Environmental uncertainty and supply chain performance: the effect of agility

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Abstract

Purpose – Today's businesses are facing a world that is more complex, turbulent and unpredictable than in the past with increasing levels of environmental complexity. Rather than proposing environmental uncertainty as a mediator/moderator of the relationship between agility and performance as others have done, the authors offer an alternative view where supply chain agility is seen as mediating the relationship between environmental uncertainty and supply chain performance.

Design/methodology/approach – The authors propose that supply chain agility is a response to the effects of environmental uncertainty and, as such, environmental uncertainty should be seen as a driver of supply chain agility. Few studies test the direct relationship between uncertainty and supply chain performance, and none simultaneously test for agility's mediation and moderation effect between environmental uncertainty and agility.

Findings – The model was statistically assessed using partial-least-squares structural equation modeling (PLS/SEM) by analyzing survey data from manufacturing managers in 136 US firms. The study results did not indicate a significant relationship between environmental uncertainty and supply chain performance. However, the authors did find a significant positive relationship between agile manufacturing and supply chain performance using measures that were primarily operations-centered rather than financial. Additionally, the authors found that agile manufacturing fully mediates the relationship between environmental uncertainty and supply chain performance.

Originality/value – The authors' model, though simple, provides a base for future research for them and other researchers who can incorporate other impacting variables into the model. The study results show that uncertainty can be a force for good and that utilizing agile manufacturing can be a new source of opportunity.

Keywords Environmental uncertainty, Agility, Supply chain performance

Paper type Research paper

Introduction

As it has been throughout modern history, we are facing uncertain times. Businesses face a world that is more complex, turbulent and unpredictable than in the past (Gligor *et al.*, 2019b) with increasing levels of environmental complexity (Mirghafoori *et al.*, 2017; McGrath, 2013) and uncertainty (Ismail and Sharifi, 2006) creating a variable that has come to be known as "environmental uncertainty" (Milliken, 1987).

Much of this change and turbulence are now considered an integral part of business in supply chains (Rasi *et al.*, 2019). Seen as one of the most fundamental problems within a complex organization (Mason, 2010), environmental uncertainty is one of the major contingencies faced by firms (Gligor *et al.*, 2019b; Tosi and Slocum, 1984) and is a key variable that affects organizational structure (Rasi *et al.*, 2019). Environmental uncertainty is also now one of the key issues in the literature on strategic management (Vecchiato, 2015). Witness the shock waves sent through countless supply chains as the COVID-19 pandemic unfolded, and heavily comanufacturing supply chains lost control over shifting production (Atmar *et al.*, 2020).

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This continuous growth in the level of environmental complexity demands the pursuit of continuous growth in flexibility and agility (Nobre, 2011; Caridi and Cigolini, 2002). Agility reflects a firm's ability to make quick adjustments to respond or adapt to changes, opportunities and threats in its environment (Gligor *et al.*, 2013).

This study is motivated by interest in both environmental uncertainty and agility, specifically the impact of agility on the relationship between environmental uncertainty and supply chain performance. Despite considerable attention to agility and the uncertainty/agility relationship, apparently there is need for further research. Rasi *et al.* (2019) stated that environmental uncertainty has been a neglected aspect of supply chain agility while others have indicated that the research stream on agility is in an incipient stage (Braunscheidel and Suresh, 2009) with limited theory development at the firm level (Humdan *et al.*, 2020; Gligor *et al.*, 2016). Also, linkages among the elements of agility are underdeveloped (Gligor *et al.*, 2019a; Gligor, 2014), and there is no unified comprehensive model of agility (Gligor, 2014). After finding that supply chain fit mediates the supply chain agility–financial performance relationship, Gligor (2016) calls for future research to investigate other mediators.

While there has been considerable attention given to the links between environmental uncertainty and organizational performance and agility and organizational performance and attention given to uncertainty as a driver for agility, there are no studies that assess the combined impact of uncertainty and agility on supply chain performance. We endeavor to do so. In addition, we investigate the subtle ways in which agility both mediates and moderates the relationship between environmental uncertainty and supply chain performance. We believe that the significant contribution of this study to the literature is fourfold: (1) to replicate the previous assessment of the direct effect of environmental uncertainty on the necessity for agility, (2) to newly assess the direct effect of agility on supply chain performance, (3) to newly assess the direct effect of environmental uncertainty on supply chain performance and (4) within the context of a single structural model, to assess the combined mediation and moderation effects of the environmental uncertainty relationship.

Literature review

Theoretical lenses

Early in the development of the discussion of agility, Christopher (2000) described agile manufacturing in the form of flexibility and responsiveness as necessary when markets or the environment is less certain. Similarly, Zhang and Sharifi (2000) discuss the increased uncertainty within which manufacturers are required to operate and identify agile manufacturing as a strategy for mitigating the negative effects of such environmental uncertainty. Consistent with Darvishmotevali *et al.* (2020), who examined the link between environmental uncertainty, organizational agility and organizational creativity in the hotel industry, we adopt the view of contingency theory to explain the link between environmental uncertainty, agility and performance. Per contingency theory, strategy cannot be the same for all conditions or fixed over time (Darvishmotevali *et al.*, 2020) implicitly requiring agility. Through the lens of contingency theory, agile firms will be more successful in coping with uncertainty (Darvishmotevali *et al.*, 2020). In other words, agile firms have the ability to adapt their resources "contingent" upon certain contextual factors, thereby achieving a logical "fit" (Romero-Silva *et al.*, 2018). Darvishmotevali *et al.* (2020) state that "the contingency approach is the most appropriate approach for dealing with an uncertain environment."

Gligor (2014, p. 579) notes that the various definitions of agility emphasize these themes: "quick response to sudden changes in supply and demand, smooth and efficient handling of disruptions, survival of unprecedented threats of business environment, change as opportunity, flexibility, speed and customer empowerment/customization." In addition to

being an appropriate response to a contingent situation, each of these implies the need for "dynamic capabilities." Dynamic capabilities are required for fostering the organizational agility to address deep uncertainty (Teece *et al.*, 2016). Dynamic capabilities are the antecedent organizational and strategic routines by which managers alter their resource base (Eisenhardt and Martin, 2000, p. 1107). Dynamic capabilities are idiosyncratic in their details and can result in sustained competitive advantage if they are VRIN (valuable, rare, inimitable and nonsubstitutable) as is consistent with the resource-based view (Eisenhardt and Martin, 2000). Therefore, we also view our work through the lens of the RBV (resource-based view).

Environmental uncertainty

Simply put, environmental uncertainty can be defined as the rate of change of instability in the environment (Gligor *et al.*, 2016; Dess and Beard, 1984). Rasi *et al.* (2019) expand the definition to say that environmental uncertainty refers to the inability to determine probabilities with a degree of certainty about how environmental factors affect the success/failure of a decision-making unit. In a seminal work on uncertainty, Milliken (1987) states that the three most common definitions of environmental uncertainty are (1) inability to assign probabilities to the likelihood of future events, (2) a lack of information about cause–effect relationships and (3) an inability to predict accurately the outcomes of a decision. This is certainly a serious problem for firms and supply chains in that it puts excessive pressure on them to effectively cope with the unknown (Panda and Rath, 2018). Firms are then compelled to address these pressures in an effective manner as is possible (Mukhejri and Mukherji, 2017).

Agility

Mirghafoori *et al.* (2017) state that "Agility has emerged as the dominant competitive vehicle for organizations operating in uncertain and ever-changing business environments and has been heralded as the business paradigm of the 21st century." While definitions share common elements (Gligor, 2014), there is no single accepted definition of agility (Humdan *et al.*, 2020; Hasani *et al.*, 2015; Gligor, 2014; Gligor *et al.*, 2012a), and it is uncommon for any two articles to offer the same definition (Gligor *et al.*, 2013, 2019a). Christopher (2000, p. 39) provides an early definition of agility as "as the ability of an organization to respond rapidly to changes in demand both in terms of volume and variety." Zhang and Sharifi (2000) describe agility as the ability to successfully respond to both anticipated and unanticipated changes in markets in such a way as to turn those changes into opportunities to exploit the market. Both Christopher (2000) and Zhang and Sharifi (2000), therefore, can be said to describe environmental uncertainty as a driver of the development of agile manufacturing. Tolf *et al.* (2015) define agility as using market knowledge to exploit opportunities in a volatile marketplace. Sambamurthy *et al.* (2003) propose that agility has three dimensions: "customer" agility, the inclusion of customers in exploring and exploiting opportunities; "partnering" agility, the ability to leverage suppliers; and "operational" agility, the ability to accomplish needed objectives with speed and accuracy. Operational agility seems to more accurately correspond to most other definitions, which incorporate the ability to quickly react and to make adjustments to or respond to changes (Asil and Farahmand, 2019; Gligor *et al.*, 2015, 2019b; Rasi *et al.*, 2019; Panda and Rath, 2018; Gligor, 2016; Mason, 2010; Braunscheidel and Suresh, 2009; Agarwal *et al.*, 2007). All definitions seem to revolve around the idea of speed (Humdan *et al.*, 2020; Gligor *et al.*, 2019b), and many note its usefulness in environments that are dynamic (Gligor, 2016) and complex (Gligor *et al.*, 2019b; Rasi *et al.*, 2019; Mirghafoori *et al.*, 2017; Gligor, 2016; Nobre, 2011; Mason, 2010). Perhaps the most encompassing definition is offered by Gligor and Holcomb (2012) as "to present a solution to customers' needs." Whatever the definition, it assumes that the environment of the organization is

frequently changing and is uncertain and unpredictable (Tolf *et al.*, 2015) and that agility is needed to satisfy customers' demand in uncertain environments (Hasani *et al.*, 2015). Each definition of agility requires that the firm possess dynamic capabilities in order to overcome the environmental uncertainty. This is consistent with the RBV of the firm in that a unique combination of resources utilized to achieve agility can be rare, desirable, nonsubstitutable and most importantly, difficult to imitate.

Theorized model

Figure 1 displays the theorized structural model. It depicts possible relationships among the constructs of environmental uncertainty, agile manufacturing and supply chain performance. Agile manufacturing is hypothesized as both mediating and moderating the established relationship between environmental uncertainty and supply chain performance.

Hypotheses

The following hypotheses are embedded within the theorized model: (1) environmental uncertainty is positively associated with supply chain performance, (2) environmental uncertainty is positively associated with agile manufacturing, (3) agile manufacturing is positively associated with supply chain performance and (4) agile manufacturing both positively moderates and mediates the relationship between environmental uncertainty and supply chain performance. The first three hypotheses set the stage for the simultaneous testing the moderating and mediating effects of agile manufacturing. While the impacts of both environmental uncertainty and agile manufacturing on organizational performance have received extensive coverage in the existing literature, the impacts of uncertainty and agility on operational measures of supply chain performance have not been extensively assessed. In addition, the moderating and mediating effects of agile manufacturing on the environmental uncertainty and supply chain performance relationship have not been previously assessed. The hypotheses combine within the theoretical model in a novel way that has not been previously presented in the literature.

Environmental uncertainty and supply chain performance

Uncertainty has been associated with negative effects on performance (Mukherji and Mukherji, 2017). From a sample of foreign ventures operating in China, Lam and Yeung (2010) found that perceived environmental uncertainty moderates the effect of staff localization on firm performance but reported a negative correlation between environmental performance

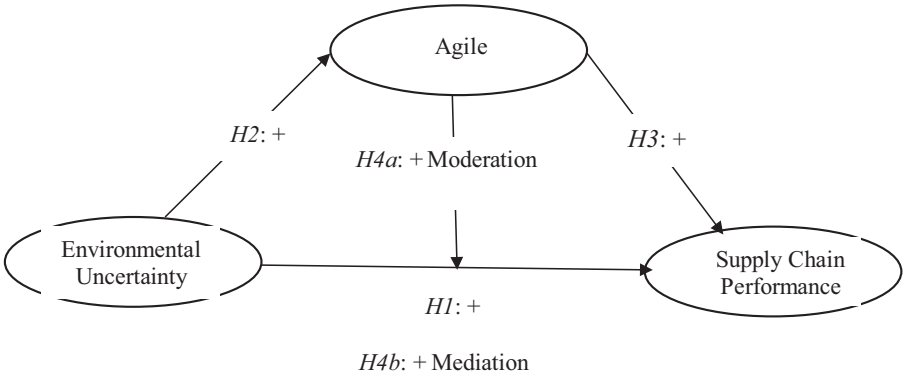


Figure 1.
Theorized structural model

and firm performance. The Lam and Yeung study (2010) measured performance as ROA, ROS, total sales growth, overall performance and success and competitive position relative to close competitors. In a study involving CEO charisma, environmental uncertainty and organizational performance, Agle *et al.* (2006) reported that environmental uncertainty did not predict significant variance in organizational performance. From a sample of CEOs from major US corporations, they reported a nonsignificant correlation between environmental uncertainty and performance. Studying top management team functional diversity and firm performance, using a sample of large US firms, Cannella *et al.* (2008) hypothesized that environmental uncertainty moderates the performance effects of top management team intrapersonal functional diversity, top management team dominant functional diversity and top management team colocation, that is, the effects become more positive as environmental uncertainty increases. Although not the focus of their study, of interest to us was their report of a negative correlation for environmental uncertainty and firm performance (ROA minus net income divided by assets).

The findings related to the type and strength of the relationship between environmental uncertainty and performance are mixed. Some studies support the notion that environmental uncertainty can encourage activities that have a positive result. Mukherji and Mukherji (2017) found that environmental uncertainty triggers certain firm activities that improve financial performance based on analysis of US entrepreneurs. Mandal (2016) found that environmental uncertainty moderates the relationship between innovation and operational performance (measured by undamaged orders, accuracy of orders and meeting deadlines) in supply chains and that the relationship was enhanced when under greater levels of uncertainty. Among the few works that studied the direct relationship between environmental uncertainty and performance were Eker and Eker (2019) and James and George (2018). Although it reported a nonsignificant correlation for the relationship between environmental uncertainty and financial performance (ROA, operating income, ROI, cash flow and cost of sales ratio), Eker and Eker's (2019) study, which analyzed data from a sample of manufacturers in Turkey, reported a positive correlation for the relationship between environmental uncertainty and nonfinancial performance (measured as market development, market share, new product development, human resource development and sales growth). James and George (2018) hypothesized that, as environmental uncertainty increases, supply chain performance also increases. James and George (2018) did not specify their performance measures, stating only that they were derived from Rexhausen (cost, service level and flexibility) and Vickery *et al.* (ROI, market share and return on sales). Analyzing survey data from coir manufacturers in India, they found the relationship between environmental uncertainty and supply chain performance to be significant.

Many firms may be compelled to address the effects of environmental uncertainty as efficiently and effectively as possible while others may see uncertainty as a source of new opportunities they can leverage (Mukherji and Mukherji, 2017). Uncertainty forces firms to look for superior alternatives to what they are currently doing (Mukherji and Mukherji, 2017). Also, environmental uncertainty can encourage innovation (Mukherji and Mukherji, 2017; Mandal, 2016). Lastly, uncertainty can trigger scanning and analysis of signals from the environment, developing and sustaining critical relationships and centralizing decisions for increased coherence, consistency and coordination of strategy (Mukherji and Mukherji, 2017). All these things can result in improved performance.

As discussed, the relationship between environmental uncertainty and the financial performance of organizations has received considerable attention in the literature with mixed results. We find no studies that specifically assess the relationship between environmental uncertainty and supply chain performance, however. In particular, we use a combination of supply-chain-centered performance measures that includes customer satisfaction, product customization, delivery speed, logistics cost, delivery dependability, responsiveness, order

flexibility, delivery flexibility, information systems support, order fill capacity, advance ship notification, inventory turns and return on assets. These supply chain performance measures are significantly different from James and George's (2018) and Eker and Eker's (2019) measures and the predominantly financial performance measurements utilized by the previously mentioned studies. We expand beyond financial measures, beyond a single industry and beyond India and Turkey into the US manufacturing sector. We believe that it is appropriate to shift the focus from the impact of environmental uncertainty on organizational performance (primarily the financial performance of the firm) to the impact of environmental uncertainty on supply chain performance in that environmental uncertainty can be both localized and supply chain wide. Under the premise that environmental uncertainty requires firms to undertake certain business activities in order to respond efficiently and effectively to customers and consumers (Mukherji and Mukherji, 2017), we posit that:

H1. Environmental uncertainty is positively associated with supply chain performance.

Environmental uncertainty and agile manufacturing

Early in the discussion of the development of agile manufacturing, both Christopher (2000) and Zhang and Sharifi (2000) described environmental uncertainty as a driver of the need to develop agile manufacturing capabilities – the higher the degree of turbulence in the business environment, the higher degree of agility needed. As markets become more uncertain, organizations adopt various practices to reduce the impact of uncertainty (James and George, 2018). Needs created by the changing and increasingly complex environment have led to the emergence of agility (Rasi *et al.*, 2019; Gligor *et al.*, 2013) as a central component of a firm's competitive strategy, especially in these uncertain environments (Gligor, 2016; Blome *et al.*, 2013). Agility is seen as a crucial competence needed for coping with unprecedented business environmental changes (Panda and Rath, 2018) and as the fundamental supply chain characteristic needed to survive as environmental forces create additional uncertainty.

While it stands to reason that agility is a natural response to environmental uncertainty, the authors found scant research that modeled environmental uncertainty as a driver of supply chain agility. Rasi *et al.* (2019) hypothesized that uncertainty both directly and indirectly (through supply chain orientation and market orientation) affects supply chain agility. Statistical analysis of data from a survey of managers of Iranian auto parts suppliers (suppliers to one company in one industry) confirmed the indirect effects but not the direct effect (Rasi *et al.*, 2019). Similarly, Guner *et al.* (2018) hypothesized that technological uncertainty positively affects supply chain agility. Statistical support was found through analysis of survey data collected through email and face-to-face interviews. Gligor *et al.* (2016) studied the relationship between environmental uncertainty and supply chain agility but with supply chain orientation and market orientation as mediators in the relationship. The direct relationship between environmental uncertainty and agility was not tested in that study. Extending the body of knowledge by utilizing data from multiple manufacturers within the US manufacturing sector, we propose that:

H2. Environmental uncertainty is positively associated with agile manufacturing.

Agile manufacturing and supply chain performance

Gunasekaran (1999) was one of the first to describe agility as a supply chain encompassing strategy stretching to include suppliers and customers as well as manufacturers. Early on, Christopher (2000) uses the term "agile supply chain" establishing the idea that agility is a supply chain level strategy. Christopher (2000) also discusses agility as dependent upon the ability to share information among supply chains, a key component of supply chain management. Agile manufacturing is a supply chain strategy, which depends upon

capabilities to integrate and coordinate with partners from suppliers' suppliers through the entire supply chain to ultimate customers (Green *et al.*, 2019). Supply chain management strategies such as agile manufacturing are specifically developed and designed to directly improve supply chain performance, ultimately improving organizational performance.

Whitten *et al.* (2012) found that a triple-A supply chain management strategy (comprised of the components of agility, adaptability and alignment) directly impacts supply chain performance, which then impacts organizational performance. A number of other studies have investigated the impact of agile production on different forms of organizational performance (marketing performance, financial performance and operational performance of the firm) (Inman *et al.*, 2011; Gligor *et al.*, 2015; Um, 2017). The results from these studies are mixed. Inman *et al.* (2011) found positive relationships between agile manufacturing and marketing, financial and operational performance of the firm. Gligor *et al.* (2015) found that the relationship between supply chain agility did not directly impact financial performance of the firm. Um (2017) utilized survey data from diverse manufacturers in the United Kingdom and South Korea to examine the direct relationship between supply chain agility and business performance and, surprisingly, found that supply chain agility negatively impacts firm performance.

Other works similar to Whitten *et al.* (2012) support the linkages between supply chain management strategies such as Total-JIT and marketing strategy alignment and supply chain and organizational performance. Green *et al.* (2014) found that Total-JIT directly and positively impacts supply chain competency (a measure of supply chain performance), which leads to improvement in organizational performance. Green *et al.* (2012) found that marketing strategy alignment throughout the supply chain directly and positively impacts supply chain performance, which in turn impacts organizational performance. Whitten *et al.* (2012), Green *et al.* (2012) and Green *et al.* (2014) findings combine to establish that the link between supply chain management strategies and organizational performance is mediated through supply chain performance, providing an explanation for the disparate results from the assessments of the agile manufacturing to organizational performance link.

Based on these theoretical discussions and the previous findings that supply chain strategies directly impact supply chain performance, we argue that supply chain agility also directly impacts supply chain performance.

H3. Agile manufacturing is positively associated with supply chain performance.

Agile manufacturing as moderator/mediator

There are studies where environmental uncertainty is a mediator/moderator (Gligor, 2019; Mandal, 2016; Gligor *et al.*, 2015; Lam and Yeung, 2010; Cannella *et al.*, 2008) but not for a relationship involving supply chain agility. There are studies where the impact of environmental uncertainty on the relationship between supply chain agility and another variable is examined (Gligor *et al.*, 2015, 2019b; Panda and Rath, 2018). However, the number of studies modeling environmental uncertainty as a driver of agility is not vast. Gligor *et al.* (2016) propose a model in which environmental uncertainty is theorized as indirectly affecting supply chain agility through supply chain orientation and market orientation. Rasi *et al.* (2019) propose a similar model in which environmental uncertainty both directly and indirectly (through supply chain orientation and market orientation) affects supply chain agility. James and George (2018) proposed that supply chain practices, not agility, mediate the relationship between environmental uncertainty and agility. Testing two models, they found (in the second model) that supply chain practices partially mediate the relationship between environmental uncertainty and performance.

In closely related papers, Gligor (2016) sought to establish a link between environmental characteristics and supply chain fit. Results of the study indicated a negative relationship

between environmental uncertainty and supply chain fit. In a later study, after finding that supply chain fit fully mediated the agility–financial performance relationship, Gligor (2016) calls for further investigation of additional mediators of the agility–financial performance relationship. In 2015, Gligor *et al.* investigated the impact of the firm's environment on the supply chain agility/firm performance relationship. Environmental uncertainty was found to moderate the relationship between supply chain agility and cost and supply chain agility and customer effectiveness. In the same study, customer effectiveness and cost were found to mediate the supply chain agility/financial performance relationship. They then noted that "additional supply chain agility/performance outcomes remain to be identified and additional mediators and moderators of the complex supply chain agility/performance relationship have yet to be explored" (Gligor *et al.*, 2015).

The previous related literature does not firmly establish mediating and moderating relationships among the constructs of environmental uncertainty, agile manufacturing and supply chain performance. To this point, it appears that much of the structural investigations have taken on an exploratory rather than confirmatory approach to determining how uncertainty, agility and performance might relate. It should be noted that none of the preceding studies specifically incorporates supply chain performance even though early theoretical works (Christopher, 2000; Zhang and Sharifi, 2000; Gunasekaran, 1999) firmly establish agile manufacturing as a supply chain level strategy. In our justifications for hypotheses 2 and 3, we present logic and past empirical findings that support viewing environmental uncertainty as a driver of agile manufacturing and as agile manufacturing as a driver of supply chain performance. Given that uncertainty drives agility (both theoretically and empirically), it seems logical that agility serves as a potential moderator/mediator to the uncertainty/performance link rather than uncertainty serving as a mediator/mediator in some fashion. In response, we propose to simultaneously test for both mediation and moderation by offering the following:

H4a. Agile manufacturing positively moderates the relationship between environmental uncertainty and supply chain performance.

H4b. Agile manufacturing positively mediates the relationship between environmental uncertainty and supply chain performance.

Methodology

Data collection process

Data were gathered through the third-party data collection service Zoomerang. Plant-level manufacturing managers working in the USA were targeted. A panel of 1,146 manufacturing managers were contacted via an e-mail process and asked to provide data for the study. Of the 136 of those initially contacted completed the survey for an effective response rate of 11.9% (136/1,146). Table 1 displays a summary of the sample demographics. The respondents are relatively experienced (an average of more than ten years in their current positions) and represent a broad array of US manufacturing managers (14 different title categories, 17 different industry categories).

Measurement scales assessment

The environmental uncertainty scale is taken from Miller and Dröge (1986). The agile manufacturing scale is taken from Inman *et al.* (2011). The supply chain performance scale is taken from Bowersox *et al.* (2000). Labeled supply chain competency in the prior research (Green *et al.*, 2014), this supply chain performance scale was chosen as it encompasses a broad spectrum of favorable supply chain outcomes. It is closely aligned with Qrunfleh and

Title	Percentage
CEO/Owner	0.74
Vice-President or Director	0.74
Plant Manager	5.15
Operations Manager	19.12
Purchasing Manager	5.15
Logistics Manager	5.88
Sales Manager	10.29
Customer Service Manager	2.21
Engineering Manager	11.03
Supply Chain Manager	2.21
Information Systems Manager	8.82
Quality Manager	5.88
Environmental Sustainability Manager	2.94
Other Manufacturing Manager	19.85
Total	100.00
Industry Category	
Food Manufacturing	5.88
Beverage and Tobacco Product Manufacturing	0.73
Textile Mills	1.47
Apparel Manufacturing	1.47
Wood Product Manufacturing	3.68
Paper Manufacturing	3.68
Printing and Related Support Activities	0.73
Chemical Manufacturing	4.41
Plastics and Rubber Products Manufacturing	9.56
Primary Metal Manufacturing	2.94
Fabricated Metal Product Manufacturing	5.15
Machinery Manufacturing	13.97
Computer and Electronic Product Manufacturing	8.82
Electrical Equipment, Appliance, and Component Manufacturing	5.15
Transportation Equipment Manufacturing	5.88
Furniture and Related Product Manufacturing	1.47
Miscellaneous Manufacturing	25.00
Total	100.00

Table 1.
Sample demographics summary (sample size = 136)

Tarafdar's (2013) market-oriented and financial outcomes, Mirghafoori *et al.*'s (2017) customer satisfaction and financial outcomes, Gligor's (2016) physical (swiftness and flexibility) and cognitive (alertness, accessibility and decisiveness) domains, Gligor *et al.*'s (2015) cost efficiency and customer effectiveness outcomes and Gligor and Holcomb's (2012b) operational performance and relational performance outcomes. Table 2 displays the measurement scales.

The measurement scales were previously developed and assessed and are therefore considered to exhibit content validity. Standardized factor loadings greater than 0.70 support a claim of sufficient convergent validity (Chiang *et al.*, 2012). The standardized factor loadings displayed in Table 3 all exceed the recommended 0.70 level.

Table 4 displays the square root of average variance extracted values for each of the study constructs and the correlations among the study constructs. The square root value for each construct exceeds the correlations with other constructs supporting a claim of sufficient discriminant validity (Wetzel *et al.*, 2009). Table 4 displays the Cronbach's alpha, composite reliability and average variance extracted values for each of the measurement scales. All alpha, composite reliability and average variance extracted values exceed the respective

Agile manufacturing (Inman *et al.*, 2011)
Please indicate the extent to which you agree or disagree with each statement. (1 = strongly disagree, 7 = strongly agree)
1. This organization has the capabilities necessary to sense, perceive and anticipate market changes
2. The production processes of this organization are flexible in terms of product models and configurations
3. This organization reacts immediately to incorporate changes into its manufacturing processes and systems
4. This organization has the appropriate technology and technological capabilities to quickly respond to changes in customer demand
5. This organization's strategic vision emphasizes the need for flexibility and agility to respond to market changes
6. This organization has formed cooperative relationships with customers and suppliers
7. This organization's managers have the knowledge and skills necessary to manage change
8. This organization has the capabilities to meet and exceed the levels of product quality demanded by its customers
9. This organization has the capabilities to deliver products to customers in a timely manner and to quickly respond to changes in deliver requirements
10. This organization can quickly get new products to market.
Environmental Uncertainty (Miller and Dröge, 1986)
Please indicate the extent to which you agree or disagree with each statement. (1 = strongly disagree, 7 = strongly agree)
1. This organization must change its marketing practices frequently
2. The actions of this organization's competitors are unpredictable
3. The demands and tastes of this organization's customers are almost unpredictable
4. It is necessary to frequently make major changes in this organization's production processes
5. This organization's products become obsolete at a rapid rate
Supply Chain Performance/Competency (Bowersox *et al.*, 2000)
Please rate your company's performance in each of the following areas as compared to the performance of your competitors. (1 = much worse than competition, 7 = much better than competition)
1. Customer satisfaction
2. Product customization
3. Delivery speed
4. Logistics cost
5. Delivery dependability
6. Responsiveness
7. Order flexibility
8. Delivery flexibility
9. Information systems support
10. Order fill capacity
11. Advance ship notification
12. Inventory turns
13. Return on Assets

Table 2.
Measurement scales

minimums of 0.70, 0.70 and 0.50 recommended by Garver and Mentzer (1999) indicating that the measurement scales exhibit sufficient reliability.

Nonresponse bias

Following the initial request to participate, responses were subsequently spread over a five-day period. The means for each of the measurement scale items for each of the five days were compared using ANOVA to assess for nonresponse bias (Armstrong and Overton, 1977). There are no significant differences noted at either the 0.01 or 0.05 levels. Based on this finding of equality of means across the series of days, it is concluded that nonresponse bias is not a significant problem in this dataset.

Construct/Measures	Loading
Agile manufacturing	
AM1	0.842
AM2	0.889
AM3	0.899
AM4	0.904
AM5	0.894
AM6	0.904
AM7	0.882
AM8	0.906
AM9	0.890
AM10	0.898
Environmental uncertainty	
EU1	0.828
EU2	0.801
EU3	0.877
EU4	0.882
EU5	0.875
Supply chain performance	
LP1	0.859
LP2	0.774
LP3	0.867
LP4	0.849
LP5	0.894
LP6	0.903
LP7	0.836
LP8	0.886
LP9	0.813
LP10	0.854
LP11	0.829
LP12	0.862
LP13	0.873

Table 3. Psychometric properties of first-order constructs

Variables	CA	CR	AVE	AM	EU	SCP
Agile manufacturing (AM)	0.971	0.975	0.794	(0.891)		
Environmental uncertainty (EU)	0.906	0.930	0.728	0.524	(0.853)	
Supply chain performance (SCP)	0.969	0.972	0.730	0.851	0.479	(0.854)

Note(s): CA = Cronbach's Alpha, CR = Composite Reliability, AVE = Average Variance Extracted, AM = Agile Manufacturing, EU = Environmental Uncertainty, SCP = Supply Chain Performance

Table 4. Reliability scores and correlations among first-order latent constructs (square root of AVE on diagonal)

Common method bias

The data collection included measures of other operations and supply chain management variables in addition to the three under study here. Lindell and Brandt (2000) recommend that the smallest correlation among variables be used as a proxy for common method variation. Following this approach, the smallest correlation among the variables in the total dataset is 0.347 between TQM-customer-focus (a variable not used in this study but collected as part of a wider dataset) and environmental uncertainty. The smallest correlation among the relationships specified in the structural model is 0.479 for supply chain performance and

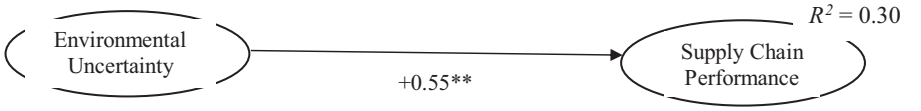
environmental uncertainty. Substituting these correlations into the formulas provided by Malhotra *et al.* (2007), the computed *z*-score is 2.38. This computed *z*-score corresponds with one-tail significance at the 0.01 level. Adjusting for common method variance using the smallest correlation (0.347), the smallest correlation among the hypothesized relationships (0.479) remains significantly different from zero at the 0.01 level. Based on the results of the proxy test, problems associated with common method bias are not considered significant (Lindell and Whitney, 2001). Malhotra *et al.* (2007) estimate that common method variance in marketing studies is at about 15.8%, in management studies at about 3.8% and in information systems studies at about 10%. We estimate that common method variance for this dataset is 12.04% (0.347^2 times 100).

Statistical analysis

Partial-least-squares (PLS/SEM) is appropriate method of statistical analysis when the objective of the analysis is to predict and maximize the percentage of the variance explained in the dependent constructs in the structural model (Matthews *et al.*, 2018; Hair *et al.*, 2011, 2017; Hair *et al.*, 2017) as is the case in this study. PLS/SEM is also well suited for testing the individual hypotheses embedded within the structural model under study (Matthews *et al.*, 2018; Hair *et al.*, 2011). It should also be noted from a practical point of view that PLS/SEM can more easily be used to assess moderation within a structural model (Mathews *et al.*, 2018). For these reasons, we believe that PLS/SEM is the statistical methodology best suited for this particular study. Specifically, WarpPLS 6.0 software is used to assess the structural model.

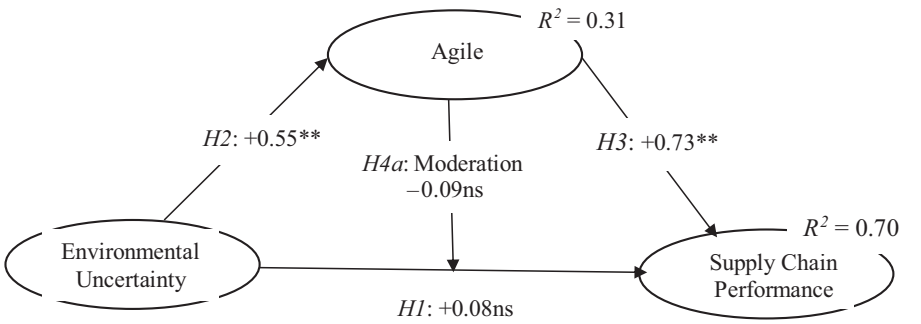
Results

Figure 2 displays the PLS/SEM results. To support the formal test of mediation, it is necessary to determine the statistical relationship between environmental uncertainty and



Environmental uncertainty to supply chain performance without agile manufacturing

(a)



H4b: Mediation: (+0.55** times +0.73**) = +0.40**

Environmental uncertainty to supply chain performance with agile manufacturing as moderator and mediator

(b)

Figure 2.
PLS/SEM results

supply chain performance prior to introducing agile manufacturing as a potential mediator. Panel A displays the statistical results for the structural model with only the direct link from environmental uncertainty to supply chain performance. Panel B displays the statistical results for the structural model with agile manufacturing introduced as both moderator and mediator. In terms of overall fit of the structural model displayed in Panel B, the Tenenhaus (2005) goodness-of-fit index of 0.61 for the model in Panel B is greater than the cutoff value for large effect sizes of 0.36 (Wetzels *et al.*, 2009). The R^2 value for supply chain performance for the model in Panel B of 0.70 falls within the 0.50–0.75 range indicating moderately strong explanatory capability (Hair *et al.*, 2011).

Moderation

The standardized coefficient for the moderator effect of −0.09 is nonsignificant signifying that environmental uncertainty and agile manufacturing do not interact. Within the context of the structural model displayed in Panel B, hypothesis 4a (moderation effect of agile manufacturing) is not supported. Agile manufacturing does not moderate the relationship between environmental uncertainty and supply chain performance.

Mediation

Panel A establishes the direct effect of environmental uncertainty on supply chain performance with a standardized coefficient of +0.55 (significant at the 0.01 level) prior to the introduction of agile manufacturing in the model. Panel B displays the results following the inclusion of agile manufacturing and confirms that agile manufacturing fully mediates the relationship between environmental uncertainty and supply chain performance. The standardized coefficient for environmental uncertainty to supply chain performance link drops from a significant 0.55 (significant at the 0.01 level) in Panel A to a nonsignificant standardized coefficient of 0.08 in Panel B. The indirect effect (EU → AP → LP) is +0.40 (+0.55 times +0 .73), significant at the 0.01 level. The introduction of agile manufacturing into the model increases the R^2 value for supply chain performance from 0.30 to 0.70. This increase in R^2 value is significant at the 0.01 level. Hypothesis 4b (mediation effect of agile manufacturing) is supported. Agile manufacturing fully mediates the relationship between environmental uncertainty and supply chain performance.

Summary of results

Within the context of the structural model presented in Panel B, hypotheses 2, 3 and 4b are supported while hypotheses 1 and 4a are not supported. The results indicate a significant positive relationship between environmental uncertainty and agile manufacturing (hypothesis 2) and a significant positive relationship between agile manufacturing and supply chain performance (hypothesis 3). Agile manufacturing fully mediates the association between environmental uncertainty and supply chain performance (hypothesis 4b). Environmental uncertainty was not found to have a significant relationship with supply chain performance (hypothesis 1) and agile manufacturing was not found to interact with environmental uncertainty to moderate supply chain performance (hypothesis 4a).

Discussion

In recent years, the competitive landscape for organizations has been changing faster than ever (Vecchiato, 2015) to the point that, for many firms, turbulence and volatility and the resulting environmental uncertainty are an integral part of their business (Rasi *et al.*, 2019). In response, many firms have adopted agility as their dominant competitive strategy (Gligor *et al.*, 2013). The need for agility to compete in today's competitive environment has prompted

researchers to designate agility as "critical" (Rasi *et al.*, 2019; Kim and Chai, 2017), as a "crucial competence" (Panda and Rath, 2018), as "must possess" (Gligor *et al.*, 2016) and "needed for survival" (Agarwal *et al.*, 2007).

Contrast of study results with previous research

Our results do not support the hypothesis that environmental uncertainty is positively associated with supply chain performance. This is contrary to our hypothesis, but the finding is not surprising in that Lam and Yeung (2010), Agle *et al.* (2006) and Cannella *et al.* (2008) had similar findings. Our findings do not support the work of Eker and Eker (2019), who reported a positive correlation for the relationship between environmental uncertainty and nonfinancial performance nor does it support James and George's (2018) contention that there is a significant positive relationship between uncertainty and supply chain performance.

Rasi *et al.* (2019) hypothesized and confirmed that uncertainty directly affects supply chain agility. Similarly, Guner *et al.* (2018) hypothesized and confirmed that technological uncertainty positively affects supply chain agility. In support of these studies, our results support our hypothesis that environmental uncertainty is positively associated with agile manufacturing. Additionally, our results follow the bounty of previous research that confirms that agile manufacturing is positively associated with supply chain performance.

Gligor *et al.* (2015) investigated the impact of environmental uncertainty on the relationship between supply chain agility and supply chain performance subsequently issuing a call for the identification of further mediators and moderators of the agility/performance relationship. While reiterating it in a later work (Gligor, 2016), he expressed the need for investigating additional mediators in order to better understand supply chain agility mechanisms that impact firm performance. Rather than proposing environmental uncertainty as a mediator/moderator of the relationship between agility and performance, we offer an alternative view where supply chain agility is seen as mediating the relationship between environmental uncertainty and supply chain performance with our findings supporting full mediation but not moderation.

Guner *et al.* (2018) hypothesized that technological uncertainty affects supply chain agility in a positive way and that supply chain agility affects the firm performance in a positive way but did not test for a mediator/moderator effect of supply chain agility. James and George (2018) had a similar model but, in their model, they studied supply chain practices, rather than supply chain agility. Our findings offer support to their work and broaden the scope of the findings in that their sample was in India and concentrated in only one industry. This also supports the work of Mukherji and Mukherji (2017), who found that environmental uncertainty forces businesses to look for alternatives through innovation, development and sustaining of critical relationships and centralizing decisions for increased focus. From this perspective, our work is actually congruent with Lam and Yeung (2010) and Agle *et al.* (2006), who did not find a positive relationship between environmental uncertainty and supply chain performance.

While Eker and Eker (2019) found a positive correlation between environmental uncertainty and performance and James and George (2018) found support for their hypothesis that as environmental uncertainty increases, supply chain performance increases, from our work one can see that the positive relationship between the two comes from the idea that uncertainty triggers certain firm activities that improve performance (Mukherji and Jukherji (2017).

Since we found no moderation effect, we see that uncertainty and agility do not interact. Variance in performance comes from the reaction to uncertainty, in this case, agility. That is, the relationships are between uncertainty and agility and between agility and supply chain

performance. The relationship between environmental uncertainty and supply chain performance is mediated by agility. While Mukherji and Mukherji (2017) found the improvement in financial measures, we found the improvement in operational supply-chain-centered measures, showing that firms, via agility, can improve both operational and financial performance.

Motivated by other research work yielding statements such as "this research stream is in an incipient stage" (Braunscheidel and Suresh, 2009), and "elements and linkages among agility elements are underdeveloped" (Gligor *et al.*, 2013), we have shown that supply agility is an appropriate, and based on the literature, probably the "most appropriate" response to environmental certainty. Our findings are also consistent with the RBV of the firm in that agility requires dynamic capabilities and unique combinations of resources. Dynamic capabilities are difficult to replicate, making agile firms rare, desirable, nonsubstitutable and difficult to imitate. Additionally, our findings reflect the assumptions of contingency theory in that strategy cannot be fixed for all situations, times or organizational levels but, in environments of uncertainty, firms should be agile. Our model, though simple, provides a base for future research for us and other researchers who can incorporate other impacting variables into the model. Also, simulations and longitudinal studies could provide additional important insight.

Theoretical and managerial implications

The environment is becoming ever more uncertain as competition at the supply chain level is intensifying. Nobre (2011) noted that a continuous growth in environmental complexity demands continuous growth in agility. Mason (2010) adds that attaining agility requires a new mindset.

From a theoretical perspective, agile production is established as fully mediating, but not moderating, the relationship between environmental uncertainty and supply chain performance. Further, uncertainty is established as a pervasive supply chain level phenomenon and agility as a supply chain level strategy with the two constructs combining in a complementary way to positively impact supply chain performance.

Our results offer encouragement and support to practitioners who are striving to or wish to achieve this mindset in their own firms. Consistent with Mukherji and Mukherji (2017), our results show that uncertainty can be a force for good and, utilizing agile manufacturing, can be a source of new opportunities that can be leveraged in these times of increasing uncertainty. Managers must identify improvement programs that mitigate the impact of uncertainty while at the same time improving supply chain performance.

The results of this study establish agile manufacturing as an effective mitigator of uncertainty and as an effective means to improve supply chain performance. When agility is not considered, uncertainty appears to lead to improved supply chain performance. This finding is not intuitively clear initially. It is only with the inclusion of agile manufacturing in the structural model that it becomes clear that uncertainty drives the need for agility, which leads to improved performance at the supply chain level. More subtly, we note that agile manufacturing is a mediator and not a moderator.

It is well established that managers are primarily held accountable for the marketing and financial performance of the organizations for which they work. It is also well established that supply chain performance directly impacts organizational performance. How best then can practicing managers mitigate the uncertainty and enhance performance? The answer to that question, recommended by the results of this study, is that managers should implement agile manufacturing.

Conclusions

We propose that supply chain agility is a response to the effects of environmental uncertainty and, as such, environmental uncertainty can be viewed as driver of supply chain agility. We conclude then that agile manufacturing is an effective strategy for mitigating and building competitive advantage in the face of increasing environmental uncertainty and that the impact of environmental uncertainty on supply chain performance is indirect through agile manufacturing. The significant contributions of this study include establishing this indirect effect of environmental uncertainty on supply chain performance through agile manufacturing. This finding and the associated conclusions are new. In addition, based on the results of this study, it can be formally concluded that agile manufacturing positively impacts performance at the supply chain level.

Combining previous findings with those of this study, it can then be concluded that uncertainty drives agility, which drives supply chain performance, which drives organizational performance. Managers are ultimately held responsible for the performance of their employing organizations. We conclude then, given all the evidence, that practicing managers striving for personal and organizational success should implement agile manufacturing as a supply chain strategy.

There are limitations to this study that should be considered. The results and conclusions must be considered in light of the source of the data – the US manufacturing sector, which is generally mature having embraced management improvement programs such market orientation, JIT, TQM, supply chain management, green supply chain management practices, as well as agile manufacturing (Green *et al.*, 2019). Replications of this study using samples from other countries and regions are necessary before results and conclusions can be more widely generalized. It should also be noted that this study is limited to the relationships among uncertainty, agility and supply chain performance only. Additional studies that incorporate these constructs into more complex structural models such as the comprehensive supply chain management model are theorized by Green *et al.* (2019) with additional antecedents to and consequences of uncertainty and agility.

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