, R. E. (2004). Leading a supply chain turnaround. *Harvard Business Review, 83*(October), 114–121.

Swink, M., Talluri, S., & Pandejpong, T. (2006). Faster, better, cheaper: A study of NPD project efficiency and performance tradeoffs. *Journal of Operations Management, 24*(5), 542–562.

Swink, M., & Zsidisin, G. (2006). On the benefits and risks of focused commitment to suppliers. *International Journal of Production Research, 44*(20), 4223–4240.

Thompson, J. D. (1967). *Organizations in action*. New York: McGraw-Hill.

Tiwana, A., Wang, J., Keil, M., & Ahluwalia, P. (2007). The bounded rationality bias in managerial valuation of real options: Theory and evidence from IT projects. *Decision Sciences, 38*(1), 157–181.

Trigeorgis, L. (1993). The nature of option interactions and the valuation of investments with multiple options. *Journal of Financial and Quantitative Analysis, 28*(1), 1–20.

Van Hoek, R. I. (2001). The rediscovery of postponement a literature review and directions for research. *Journal of Operations Management, 19*(2), 161–184.

Van Mieghem, J. A., & Dada, M. (1999). Price versus production postponement: Capacity and competition. *Management Science, 45*(12), 1631–1649.

Waller, M. A., Dabholkar, P. A., & Gentry, J. J. (2000). Postponement, product customization, and market-oriented supply chain management. *Journal of Business Logistics, 21*(2), 133–159.

Wang, H., & Lim, S. S. (2008). Real options and real value: The role of employee incentives to make specific knowledge investments. *Strategic Management Journal, 29*(7), 701–721.

Yang, B., Burns, N., & Backhouse, C. (2004). Postponement: A review and an integrated framework. *International Journal of Operations and Production Management, 24*(5), 468–487.

Zinn, W., & Bowersox, D. J. (1988). Planning physical distribution with the principle of postponement. *Journal of Business Logistics, 9*(2), 117–137.

Zsidisin, G. A. (2003). Managerial perceptions of supply risk. *The Journal of Supply Chain Management, 39*(1), 14–25.

Zsidisin, G. A., Ellram, L. M., Carter, J. R., & Cavinato, J. L. (2004). An analysis of supply risk assessment techniques. *International Journal of Physical Distribution and Logistics Management, 34*(5), 397–413.

APPENDIX

Measurement Scales

Supply chain options

[5-point scale; *strongly disagree* to *strongly agree*]

Answer the following questions about supply chain options based on the major supply chain project that you selected earlier (i.e., logistics management, supply management, operations management, information technology, or another strategic project).

Unlocking options

- This supply chain project is very necessary for us to unlock future opportunities.
- This supply chain project is a very necessary foundation for us to develop future capabilities.
- This supply chain project is very important to the advancement of our organization.

Stage options

- This supply chain project could easily be funded incrementally in stages.
- This supply chain project could easily be completed in incremental stages.
- This supply chain project could easily be completed in a series of smaller projects.

Deferral options

- Many financial uncertainties could be resolved if this supply chain project were postponed.
- Many human resource uncertainties could be resolved if this supply chain project were postponed.
- Many technical uncertainties could be resolved if this supply chain project were postponed.

Scale options

- The financial resources that were allocated for this supply chain project could easily be expanded.
- The human resources that were allocated for this supply chain project could easily be expanded.
- The technical resources that were allocated for this supply chain project could easily be expanded.

Switch use options

- The supply chain resources allocated for this project could easily be redeployed for another purpose.
- The supply chain resources allocated for this project could easily serve another role in our organization.
- The supply chain resources allocated for this project could easily be transferred for use by others in our organization.

Abandonment options

- The financial resources allocated to this supply chain project could be put to other more important uses if the project was not undertaken.
- The human resources allocated to this supply chain project could be put to other more important uses if the project was not undertaken.

- The technical resources allocated to this supply chain project could be put to other more important uses if the project was not undertaken.

Supply chain risk uncertainty

- Our supply chains are constantly being threatened by external risks.
- We constantly have to plan for significant external problems that may arise in our supply chains.
- Our supply chains constantly face supply base, operations, and/or logistical obstacles.

NPV

NPV was measured as the multiplicative effect of the "Relative NPV" with referent to cost versus benefits and the "Importance" placed on the specific supply chain project.

- Relative to NPV: This project's costs will greatly exceed its benefits – This project's benefits will greatly exceed its costs. [5-point scale; *costs greatly exceed benefits* to *benefits greatly exceed costs*.
- Performance relative to NPV. [5-point scale; *not important at all* to *essential*]

Perceived value

- What is your estimated ROI of this supply chain project (in percent)?

Control variables

- Age of the firm (years)
- Size of the firm (in number of people)
- Percentage of supply chain activities that are international in scope
- Primarily a service firm (= 1) or manufacturing firm (=2)

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