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The Effect of Supply Chain Absorptive Capacity on Customization, Product Innovation and Business Performance

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This paper investigates the effects of supply chain absorptive capacity on customization, production innovation, and in turn, business performance. Building upon the organization and strategy literature, we constructed multi-item measurement scales that tap into five dimensions of absorptive capacity, which were adapted to supply chain management context. Using survey-based data gathered from 174 U.S. supply chain managers, we applied structural equation modeling to assess the influence of supply chain absorptive capacity on business performance and provide empirical insights regarding the mediating role of customization and product innovation capabilities between absorptive capacity and business performance. Our study provides empirical insights that the construct of absorptive capacity is relevant to supply chain management research and practice.

Key words: supply chain, absorptive capacity, customization, innovation

1. Introduction

Although operations management research has recognized the value of organizational learning (Hult, Ketchen, Cavusgil and Calantone, 2006; Hult, Ketchen and Slater, 2004; Craighead, Hult and Ketchen, 2009; Fugate, Stank and Mentzer, 2009); application of absorptive capacity (ACAP) theory to operations/supply chain management is scant (Malhotra, Gosain and EI Sawy, 2005; Rosenzweig and Roth, 2004; Rosenzweig, Roth and Dean, 2003; Roth, G. E. Gaynor, 1996; Roth and Jackson III, 1995; Tu, Vonderembse, Ragu-Nathan and Sharkey, 2006). This research fills the gap between ACAP theory and supply chain management research by introducing explicit measures of ACAP constructs and providing alternative theoretical and empirical models of absorptive capacity. In addition we relate ACAP to operational capabilities such as customization and product innovation, and, in turn, business performance.

Numerous definitions of absorptive capacity exist within the organizational learning literature. Cohen & Levinthal's original concept of absorptive capacity is a firm's ability to value, assimilate and apply new external knowledge for commercial gain (Cohen and Levinthal, 1990). Subsequently, Zahra & George reconceptualize the construct as a dynamic capability consisting of four dimensions: acquire, assimilate, transform and exploit, making a distinction between the constructs of assimilation and transformation (Zahra and George, 2002). Alternatively, a five dimension model is proposed by Todorova & Durisin, emphasizing the difference between recognition and acquisition of new knowledge, as well as redefining assimilation and transformation as an iterative rather than a sequential process (Todorova and Durisin, 2007). Most recently, Lichtenthaler conceptualizes absorptive capacity as exploratory, transformative and exploitative learning processes where exploratory learning includes recognition and assimilation, transformative learning consists of maintaining and reactivating knowledge, and exploitative learning is the application of new knowledge (Lichtenthaler, 2009). Based on the existing literature, we define supply chain absorptive capacity (SC ACAP) as *a manufacturer's ability to value, acquire, assimilate, transform and apply new supply chain knowledge in order to improve operational capabilities and business performance*.

This paper contributes to the operations management literature by reconciling past conceptualizations of ACAP, developing a theory of ACAP in a supply chain context, and offering empirical justification of SC ACAP and its affect on performance. Hence this article attempts to answer four basic research questions:

1) *How does ACAP translate into a supply chain context?* Prior manufacturing operations management use of ACAP has been confined to the plant level (Rosenzweig and Roth, 2004; Roth, G. E. Gaynor, 1996; Tu, et al., 2006); however in order to fully understand the explanatory power of ACAP, we need to extend its application from the plant to the supply chain level. We operationalize ACAP for supply chain management from a manufacturer's perspective, describing the five dimensions as they occur in supply chain management activities, including attention to environmental scanning activities, allocation of resources towards acquisition of knowledge, active comprehension and adaptation of new supply chain knowledge, and, ultimately, application of new knowledge to supply chain tasks.
2) *What are the competing conceptualizations of supply chain SC absorptive capacity?* We rigorously examine the multi-dimensional nature of absorptive capacity by offering two competing models of SC ACAP. Our first model captures SC ACAP as second-order factor where the attributes of absorptive capacity are allowed to covary simultaneously (Lichtenthaler, 2009; Tu, et al., 2006). We also test a competing theoretical model. The

alternative model is consistent with the organizational learning literature, in which sequential relationships among the dimensions of absorptive capacity are modeled (Todorova and Durisin, 2007). Our comparison of these two models supports our conceptualization of SC absorptive capacity as a set of dimensions which are complementary and operate holistically.

3) *Does SC ACAP have an effect on operational capabilities such as customization and product innovation?* Multiple authors have proposed that ACAP leads to development of new processes and products (Cockburn and Henderson, 1998; Cohen and Levinthal, 1990; Ejermo, 2004; George, Zahra, Wheatley and Khan, 2001; Jansen, 2005; Jansen, Van Den Bosch and Volberda, 2005; Kessler, Bierly and Gopalakrishnan, 2000; Knott and Drive, 2008; Lane, Salk and Lyles, 2001; Lichtenthaler, 2009; Matusik and Heeley, 2005; McKelvie, 2007; Mowery, Oxley and Silverman, 1996; Todorova and Durisin, 2007; Zahra and George, 2002). In this research, we capture the concept of "new process development" with the operational capability of customization, whereas we represent the concept of "new product development" with product innovation capability. Product innovation requires application of new knowledge to product design. However, for product innovation to be achieved, the new knowledge must be included in the manufacturing process, rendering the ability to incorporate learning into operations critical to new product development. Therefore, we study the effect of SC ACAP on both customization and product innovation capabilities.

4) *Does SC ACAP have an effect on bottom-line business performance?* Both the conceptual and empirical literature have established the linkage between ACAP and business performance (Stock, Greis and Fischer, 2001; Zornoza and Julián, 2008; Knott

and Drive, 2008; Lane and Lubatkin, 1998; Lane, et al., 2001; McKelvie, 2007; Rosenzweig, et al., 2003; Todorova and Durisin, 2007; Tu, et al., 2006; Zahra and George, 2002). In this work we extend the existing literature to supply chain management by empirically examining how SC ACAP affects business performance such as market share and profitability.

The implications of SC ACAP for practice are significant: firms that expect their operations and supply chain management functions to create a competitive advantage are necessarily concerned with how to invest their resources in these areas. If, as posited by the knowledge-based view of the firm, knowledge is potentially the most important firm resource (Grant, 1996), and, if, as evidenced by a breadth of literature demonstrating the competitive value of superior supply chain management (SCM), supply chains continue to offer strategic advantages, then organizational learning in the supply chain context is of interest to both researchers and practitioners (Fugate, et al., 2009; Malhotra, et al., 2005). As a result, ACAP theory is eminently adaptable to the supply chain context. The remainder of this paper is organized as follows: we first review the extant ACAP literature, developing a holistic view of the construct and applying it to the supply chain context. We then develop our hypotheses by integrating the ACAP, organizational learning, supply chain management, product customization, and product innovation literature. We test our hypotheses with a sample of 174 cases, using structural equation modeling to support both our measurement and structural models. Finally, we discuss our results, the limitations of the study, and provide implications for practice and future research.

2. Literature Review and Hypothesis Development

Knowledge derived through supply chain activities is recognized as a critical component of managing supply chain performance (Hult, et al., 2006; Hult, Ketchen and Nichols, 2003; Hult, et al., 2004) and the capacity to generate new knowledge within the supply chain has been shown to positively affect both supply chain and firm performance (Craighead et al., 2009). These findings are consistent with the knowledge-based view (KBV) of the firm which considers knowledge as a strategic resource which is developed cumulatively and is therefore complex and difficult to imitate (Grant, 1996; Nonaka, 1994; Nonaka, Toyama and Nagata, 2000; Spender, 1996). Organizational learning theories have found a variety of applications in operations and supply chain management, including problem solving (Mohrman and Mohrman Jr, J. R. Galbraith, Lawler, E. E., 1995), implementation of new process technologies (Tu, et al., 2006, cycle time (Hult, et al., 2006), process change (Carrillo and Gaimon, 2004), and process improvement (Okhuysen and Eisenhardt, 2002). More specific to the supply chain, suppliers and customers have been identified as important sources of new external knowledge (Dyer and Singh, 1998). The resulting interactions of supplier, customer and manufacturer to solve problems, respond to customer needs, design or modify products and share practices have been shown to positively affect knowledge creation (Huang, Kristal and Schroeder, 2008).

Accordingly, the application of absorptive capacity to the supply chain is a logical extension of KBV and organizational learning research; ACAP is also a dynamic capability that is developed cumulatively and allows for reconfiguration under turbulent environmental conditions (Lichtenthaler, 2009). The definition of dynamic capabilities proposed by Teece et al. is adopted here: dynamic capabilities are “the firm’s ability to integrate, build and reconfigure internal and external competences to address rapidly changing environments,” (Teece, Pisano and Shuen, 1997). Absorptive capacity, as a measure of a firm's ability to learn, to create advantage from learning, and potentially also to survive radical industry change is a dynamic capability which can only be developed with long-term investment (Todorova and Durisin, 2007). Furthermore, since improved capabilities take considerable time to develop, a firm with a disadvantage as compared to their competition may have limited opportunities to close the competitive gaps (Teece, et al., 1997). Because ACAP offers the potential to make organizational learning processes more transparent, SC ACAP may advance our understanding of how new knowledge creates difficult to imitate competitive capabilities within the supply chain (Eisenhardt and Martin, 2000; Teece, et al., 1997).

Since its introduction by Cohen & Levinthal in 1990 the construct of absorptive capacity (ACAP) has attracted significant interest among management researchers, particularly in the field of innovation (Cohen and Levinthal, 1990; Jansen, et al., 2005; Lane, et al., 2001; McKelvie, 2007; Zornoza and Julián, 2008; Mowery, et al., 1996; Szulanski, 1996). The dimensions of ACAP have been measured and conceptualized in a variety of domains with very little consensus (Cohen and Levinthal, 1990; Cohen and Levinthal, 1994; Lane and Lubatkin, 1998; Zahra and George, 2002). Nevertheless, interest in the construct remains high, and the debate regarding dimensions, definitions and measurement continues (Lichtenthaler, 2009; Todorova and Durisin, 2007).

Insert Table 1 about here

In their initial conceptualization, Cohen & Levinthal proposed three dimensions of ACAP: value, assimilate and apply (Cohen and Levinthal, 1990). A significant portion of these authors' contribution consists of the adaptation of individual cognition principles to the context of the organization. Absorptive capacity theory, at its most elemental level, proposes that the ability of a firm to evaluate and benefit from new external knowledge depends, in part, on the existing knowledge within the firm (Cohen and Levinthal, 1990). To the extent that a new piece of knowledge is consistent with existing firm knowledge and practices, it is more easily recognized, acquired, developed, and finally, applied within the firm. Conversely, knowledge that is radically different from what the firm already practices will be more difficult to detect, acquire and apply, leading to a potential "paradox" for firms that excel in a given skill set – while they may be highly attuned to new knowledge that corresponds to existing capabilities they may simultaneously become insensitive to of new types knowledge which may be the key to disruptive innovation and more profitable organizational learning (Leonard-Barton, 1992). Firms that invest in maintaining and increasing their absorptive capacity through research and development, interactions with suppliers and customers, trade associations, ongoing training and educational investments, etc. can begin to address their "core rigidities" by broadly scanning for new knowledge rather than confining their activities to sets of knowledge that match their existing competencies and skills (Leonard-Barton, 1992).

Empirical work following Cohen & Levinthal's original conceptualization supported and extended the three dimension model, including Lane et al.'s (2001) relative absorptive capacity between teaching and learning firms, Szulanski et al's 1996 treatment of intra-firm transfer of best practices, research alliances (Mowery, et al., 1996) and cased-based research (Volberda and de Boer, 1999). Results from these research efforts were mixed, however, as were the definitions and measurements used. Zahra & George (2002) proposed a reconceptualization of ACAP which broadened the theory to four dimensions of acquire, assimilate, transform, and exploit. In addition to adding transform to ACAP dimensions, these authors proposed that ACAP existed in two phases: potential (PCAP) and realized (RCAP) absorptive capacity (Zahra and George, 2002). By separating the dimensions in this manner, the authors create the possibility of differentiating between investments in ACAP that explore the possibility of new knowledge and its benefits and investments that generate tangible benefits. The idea that ACAP as a construct could be separated into potential and realized elements is of interest particularly if it can explain how firms achieve the conversion of new knowledge from a potential opportunity to realized benefit. Adding *transform* to ACAP dimensions aligns the theory more faithfully with individual cognition theory, adding detail previously missing by discriminating between *assimilation*, which deals predominantly with knowledge that closely matches existing firm routines and cognitive schema, and *transformation*, which requires significant adaptation of either the new knowledge, or of the organization itself (Zahra and George, 2002). This reconceptualization and four dimension model underlies subsequent empirical literature involving ACAP (Jansen, 2005; Jansen, et al., 2005; McKelvie, 2007). Other authors have proposed alternative models (Lichtenthaler, 2009; Tu, et al., 2006; Yli-Renko, Autio and Sapienza, 2001), an indication of the continuing dissension within the academic community regarding the nature of the construct. In 2006 Lane et al. suggested that ACAP research had become "reified," and had strayed so far from the original intent of the theory that serious re-evaluation was required (Lane, Koka and Pathak, 2006).

Subsequently, Todorova & Durisin's research note proposes a five dimension model of ACAP, suggesting that Zahra & George's model contains several flaws or omissions, including an under-emphasis on scanning and recognition activities (Todorova and Durisin, 2007). In addition, these authors call into question the separation of ACAP dimensions into PCAP and RCAP, instead theorizing that assimilation and transformation are complimentary and potentially iterative steps in the adoption process for new firm knowledge (Todorova and Durisin, 2007).

While less parsimonious than prior conceptualizations, the Todorova & Durisin model provides a richer, more detailed description of the organizational learning process. The five dimension description of the construct is intuitively appealing because each element represents a distinct set of firm activities and resource allocations for new knowledge creation. We therefore propose that it is critical to include all five dimensions, and to consider ACAP a holistic construct where no one dimension exists independently or has utility without the accompanying other dimensions (Lichtenthaler, 2009). We define each of the five dimensions of SC ACAP in the following sections.

2.1.1 Value

We define the construct of value, henceforth referred to as "value" as scanning for, detecting and assessing the potential benefit of new supply chain knowledge; it is a prerequisite for all other ACAP dimensions to be initiated (Todorova and Durisin, 2007). Value involves the recognition of the potential for benefit to be accrued by the firm should a potential new piece of knowledge be integrated into the organization. Without recognition, the resources necessary to bring the knowledge into the organization (acquire) cannot be allocated and the process of adapting the information and ultimately applying it to firm processes does not occur. Valuing information is analogous to environmental scanning, albeit with the requisite orientation towards identifying practices, technology, and information that could benefit the organization.

Our definition of value is consistent with Cohen & Levinthal's original representation of the dimension as "a firm's ability to recognize the value of new information," (Cohen & Levinthal, 1990, p. 128) and accounts for the decisions that firms must make in order to decide what types of knowledge to acquire, which requires allocation of scarce resources. Not all relevant knowledge will be chosen for integration into firm processes; it is valuation that describes the discrimination between new pieces of knowledge. In addition, with the dimension of value, we perceive the first hint of possible contradictory effects of ACAP: in honing the ability to recognize valuable knowledge, the firm, by necessity becomes more skilled and aware of knowledge that is similar to its existing set of capabilities. As a result, more divergent, disruptive types of new knowledge may fail to be recognized as important or useful and therefore may be overlooked in favour of additional capability development in the realm of extant knowledge (Leonard-Barton, 1992).

2.1.2 Acquire

We define the dimension of acquire is defined as the intensity, speed, direction and effort directed towards gaining knowledge for application to the supply chain (Cohen and Levinthal, 1994; Todorova and Durisin, 2007; Zahra and George, 2002). Acquisition occurs when the firm acts to bring new knowledge into the boundaries of the firm. While valuing involves recognition, acquire is distinguished by the commitment of resources to whatever activity (purchasing, consulting, etc.) is necessary to internalize the knowledge for firm use. In the case of a new technology, the action of purchasing the right to use the technology is an obvious and discrete manifestation of acquire. More subtly, a firm may acquire new knowledge by choosing to send a team of employees to a supplier's facility to observe a best practice. In this sense, acquire could occur with a discrete outlay of capital, or over time as resources are deployed to gather a piece of new knowledge and return it to the manufacturer. Along the continuum between outright purchase of knowledge and more incremental methods of acquisition, acquire, as a dimension of ACAP, is, like value, a prerequisite to the new knowledge traveling towards further interpretation and eventual application. If value exists as an awareness or perception of possible benefit, acquisition is the activity that takes place that enables a firm to act on the new knowledge in a more tangible way by moving elements of knowledge from outside the firm to within the boundaries of the firm.

2.1.3 Assimilate & Transform

Consistent with Todorova & Durisin, we define assimilation and transformation in the supply chain context as follows: assimilation is the manufacturer's ability to create an understanding of new supply chain knowledge and to interpret it for implementation where the new knowledge fits within existing organizational cognitive schema and current organizational structures. Transformation is conceptually and operationally distinct from assimilation; we define it as the manufacturer's ability to alter existing knowledge structures and combine new supply chain knowledge with modified cognitive schema (Todorova and Durisin, 2007).

In the original conceptualization of ACAP, assimilate encompasses all processes between valuing and applying new knowledge; however Cohen and Levinthal did not discriminate between simple and complex adaptations of knowledge (Cohen and Levinthal, 1990). Alternatively, Zahra & George's inclusion of transform into the ACAP construct suggests that assimilation is a necessary prerequisite to useful application of knowledge because it includes interpretation, understanding and comprehension (Zahra and George, 2002). This description of assimilation as a necessary, but not sufficient condition of benefiting from new knowledge supports these authors' division of ACAP into potential and realized subcategories, with the separation between PCAP and RCAP occurring between assimilate and transform.

As a result, we posit that assimilate and transform are two different but complimentary learning processes (Todorova and Durisin, 2007). Assimilation occurs as a manufacturer begins to interpret the knowledge for their own use, and rapidly moves into direct application when the new knowledge is sufficiently congruent with existing tasks, processes and structures. Alternatively, transformation is necessary prior to application when the new knowledge is not immediately understood or comprehended. In these cases, either the knowledge or the manufacturer's existing processes and structures, or both, need to be changed in order for the new knowledge to fit within the organization and produce benefit.

2.1.4 Apply

We define apply as the manufacturer's ability to incorporate new supply chain knowledge into operations to achieve improvements and objectives (Cohen and Levinthal, 1990; Todorova and Durisin, 2007; Zahra and George, 2002). This final dimension of ACAP is less debated perhaps than all of other components of the construct. Apply occurs when the new knowledge is integrated into the manufacturer's supply chain; although this is the dimension of ACAP where we would expect benefit to accrue to the manufacturer due to the implementation of a best practice or technology, achievement in this dimension has another, more subtle effect. Because a premise of absorptive capacity theory is that the organization's ability to learn is predicated, in part, on existing knowledge, the successful incorporation of new knowledge enlarges the existing knowledge base. Existing knowledge is a prerequisite for absorptive capacity; manufacturers who successfully apply new knowledge gain not only from that particular exploitation activity, but also because future knowledge gathering activities are informed by the experience of implementation. Essentially, the more a manufacturer practices the activities associated with each dimension and the more applications are derived from their cumulative development of supply chain ACAP, the more readily the organization will be able to value, acquire, assimilate, transform and, finally, apply other new sets of knowledge.

2.2. Supply Chain Absorptive Capacity as a Second-Order Construct

We model SC ACAP as a second order latent construct, operating holistically to influence the mediating variables of product innovation and customization. This specification is theoretically supported by prior empirical use as a second order construct (Lichtenthaler, 2009; Tu, et al., 2006) and by complementarity theory (Milgrom and Roberts, 1995). Applying complementarity to absorptive capacity dimensions suggests that the sum of the individual components of ACAP has a greater influence on firm performance than any single element of ACAP individually (Lichtenthaler, 2009). In addition, we propose that, in the supply chain context, there is likely to be iteration between ACAP dimensions. For example, many sets of new knowledge may be assessed for value before moving on to apply; the continuous scanning of the environment for new relevant knowledge increases the manufacturer's SC ACAP, even though at this point no specific knowledge has been acquired and passed through to implementation. Similarly, we envision a knowledge set, particularly a technology, moving into acquisition and then back to value as different modules and upgrades are assessed once initial purchase decisions have been made, but final specifications are still being determined. The justification for an iterative relationship between assimilate and transform has been discussed previously; by allowing these dimensions to form a latent variable we overcome the limitations imposed by the sequential model (Lichtenthaler, 2009; Todorova and Durisin, 2007; Tu, et al., 2006). Finally, apply could be an iterative dimension as well, for example, when an implementation does not yield the expected benefit or otherwise performs poorly, the knowledge may need to move back, or regress to assimilation and transformation prior to full benefit of application being realized.

The nature of absorptive capacity in the supply chain context makes the sequencing of ACAP dimensions less relevant than in, for example, a firm with basic research and development expenditures. Many of the valuing and acquisition activities that form the “front end” of SC ACAP will not be stand alone activities or large, discrete budget items. Therefore, while we maintain that the dimensions represent distinct activities and require different types of resources, we posit that a second order model that allows for covariance between the dimensions will be superior to a sequential model.

> *Hypothesis 1 – Supply chain absorptive capacity is a second-order construct reflected by five dimensions: value, acquire, assimilate, transform, and apply.*

2.3. Effect of SC Absorptive Capacity on Customization and Product Innovation

Although the innovation literature has investigated the relationship between ACAP and constructs such as R&D productivity (Cohen and Levinthal, 1990; Mowery, et al., 1996 Knott and Drive, 2008; Lane and Lubatkin, 1998), technological innovation (McKelvie, 2007); and product/process innovation (Lichtenthaler, 2009; Yli-Renko, et al., 2001), our study extends the existing literature by demonstrating support of a relationship between supply chain learning capabilities (SC ACAP) and two operational capabilities: customization and product innovation. Product innovation and customization require the reconfiguration or recombination of firm knowledge and skills in order to develop new products and modify processes. Accordingly, firms that have the ability to accomplish this reconfiguration in a timely manner to address new competitive challenges are more likely to be more successful product innovators. Built cumulatively and over time, SC ACAP contributes to a manufacturer’s ability both to adapt to new product designs as well as to achieve customization.

We adopt the definition provided by Tu et al. (2001, p. 203) and later used by Huang et al. (2008) of customization as “the ability of the firm to quickly produce customized products on a large scale at a cost comparable to non-customized products”(Huang, et al., 2008; Tu, Vonderembse and Ragu-Nathan, 2001).

Hypothesis 2a – Supply chain absorptive capacity directly and positively affects a manufacturer's ability to customize its products.

The interaction between knowledge development capacity and intellectual capital positively affects the firm's product responsiveness which is analogous to product innovation. (Craighead, et al., 2009). ACAP is the combination of a firm's prior knowledge (intellectual capital) and ongoing investments in knowledge development. As these authors observe, this interaction may represent combinative capabilities (Kogut and Zander, 1992). Petersen, Handfield and Ragatz (2005) suggest that successful integration of suppliers into new product design improves product development effectiveness and positively affects supply chain design decisions. To the extent that SC ACAP represents a degree of interactions with suppliers for the purpose of learning, we posit that SC ACAP positively affects product innovation capability:

Hypothesis 2b – Supply chain absorptive capacity directly and positively affects a manufacturer's product innovation capability.

2.4. Customization and Product Innovation

Customization is one factor that improves the likelihood that a manufacturer will discover attractive opportunities for product innovation (van Hoek, Harrison and Christopher, 2001). As Salvador, de Holan, and Piller (2010) suggest, customization is "a process for aligning an organization with its customers' needs "(pg. 71). In other words, customization is a factor in a manufacturer's ability to make successful design changes during the production process, and thus enables manufacturers to excel at new product introduction (Gao, Zhang and Liu, 2007;Von Hippel and Katz, 2002). Furthermore, Suarez, Cusumano and Fine (1996) and Narasimhan, Talluri, and Das (2004) suggest that changes in manufacturing processes for meeting different requirements of the customers lead to new product development capabilities (Narasimhan, Talluri and Das, 2004; Suarez, Cusumano and Fine, 1996). As Salvador et al. (2010) state building customization capabilities lead manufacturers to innovate new products more efficiently. Therefore we propose:

Hypothesis 3 – The manufacturer's product customization capability directly and positively affects product innovation.

2.5. Supply Chain Absorptive Capacity, Customization, Product Innovation and Business Performance

Previously we proposed a positive relationship between SC ACAP and two operations capabilities: customization and product innovation. Researchers in the general management literature also suggest that absorptive capacity will impact an organization's overall business performance (Stock, et al., 2001; Zornoza and Julián, 2008;Knott and Drive, 2008; Lane and Lubatkin, 1998; Lane, et al., 2001; McKelvie, 2007; Rosenzweig, et al., 2003; Todorova and Durisin, 2007; Tu, et al., 2006; Zahra and George, 2002), asserting that absorptive capacity enables organizations to adapt both incremental and revolutionary process/product changes. In accordance with the resources-capabilities-performance relationship underlying both the resource-based view and the KBV (Eisenhardt and Martin, 2000; Garud and Ahlstrom, 1997; Kogut and Zander, 1992; Menor and Roth, 2007), we argue that customization and product innovation capabilities mediate the relationship between SC ACAP and a manufacturer's overall business performance as represented by market share and profit.

The logic behind this mediation argument is this: effective SC ACAP translates into operations capabilities (such as customization and product innovation), which are embedded in a manufacturer's resources and inherently difficult to imitate (Hayes, Pisano, Upton and Wheelwright, 2005); it is through these capabilities that absorptive capacity will influence business performance (Stock, et al., 2001; Zornoza and Julián, 2008; Knott and Drive, 2008; Lane and Lubatkin, 1998; Lane, et al., 2001; McKelvie, 2007; Rosenzweig, et al., 2003;

Todorova and Durisin, 2007; Tu, et al., 2006; Zahra and George, 2002), such as market share and profitability. Our hypotheses are formulated as follows:

Hypothesis 4: Customization capability mediates the relationship between SC ACAP and market share (profit).

Hypothesis 5: Product Innovation capability mediates the relationship between SC ACAP and market share (profit).

2.6. Market Share and Profit Level

Since the mid-seventies, many studies investigated the relationship between market share and profit level. Although some studies documented the positive relationship between market share and profit level (Buzzell, Gale and Sultan, 1975), there are other studies that showed the positive relationship between market share and profit level is context specific (Prescott, Kohli and Venkatraman, 1986). One of the rationales behind this significant effect is economies of scale. In other words, high-market-share businesses can achieve lower costs when higher production rates lead to reduced variable costs (Levinthal and Myatt, 1994). Also, as in the Wal-Mart case, for example, firms with high market share can exert power on their suppliers in order to lower their material costs as well (Mottner and Smith, 2009). Therefore we propose that:

Hypothesis 6. Market share positively affects profit level.

2.7. Control Variables

We use two control variables: environmental dynamism and manufacturing unit size as measured by the number of employees. We define environmental dynamism as the level of market turbulence with respect to products, technologies, and product demand (Huang, et al., 2008; Lichtenthaler, 2009; Ward and Duray, 2000; Kristal, Huang and Roth, *forthcoming*). Environmental dynamism reduces manufacturers' ability to make reliable forecasts based on the information available, creating significant barriers to business performance. We have specified environmental dynamism as a control variable due to its relevance to performance. This is further supported by literature suggesting that environmental dynamism may be the most influential element of the competitive environment with respect to business unit survival (Anderson and Tushman, 2001). In addition, dynamic environments could drive manufacturers to place greater emphasis on organizational learning, product innovation and customization activities. To assess dynamism we used extant measures; survey respondents provided a relative rating of product, technology and demand turbulence in their market environment (Ward and Duray, 2000) (*see* Appendix A).

The second control variable is manufacturing unit size as represented by the number of employees. Size has been identified as a factor influencing organizational performance (Chen and Hambrick, 1995 Mintzberg, 1979), learning (Hult, et al., 2006), and technology integration (Stock and Tatikonda, 2004) and innovation (Lichtenthaler, 2009; McKelvie, 2007). Larger manufacturing units typically have greater market share as well as more resources and greater control over the competitive environment (Dean, Brown and Bamford, 1998); however, they also tend to be management levels within their organizational hierarchy than smaller business units, leading to increased bureaucracy as well as a disinclination to change (Daft, 1998). More specific to this study, larger manufacturing unit size in terms of the number of employees suggests greater resources available for organizational learning, process improvement, implementation, customization and product innovation activities (Huang, et al., 2008; McKelvie, 2007). As a result we would expect that larger manufacturing units would have greater organizational learning, customization and product innovation capabilities due to these available resources. By including manufacturing unit size as a control, we will be able to separate the effects of greater labor resources from the effects of supply chain absorptive capacity.

3. Methods

3.1. Data Collection and Sample

The data used in this study is obtained from a larger research program that has been applied to the investigation of supply chain adaptivity and learning (Kristal, et al., *forthcoming*). The data was collected through a survey administered to a sampling frame of 3,200 potential respondents obtained from the Institute for Supply Management (ISM) membership directory; final survey results included 174 complete cases. The survey was directed at manufacturing-intense business units; potential respondents occupied positions Titled 1 and 2 according to ISM's classification system (ISM, 2009). Respondents' positions within the organization varied and included president, vice president, director, general manager, supply chain manager, and purchasing manager. The majority of responses were obtained from medium to large sized manufacturing firms (approximately 35 percent of respondents were from firms with more than 1,000 employees) with significant market positions (more than 57 percent of the manufacturers reported market shares over 32 percent). Respondents were asked to indicate the strategic business unit represented by their answers: 52.90 percent represented the entire company, 32.20 percent of responses were for the group or division level, 12.10 percent represented the plant level, and 2.80 percent indicated that they represented other types of business units. A summary of primary industries represented in our sample and their level of manufacturing customization are presented in Table 2. Generally, respondents reported themselves to be knowledgeable about the subjects in the survey, with 17 percent reporting themselves to be "very knowledgeable," 38 percent reporting "above average knowledge" and 35 percent reporting themselves to be "knowledgeable". Additional details regarding the survey administration process and sample are provided in Kristal et al., forthcoming.

Insert Table 2 about here

3.2. Measures

Apart from the work of Tu et al. (2006), the explicit adaptation of absorptive capacity in supply chain management research is non-existent (Tu, et al., 2006). As the first empirical application of the notion of absorptive capacity in supply chain management research, we developed our items based on the conceptual literature in organization learning. Our measures were originally based in Zahra & George's four-dimension model of ACAP (Zahra and George, 2002). Accordingly, we developed multiple item measures of acquire, assimilate, transform and exploit. However, after the measures were implemented, our conceptualization was influenced by Todorova & Durisin's 2007 five-dimension ACAP model. Having deduced that the five-dimensions were theoretically distinct, justified, and relevant to the supply chain context, we re-examined our measures and allocated them, according to the definitions provided here, to each of the five Todorova & Durisin dimensions (Todorova and Durisin, 2007). We confirmed the supply chain absorptive capacity scales by assessing the psychometric properties of these items using the responses from the ISM field survey database. The constructs of value, acquire, assimilate, transform, and apply were captured on self-anchored, five-point Likert-type scales, ranging from 1 = Strongly Disagree, 3 = Neutral, to 5 = Strongly Agree (*see* Appendix A for exact questions and item wording).

With respect to product innovation and customization measures, we employed items that were used in prior research. We operationalized product innovation as a manufacturer's ability to rapidly develop and deploy new products that exceed existing performance boundaries (Giffi, Roth and Seal, 1990; Menor and Roth, 2007; Roth, 1989; Roth, 1996; Miller and Roth, 1988). Similarly, we operationalized customization as the ability of a manufacturer to customize its products to the needs of the customer (Alford, Sackett and Nelder, 2000; Christensen, Germain and Birou, 2005; Da Silveira, Borenstein and Fogliatto, 2001; Duray, 2002). Managers were asked to compare their product innovation and customization capabilities with respect to their competitors' performance on each using a 5-point Likert scale ranging from 1 = Relatively Weak, 3 = Average, to 5 = Market Leader.

We evaluated business performance using two widely adopted existing measures: profit level and market share (Kristal, et al., *forthcoming*; Rosenzweig, et al., 2003). Respondents rated business performance (i.e., market share and profitability) compared to their competition, using a self-anchored five-point Likert scale, ranging from 1 = Relatively Weak, 3 = Average, to 5 = Market Leader (Prescott, et al., 1986; Venkatraman and Prescott, 1990). Objective data for business performance is difficult to obtain, particularly at the business unit level, and even so-called "objective" measures have their own errors and bias, therefore we accepted these senior managers' perceptions of their business performance (Narasimhan and Das, 2001). Subjective measures of business performance have been used successfully researchers in other management disciplines (e.g., Venkatraman and Prescott, 1990 ; Prescott, et al., 1986) as well as in the field of operations management (Rosenzweig, et al., 2003; Roth, 2007). We present the list of items used in the study in Appendix A; and in Section 3.3, their psychometric properties.

3.3. Measurement Properties

We use Little's (1988) missing completely at random (MCAR) test to evaluate the pattern of missing data for each item (Little, 1988). Our items do not deviate from a MCAR pattern (χ^2 = 1091.65, df = 1123, p = .74); therefore, missing values were handled using a Full Information Maximum Likelihood (FIML) approach, which uses all available data to generate maximum likelihood-based statistics (Arbuckle, 2005; Little and Rubin, 1989). AMOS 17 was used to conduct a confirmatory factor analysis (CFA) in to assess both construct reliability and validity (Anderson and Gerbing, 1988; *see* Appendix B). Because of sample size considerations, we evaluated two measurement models. Measurement Model I contains the absorptive capacity constructs, and Measurement Model II contains the endogenous variables of product innovation, customization, and market share and profit level, along with the exogenous control variable, environmental dynamism. The overall fit of the both measurement models are good (Bollen, 1989) (Measurement Model I: $\chi 2$ = 219.73.12; df = 139; p < .01; IFI =.95; NNFI = .93; CFI = .95; RMSEA = .06; Measurement Model II: $\chi 2$ = 260.03; df = 112; p < .01; IFI =.96; NNFI = .95; CFI = .96; RMSEA = .07). Each individual measurement item is significantly associated with its corresponding latent construct, and has a coefficient greater than twice the standard errors (*see* Appendix B), supporting both unidimensionality and convergent validity (Anderson and Gerbing, 1988). In order to analyze construct reliability, we used the statistics of composite reliability and average variance extracted (AVE) (Fornell and Larcker, 1981; Hair, Anderson, Tatham and Black, 1998; Williams, Edwards and Vandenberg, 2003). All of our composite reliability values are greater than 0.70 and AVE values greater than or at the level of 0.50 (*see* Appendix B), indicating acceptable reliability levels (O'Leary-Kelly and J. Vokurka, 1998; Fornell and Larcker, 1981).

To evaluate discriminant validity, we created all possible pairs of latent constructs and tested each pair using nested models. First, the pair was freely correlated; then the correlation of the latent construct pairs was set to 1.00. By testing for a significant chi-square difference between the two models, we demonstrate that the constructs are distinct. In Table 3, we present the results of these chi-square difference tests. All the chi-square differences are statistically significant (p < .001), supporting discriminant validity among the theoretical constructs (Bagozzi, Yi and Phillips, 1991; O'Leary-Kelly and J. Vokurka, 1998; Stratman and Roth, 2002).

Insert Table 3 about here

We also assessed the criterion-related validity of the business performance and product innovation capability measures. We correlated the construct of profit level, market share and product innovation with quasi-objective measures again answered by respondents (*see* Appendix A for Criterion Validity measures). The correlation between profit level and profit before taxes was positive (r = 0.35) and significant (p < 0.001), similarly the correlation between market share construct and market share of the highest revenue generating product was also positive (r = 0.37) and significant (p < 0.001). Lastly, the product innovation construct was positively correlated with the relative percentage of revenues from new products (r = 0.33; p < 0.001). Finally, we assessed the common methods variance. One of the remedies for common methods variance is the randomization of the questions; when collecting data we randomized the sequence of items, sought knowledgeable respondents, guaranteed respondents complete anonymity, which was required by our university’s Institutional Review Board, and asked respondents to answer the questions as best they could (Dillman, 2009). Second, after the survey, we statistically assessed common method bias by introducing “method” as an additional latent factor in the measurement models, and allowing it to lead to all observed indicators (Podsakoff, MacKenzie, Lee and Podsakoff, 2003; Siemsen, Roth and Oliveira, 2009). If common method bias exists, the introduction of the method factor into the measurement models would make the item loadings of the theoretical constructs insignificant. Our evaluation did not produce this result, therefore we conclude that our data do not show a significant amount of common methods bias (Kristal, et al., Forthcoming). After establishing the reliability and the validity of our scales, and following the recommendations of Nasser, Alhija, and Wisenbaker (2006), we created summated scales (i.e. averaged the items that represent a construct) for our theoretical constructs. In Table 4, we present the correlation matrix and the descriptive statistics among the observed indicator items and control variables (Nasser-Abu Alhija and Wisenbaker, 2006).

Insert Table 4 about here

4. Results

In order to test our model of supply chain absorptive capacity, we first tested our primary hypothesis derived from our theory as described in Section 3. In order to rule out a possible alternative theory, we have also conducted a post-hoc analysis to test the viability of the sequential ACAP model in our supply chain and manufacturing context (Todorova and Durisin, 2007). The following sections describe our testing of both of these models.

4.1. Hypothesis Testing

We first tested Hypothesis 1, where we depicted SC ACAP as a higher-order construct that is reflected by the constructs of value, acquire, transfer, assimilate, and apply (*see* Appendix C). In order to assess the theoretical relationships, we used AMOS 17 to test the higher-order model, ensuring that these constructs adequately reflect SC ACAP. The fit statistics of the second order model indicate good fit between the model and the data (χ^2 = 258.51; df = 144; p < .01; IFI =.93; NNFI = .90; CFI = .93; RMSEA = .07). Also, the structural loadings of the second order model are higher than 0.70 and significant at p < 0.001 level indicating that the first order constructs of value, acquire, assimilate, transform and apply indeed reflect the higher-order construct of SC ACAP, supporting Hypothesis 1.

After demonstrating the higher-order properties of SC ACAP, we continued our analysis by estimating the theoretical model as depicted in Figure 1. We test the theoretical relationships among the constructs of SC ACAP, customization, product innovation, market share, profit, and our control variables simultaneously. To evaluate the significance of the direct, indirect, and total effects, we use current best practices in the estimation of mediation models (MacKinnon, Lockwood, Hoffman, West and Sheeis, 2002; MacKinnon, Lockwood and Williams, 2004; Preacher, Rucker and Hayes, 2007; Shrout and Bolger, 2002), and estimate the model simultaneously using bootstrapping. Bootstrapping is a nonparametric resampling procedure that does not require the sampling distribution normality assumed by most estimation techniques (Shrout and Bolger, 2002). This procedure provides an empirical approximation of the sampling distribution of the indirect (i.e. mediation) effects, and uses it to construct the confidence intervals necessary to evaluate significance. To improve the performance of the confidence intervals estimated by the bootstrap method (Efron and Tibshirani, 1993; MacKinnon, et al., 2004), we estimate the path model as depicted in Figure 1 with 90% bias-corrected confidence intervals. The model was replicated 1,000 using AMOS 17; the results are depicted in Table 5.

Insert Table 5 about here

Our results indicate that the theoretical model fits the data adequately (χ^2 = 76.87; df = 35; p < .01; IFI =.95; NNFI = .92; CFI = .95; RMSEA = .08). As depicted in Table 4, supply chain absorptive capacity loads onto the five theoretical constructs that constitute this construct. Moreover, it significantly affects both customization (D.E = 0.34, $p < 0.01$) and product innovation (T.E. = 0.40, $p < 0.01$) capabilities, supporting Hypothesis 2a and 2b. We also find significant direct effect (D.E. = 0.39, $p < 0.01$) of customization capability on product innovation which supports Hypothesis 3. van Hoek et al. (2001) suggest customization no longer has to be based solely on contained variety and customers are not restricted to selecting from an assortment of existing options. Instead, customers can define the product areas for customization and determine which product options should be customized (van Hoek, et al., 2001). This implies that customer involvement in product development will go beyond the involvement in engineering a finished product into the actual design and development of products. In other words, this link shows us how process based improvements can lead to product based innovations. Instead of innovating for new models and product generations, innovation can stem from customer requirements which specify what kind of new products to introduce. On the other hand, customization capability does not have a direct effect on market share (D.E. = 0.14, $p > 0.10$) and profit levels (D.E = 0.02, $p > 0.10$), but instead affects business performance indirectly through product innovation capability. Product innovation positively affects market share (D.E. = 0.35, $p < 0.01$), and similar to customization, affects profit level indirectly (I.E. = 0.22, $p < 0.01$) through market share.

Next we tested Hypotheses 4 and 5, where we posit that both customization and product innovation capabilities mediate the relationship between the supply chain absorptive capacity and business performance. Our results indicate that SC ACAP has an indirect significant effect on both market share (I.E. =0.19, $p < 0.01$) and profit levels (I.E. = 0.17, $p < 0.01$), through customization and product innovation capabilities. Following the recommendations of Judd and Kenny (1981), we also add two more paths that link SC ACAP to market share and profit levels (Judd and Kenny, 1981). Neither of these paths is significant and do not improve the fit of the theoretical model, indicating that the customization and product innovation capabilities fully mediate the relationship among SC ACAP and business performance supporting Hypotheses 4 and 5. Lastly, as stated in Hypothesis 6, market share positively affects profit level (D.E. = 0.61, $p < 0.01$).

As for the control variables, even though environmental dynamism positively affects SC ACAP (D.E. = 0.27, $p < 0.01$), we do not observe a significant effect of number of employees on SC ACAP (D.E. = 0.12, $p > 0.10$). This result supports the idea that higher levels of competition generate awareness among manufacturers of the importance of absorptive capacity. Both environmental dynamism (T.E. = 0.30, $p < 0.01$) and the number of employees (T.E. = 0.22, $p < 0.01$) positively affect product innovation capability, although they do not have a significant effect on the customization capability.

4.2. Post-Hoc Analysis

In order to offer an alternative to the second order SC ACAP construct and to incorporate the most recent theoretical work in the field of ACAP, we conducted a post-hoc analysis of a sequential SC ACAP model which specifies the relationships among the five dimensions as proposed by Todorova & Durisin (2007) with value as a prerequisite to rest of the SC ACAP constructs (*see* Figure 2) (Todorova and Durisin, 2007).

Insert Figure 2 about here

For the purposes of causal modeling, we acknowledge a limitation in our alternative model which does not allow for an iterative relationship to be tested between assimilation and transformation constructs as originally specified by Todorova & Durisin (2007). Instead, we propose three paths: two paths directly from acquire to assimilate (A), and transform (B), and a path from assimilate to transform (C). Lastly, one path from assimilate to apply (D) and one path from transform to apply (E). We suggest that path A from acquire to assimilate will be appropriate for most types of knowledge which require some level of interpretation and comprehension before a decision is made as to what might need to be changed in order to apply them. Path B, proceeding directly from acquire to transform occurs when the firm understands at the point of acquisition that a significant alteration of either the knowledge or the organizational processes and structure will be required in order to derive benefit from the acquisition. A clear example of this occurs when a firm adopts a new ERP system, particularly where no ERP system existed before. In this case the firm can readily comprehend that application of the system will require significant adaptation of the organization as processes are standardized and old systems are discarded, and, possibly, that adaptation of the ERP technology itself will be necessary in order to tailor it to the specific needs of the firm. We propose that it is logical to envision many new sets of knowledge moving through the process from assimilate to transform and then onward towards application. This path is consistent with new knowledge being interpreted and understood prior to the firm forming a strategy for adaptation for use and acknowledges the inherent difficulty of transferring seemingly explicit knowledge due to implicit or tacit dimensions of the knowledge which are not readily apparent upon acquisition (Von Hippel and Katz, 2002).

The reciprocal path from transformation to assimilation is neglected here (Todorova and Durisin, 2007). While we agree that this is a possible direction for the process, we believe that it is less likely to occur than Paths A, B, and C. In practice this path could occur when a procedure or technology fails to meet expectations during the transformation process and the adaptation of the knowledge needs to move back to a more fundamental level of understanding, hence a regression towards assimilation.

As in our theoretical model (Figure 1), we tested this model using AMOS 17 by incorporating the direct, indirect and total effects with bootstrapping. Our results indicate that value significantly affects all the other SC ACAP constructs. Interestingly, acquire affects transform indirectly via assimilation (I.E. = 0.34, $p < 0.01$). There is a strong relationship between assimilation and transformation, where assimilation directly affects transformation (D.E. = 0.53, $p < 0.01$). Similarly, both assimilation (D.E. = 0.65, $p < 0.01$) and transformation (D.E. = 0.48, $p < 0.01$) significantly affect apply. Apply affects both customization (D.E. = 0.27; $p < 0.01$) and product innovation (D.E. = 0.34, $p < 0.01$) significantly.

Similar to our theoretical model as depicted in Figure 1, customization positively affects product innovation capability (D.E. = 0.42, $p < 0.01$). On the other hand, customization capability does not have a direct effect on market share (D.E. = 0.14, $p > 0.10$) and profit levels (D.E = 0.02, $p > 0.10$), instead customization capability affects business performance indirectly through product innovation capability. Product innovation positively affects market share (D.E. = 0.35, p < 0.01), and similar to customization, it affects profit level indirectly (I.E. = 0.22, $p < 0.01$) through market share. Lastly, market share positively affects profit level (D.E. = 0.61, p < 0.01).

As for the control variables, similar to our theoretical model, the results indicate that both environmental dynamism (D.E. = 0.22; $p < 0.01$) and number of employees (D.E. = 0.17; $p < 0.01$) significantly affect the first SC ACAP construct of value. This result indicates that higher competition may raise awareness of the importance of new knowledge among manufacturers. Similarly, larger organizations are more inclined to recognize the value of new knowledge. Both environmental dynamism and number of employees have positive significant indirect effects on the rest of the SC ACAP constructs (*see* Table 6). Environmental dynamism (T.E. = 0.25, $p < 0.01$) and number of employees (T.E. = 0.22, $p < 0.01$) also positively affect product innovation capability, though they do not have a significant effect on customization capability. We summarize results of the alternative model in Table 5, below.

Insert Table 6 about here

Despite the significant relationships among the constructs, the *alternative model* does not fit the data well (χ^2 = 125.16; df = 34; p < .01; IFI =.88; NNFI = .75; CFI = .87; RMSEA = .12). As a result, we conclude that our theoretical model not only fits the data better than the *alternative model*, but provides a better theoretical explanation to the relationships among the constructs. This is consistent with prior work which has proposed and found support for higher order representations of ACAP (Lichtenthaler, 2009; Tu, et al., 2006).

5. Discussion and Conclusions

This study has explored different conceptualizations of absorptive capacity and extended the theory to the context of supply chain management. Although the literature has been inconsistent in its description and use of ACAP, a number of applications have proposed that the construct's complexity is better represented by a higher order model. Our work builds on these studies and empirically demonstrates that, in the supply chain management context, ACAP can be modeled as a five dimension, second order construct. In contrast with more sequential models, our representation allows for covariation between different facets of ACAP, which we propose is consistent with the nature of organizational learning via supply chain activities – iterative, overlapping processes which combine to allow firms to incorporate knowledge from suppliers and customers in order to create competitive advantages.

Furthermore, our study demonstrates that supply chain absorptive capacity is positively related to both product innovation and customization. The linkage between operational capabilities and various facets of a manufacturer's performance is well-established; however, this work provides support for supply chain absorptive capacity's antecedent role in contributing to the specific capabilities of customization and innovation. Providing this empirical evidence helps establish concrete reasons for manufacturers to choose to make the necessary commitment to developing learning capabilities. This is particularly important because ACAP, as a cumulative, knowledge-based capability, requires consistent investment over time. Furthermore, while organizational learning has long been recognized as a source of competitive advantage when applied through activities such as basic research and development, learning from supply chain activities may be poorly understood, undervalued, and, as a result, underfunded. For manufacturers who seek to create and maintain superior supply chain operations, our results suggest that neglecting the learning components of supply chain management could have negative implications for other operational capabilities. In effect, by not capitalizing on supply chain learning, these manufacturers do not realize the full potential competitive advantage afforded by their supply chains.

This work offers another important contribution in terms of advancing ACAP theory and measurement: although it is acknowledged as a powerful theory, lack of consistency in specification and measurement has inhibited the progress of ACAP research. By examining prior conceptualizations and incorporating Todorova & Durisin's 2007 modifications into our study, we provide a platform for future ACAP applications in the five-dimension, second order context. However, it is important to recognize the breadth as well as limitations of this study. First, the sample is based solely on United States-based firms; it does, however, include multiple industry categories which have both manufacturing and research-intensive products, as well as complex and sophisticated supply chain structures. Second, the data is cross-sectional; therefore we cannot make definitive causal claims regarding the relationships described in this study, although we can offer the evidence of the post-hoc test of the competing model in support of our framework. Longitudinal study would provide additional basis for the network of relationships between SC ACAP, operational capabilities and business performance.

In addition, the complexity of SC ACAP and the interrelated nature of its underlying dimensions argue for rigorous measurement development. Future research would benefit from more intensive development of a SC ACAP scale that follows Roth and Menor's (2007) scale development process. This study also is limited, as is common in supply chain research, by the one-sided nature of the measures; dyadic study of SC ACAP would improve our understanding of learning processes in the supply chain and would represent a unit of analysis that is under-emphasized in the literature.

With respect to practice, the concept of SC ACAP and its relationship to important manufacturing capabilities, including innovation and customization, have significant implications. First, as mentioned previously, we believe that organizations may significantly underestimate the importance of learning through their supply chain management activities. This miscalculation could prevent manufacturers from recognizing the importance of incremental, long-term investment in developing learning capabilities in the supply chain. The dimension of value, in particular, may not be readily understood by operations managers as an appropriate investment of resources. Supply chains, which for many years were largely functional, are now strategic weapons, however environmental scanning skills may not be a part of many supply chain managers' repertoires. Moreover, under the pressure of day-to-day operations, managers are likely to find it difficult to justify devoting resources to devote to long-term, poorly understood potential future gains. In this respect, future SC ACAP research can offer practitioners additional evidence to support such investments by demonstrating more specifically how SC ACAP benefits operational and financial performance and, possibly, more details about how to develop effective supply chain learning capabilities.

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Appendix A. Constructs and Scale Items

Supply Chain Absorptive Capacity Constructs *(Representative References: Zahra and George 2002; Cohen and Levinthal 1994; and Todorava and Durisin 2007).*

Listed below are supply chain (knowledge) management practices that may affect firms' ability to compete in an industry. Please indicate your level of agreement with these statements about your business unit's supply chain practices over the past 12 months.

1 = Strongly Disagree, 3 = Neutral, 5 = Strongly Agree

Value (V): A manufacturer's assessment of the utility or worth of new supply chain knowledge from outside the organization.
V1: Creating new supply chain knowledge is highly valued by our organization
V2: In general, we are able to see how new supply chain practices might transform the way we operate our own business.
V3: We have processes to analyze the potential usefulness of new supply chain ideas from external resources.

Acquire (AC): A manufacturer's acquisition of new supply chain knowledge in terms of intensity, speed, direction and effort to gain new knowledge.
AC1: We allocate a noteworthy amount of our revenues to the gathering of new supply chain information.
AC2: Our firm has extensive experience in gathering supply chain data from external resources.
AC3: Our firm has invested significantly in activities that will speed up its ability to gather information about new supply chain practices.
AC4: We allocate a significant amount of revenues into R&D activities that are utilized in supply chain applications.

Assimilate (AS): A manufacturer's ability to create understanding of new supply chain knowledge and interpret it for implementation.
AS1: Our firm has a high level of ability to assimilate new supply chain knowledge.
AS2: Organizational conversation keeps alive the lessons learned from supply chain management history.
AS3: We have formal processes for recording our past experiences with the problems that we face in our supply chain practices.
AS4: We have specific mechanisms for sharing lessons learned in the supply chain management processes.

Transform (TR): A manufacturer's ability to alter existing supply chain knowledge structures and combine new knowledge with modified cognitive schema.
TR1: Our supply chain managers transform new ideas into actions.
TR2: We have the ability to implement supply chain innovations
TR3: Once they are introduced, we adjust quickly to new methods.

TR4: We are able to implement new supply chain concepts.

Apply (AP): A manufacturer's ability to apply new supply chain knowledge into operations for commercial advantage.
AP1: Our firm has the ability to quickly alter its supply chain strategy based on new developments in our industry.
AP2: We are able to use new supply chain knowledge to create new competitive capabilities.
AP3: Our firm has a high level of ability to apply new supply chain knowledge.
AP4: We leverage new knowledge to improve how we manage our supply chain.

Operations Capabilities Constructs
Listed below are the critical success factors for competing in an industry. Please indicate your assessment of the strength of your business unit for each capability relative to your competitors' in the same markets over the past 12 months. Please think of **your primary product(s)** while answering these questions.

1 = Strongly Disagree, 3 = Neutral, 5 = Strongly Agree

Customization (C): A manufacturer's ability to customize its products to the needs of the customer (Representative References: Huang, et al., 2008).

C1: Responding to unique requirements of different customers.
C2: Rapidly handling custom orders (i.e., engineer-to-order).
C3: Ability to customize/change products to meet mass-market demands.

Product Innovation (PI): A manufacturer's ability to rapidly develop and deploy new products that exceed existing performance boundaries (Representative References: Menor et al. (2007), Roth (1996), Giffi et al. (1990), Roth et al. (1989), Roth and Miller (1988)).
PI1: Ability to rapidly introduce new products
PI2: Ability to have a short development time for new products
PI3: Ability to generate revenues from products in the introduction and growth stages
PI4: Being first in the market wit new product introductions
PI5: Ability to develop products from new idea to production in a short time
PI6: Ability to generate revenues from new technology

Business Performance
How do you perceive your business unit's performance relative to your competitors.

1 = Relatively Weak, 3 = Average, 5 = Market Leader

Market Share (MS): Relative sales and market growth (Representative References: Dess and Robinson (1984), Vickery et al. (1997), Ward et al., (1998); Roth, et al. (2007)).

MS1: Your position on your sales growth rate compared to your competitors'
MS2: Your satisfaction with your sales growth rate compared to your competitors'

MS3: Your market-share gains relative to your competitors'

Profit Level (P): Relative profit performance (Representative References: Dess and Robinson (1984), Vickery et al. (1997); Ward et al. (1998), Roth, et al. (2007)).
P1: Return on corporate investment position relative to competition
P2: Net profit position relative to competition
P3: ROI position relative to competition
P4: Return on sales position relative to competition

Control Variables
Listed below are critical business-environment factors for competing in an industry. Please indicate your perceptions regarding the following aspects of business environment change.

1 = Very Slow, 3 = Average, 5 = Very Rapid

Environmental Dynamism (ED): The degree of turbulence in products, technologies, and product demand in a market (Representative References: Ward and Duray, 2000).

ED1: The rate at which products and services become outdated
ED2: The rate of innovation of new products and services
ED3: The rate of change of tastes and preferences of customers in your industry

Firm Size

What is your business unit's number of employees?

[ ] Under 50 [ ] 50 – 99 [ ] 100 – 499 [ ] 500 – 999 [ ] 1000 – 2499 [ ] Over 2500

Criterion Validity Measures
Profit
On average, what has been your business unit's profit level (before taxes) as of currently?
[ ] Negative [ ] Breakeven [ ] Under 5% [ ] 5 – 10% [ ] 10 – 15% [ ] 15 – 20% [ ] Over 20%

Market Share
Considering the one product that yields the highest percentage of revenue for your business unit, what is your business unit's average market share as of currently?
[ ] Under 8% [ ] 8 – 16% [ ] 16 – 24% [ ] 24 – 32% [ ] 32 – 40% [ ] 40 – 48% [ ] Over 48%

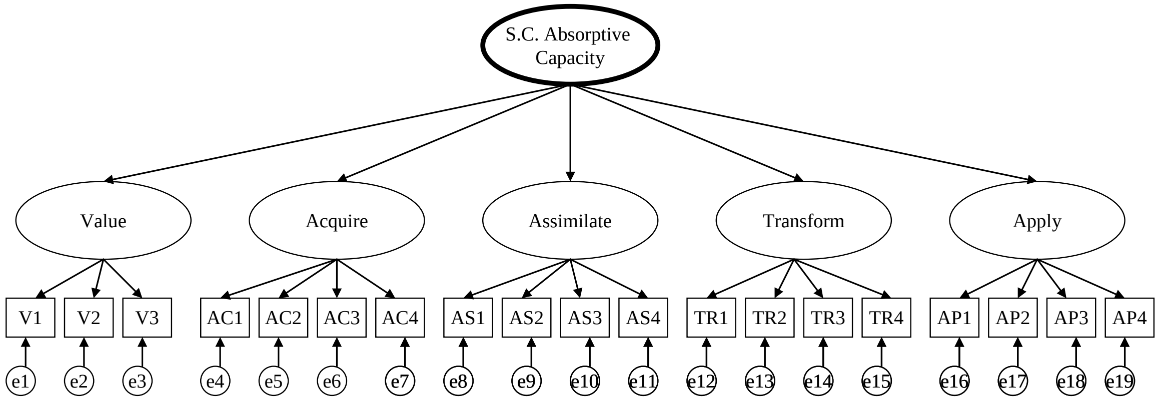
New Product Development Capability
Of your business unit's sales, approximately what percentage is from new products?
New product sales % (over the past 12 months)

Appendix B. Measurement Model (CFA) Results

Measurement Model I (χ^2 = 219.73.12; df = 139; *p* < .01; IFI =.95; NNFI = .93; CFI = .95; RMSEA = .06)					
	Standard Loadings	Standard Errors	Critical Ratio	Composite Reliability	Average Variance Extracted
Value				0.74	0.49
V1	0.78	0.20	7.64		
V2	0.61	---	---		
V3	0.69	0.17	7.13		
Acquire				0.80	0.50
AC1	0.77	---	---		
AC2	0.68	0.65	0.11		
AC3	0.90	0.69	0.11		
AC4	0.72	0.72	0.10		
Assimilate				0.80	0.51
AS1	0.83	---	---		
AS2	0.64	0.09	8.57		
AS3	0.62	0.11	8.37		
AS4	0.74	0.11	8.77		
Transform				0.80	0.50
TR1	0.66	---	---		
TR2	0.82	0.16	8.56		
TR3	0.71	0.13	7.90		
TR4	0.62	0.16	6.70		
Apply				0.88	0.64
AP1	0.83	0.07	13.55		
AP2	0.77	0.07	12.20		
AP3	0.87	---	---		
AP4	0.74	0.08	11.08		

Measurement Model II (χ^2 = 260.03; df = 112; *p* < .01; IFI =.96; NNFI = .95; CFI = .96; RMSEA = .07)					
	Standard Loadings	Standard Errors	Critical Ratio	Composite Reliability	Average Variance Extracted
Customization (C)				0.75	0.50
C1	0.72	---	---		
C2	0.61	0.18	4.94		
C3	0.79	0.19	5.98		
Product Innovation (PI)				0.89	0.57
PI1	0.81	---	---		
PI2	0.81	0.09	11.48		
PI3	0.70	0.08	9.56		
PI4	0.69	0.09	9.31		
PI5	0.87	0.09	12.65		
PI6	0.66	0.08	8.86		
Market Share (MS)				0.91	0.77
MS1	0.91	---	---		
MS2	0.85	0.08	13.64		
MS3	0.88	0.07	14.58		
Profit Level (PL)				0.92	0.75
PL1	0.83	---	---		
PL2	0.89	0.09	12.75		
PL3	0.91	0.08	13.14		
PL4	0.84	0.08	11.59		
Environmental Dynamism (ED)				0.80	0.57
ED1	0.72	---	---		
ED2	0.82	0.14	7.99		
ED3	0.72	0.14	7.72		

Appendix C. Supply Chain ACAP as a Second Order Construct



S.C. Absorptive Capacity as a Higher-Order Construct					
Endogenous Variable	**Predictor**	**Standardized Parameter Estimates**	**S.E.**	**C.R.**	***p*-value**
Value	**S.C. Absorptive Capacity**	0.94	0.10	7.63	***
Acquire		0.74	0.10	7.63	***
Assimilate		0.90	---	---	[a]
Transform		0.82	0.08	7.84	***
Apply		0.95	0.10	10.52	***
V1	**Value**	0.77	0.19	7.81	***
V2		0.62	---	---	[a]
V3		0.69	0.16	7.16	***
AC1	**Acquire**	0.76	---	---	[a]
AC2		0.66	0.12	7.83	***
AC3		0.69	0.11	8.22	***
AC4		0.72	0.11	8.54	***
AS1	**Assimilate**	0.85	---	---	[a]
AS2		0.63	0.09	8.40	***
AS3		0.61	0.10	8.16	***
AS4		0.73	0.11	8.65	***
TR1	**Transform**	0.66	---	---	***
TR2		0.82	0.16	8.53	***
TR3		0.70	0.13	7.86	[a]
TR4		0.62	0.16	6.67	***
AP1	**Apply**	0.83	0.07	13.36	[a]
AP2		0.77	0.07	12.11	***
AP3		0.87	---	---	***
AP4		0.74	0.08	11.09	***

Table 1: Representative ACAP Conceptualizations, Measurements, and Results

Conceptualization	Study	Unit of Analysis	Sample	ACAP Measures	Model/Outcomes
Absorptive capacity: value, assimilate & apply	Cohen & Levinthal, 1990	Firm	1719 business units of 318 firms in 151 lines of business	R&D intensity (% of sales), relevance of research fields	ACAP mediates the relationship between technological opportunity, appropriability and firm R&D investment.
	Mowery, Oxley,& Silverman, 1996	Alliance	792 strategic alliances with at least one US partner; control sample of 858 unallied firms	Cross-citation rates for alliance partners; firm learning through alliance measured as difference in cross citation rate for 1 year sample frame	Similarity between allied firm knowledge bases type of alliance influences knowledge transfer. Suggests that alliances provide access to new knowledge, but not necessarily acquisition. Equity ventures transfer knowledge more readily than licensing agreements. Cultural differences may contribute to reduced knowledge transfer.
	Szulanski, 1996	Learning-Teaching Dyad	271 observations of 122 best-practice transfers in 8 firms	9 items dealing with common language, vision, existing knowledge, necessary skills, competency, & problem-solving capabilities of learning firm	Learning firm's lack of ACAP, ambiguity regarding capability, arduous relationship between learning-teaching firms are barriers to knowledge transfer.
	Lane, Salk & Lyles, 2001	International joint ventures (IJV)	78 international joint ventures	Trust, relevant prior knowledge, assimilate = learning structures & processes,	ACAP is positively related to knowledge transfer from foreign parent to IJV. Knowledge transfer is positively associated with IJV performance. Prior relevant knowledge influences ability to recognize valuable new knowledge.
	George et al., 2001	Alliances	2456 alliances between biopharmaceutical firms	R&D spending, number of patents	ACAP is positively related to alliance performance performance.
Potential absorptive capacity: acquisition & assimilation Realized absorptive capacity: transformation & exploitation	Zahra & George, 2002	Firm	Conceptual	Not applicable	ACAP consists for four dimensions: acquire, assimilate, transform and exploit. Acquisition and assimilation are potential absorptive capacity (PCAP) and transformation and exploitation are realized absorptive capacity (RCAP). Assimilation consists of understanding and interpretation; transformation is adaptation of knowledge or organizational processes and structures when new knowledge is inconsistent with current cognitive schema.
	McKelvie, 2007	Firm	Newer Swedish telecom, information technology, media & entertainment firms - longitudinal with 1 year interval	Market & technological measures of acquisition, assimilation, transformation and exploitation	Acquisition and assimilation lead to transformation, application, and, ultimately, innovation performance. Technical knowledge acquisition is more important in dynamic environments. Market and technical knowledge acquisition have discriminant validity and explain a significant portion of variance in subsequent ACAP dimensions.
	Jansen, 2005	Firm	462 respondents single European banking firm	Multi-item measures of acquisition, assimilation, transformation, and exploitation	Organizational coordination capabilities are positively related to PCAP. Organizational factors related to socialization are positively related to RCAP.

Conceptualization	Study	Unit of Analysis	Sample	ACAP Measures	Model/Outcomes
Relative absorptive capacity of student firm (underlying dimensions assumed to be value, assimilate & apply)	Lane & Lubatkin, 1998	Dyad – alliance between student & teaching firm	69 R&D alliances between pharmaceutical & biotech firms	Learning dyad construct jointly determined by 3 characteristics of student & teacher firms: similarity of knowledge bases, organizational structure and dominant logics (compensation practices, centralization, management formality)	Similarities between learning & teaching firm knowledge bases, organizational structures, and dominant logics are positively related to learning outcomes. These measures explain more variance than R&D intensity.
Absorptive capacity: acquisition & exploitation	Yli-Renko, Autio, Sapienza, 2001	Firm	180 UK entrepreneurial high-technology firms	Knowledge acquisition = technological & market knowledge. Knowledge exploitation = new product development, technological distinctiveness, and reduced sales costs	Social interaction and network ties are positively related to knowledge acquisition. Knowledge acquisition mediates the relationship between social capital and new product development, technological innovation, and sales costs.
Absorptive Capacity: identify, communicate, and assimilate relevant external & internal knowledge	Tu, et al., 2006	Plant	303 respondents from Society of Manufacturing Engineers database	Prior relevant worker knowledge, prior relevant management knowledge, communications network, communications climate, knowledge scanning	ACAP is a 2nd order construct. ACAP is positively related to implementation of time-based manufacturing practices. All dimensions of ACAP are positively related to implementation of time-based manufacturing practices; prior relevant knowledge is not statistically significant.
Absorptive capacity: efficiency, scope, flexibility	Van den Bosch et al., 1999	Firm	Case-based research in 2 Dutch publishing firms	Organizational forms and combinative capabilities	Firms evolve in a dynamic environment to create organizational forms and combinative capabilities that can effectively absorb knowledge.
Exploratory, transformative, and exploitative learning	Lichtenthaler, 2009	Firm	Pairs of respondents from 175 medium & large industrial firms in Germany in automotive, machinery, chemicals, pharmaceuticals, semiconductors & electronics	6 scales for 3 learning processes: exploratory learning = recognition and assimilation; transformative learning = maintaining and reactivating; exploitative learning = transmutation and application	ACAP supported as a higher order construct comprised of 3 different learning processes. Learning processes are complementary and positively associated with performance and innovation.

Table 2: Sample Profile

Primary Industry	
Automotive	8.30%
High Tech	20.10%
Chemical	15.50%
Aerospace and Defence	5.70%
Pharmaceutical	5.70%
Consumer Goods	35.60%
Other*	9.10%
Total	100.00%

Level of Customization for the Majority of the Products Produced by a Manufacturer	
Standard Products	41.50%
Standard Products with Custom Options	25.20%
Customized Products	33.30%

*Includes industries such as food manufacturing, appliance manufacturing; hydraulic valves manufacturing; manufacturing of electrical distribution and automated products; office equipment manufacturing; printing ink and cartridges; plastics moulding; and food and beverage manufacturing.

Table 3. The chi-square difference test results among the theoretical constructs

Constructs	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Value (1)									
Acquire (2)	17.15***								
Assimilate (3)	19.41***	27.18***							
Transform (4)	18.24***	60.62***	23.63***						
Apply (5)	8.41**	94.12***	19.56***	10.65***					
Customization (6)	53.93***	76.53***	62.52***	63.13***	67.80***				
Product Innovation (7)	78.91***	170.44***	105.25***	73.97***	224.93***	34.33***			
Market Share (8)	101.30***	276.83***	139.50***	99.12***	273.83***	54.69***	238.33***		
Profit Level (9)	100.70***	186.44***	132.54***	100.32***	267.05***	56.63***	331.86***	142.08***	
Environmental Dynamism (10)	99.64***	145.54***	138.75***	140.63	144.87***	63.52***	123.66***	145.31***	147.07***

$^{***}p < 0.001$; $^{**}p < 0.01$

Table 4. Correlation and Descriptive Statistics

Constructs	Mean	Std. Dev	N	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Value (1)	3.15	.75	168										
Acquire (2)	2.58	.75	168	.62***									
Assimilate (3)	3.04	.74	174	.62***	.66***								
Transform (4)	3.50	.61	174	.57***	.42***	.58***							
Apply (5)	3.17	.79	168	.74***	.54***	.69***	.72***						
Customization (6)	3.72	.67	165	.31***	.16**	.30***	.27***	.28***					
Product Innovation (7)	3.20	.80	166	.38***	.29***	.44***	.39***	.41***	.51***				
Market Share (8)	3.39	.71	136	.13	.12	.21***	.15*	.13	.28***	.38***			
Profit Level (9)	3.38	.86	138	.12	.06	.28***	.14	.21**	.26***	.37***	.65***		
Environmental Dynamism (10)	2.71	.74	174	.25***	.20***	.27***	.21***	.24***	.08	.34***	.05	.01	
Number of Employees (11)	3.62	1.57	130	.19**	.11	.08	.16*	.09	.08	.25***	.02	.01	.18**

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

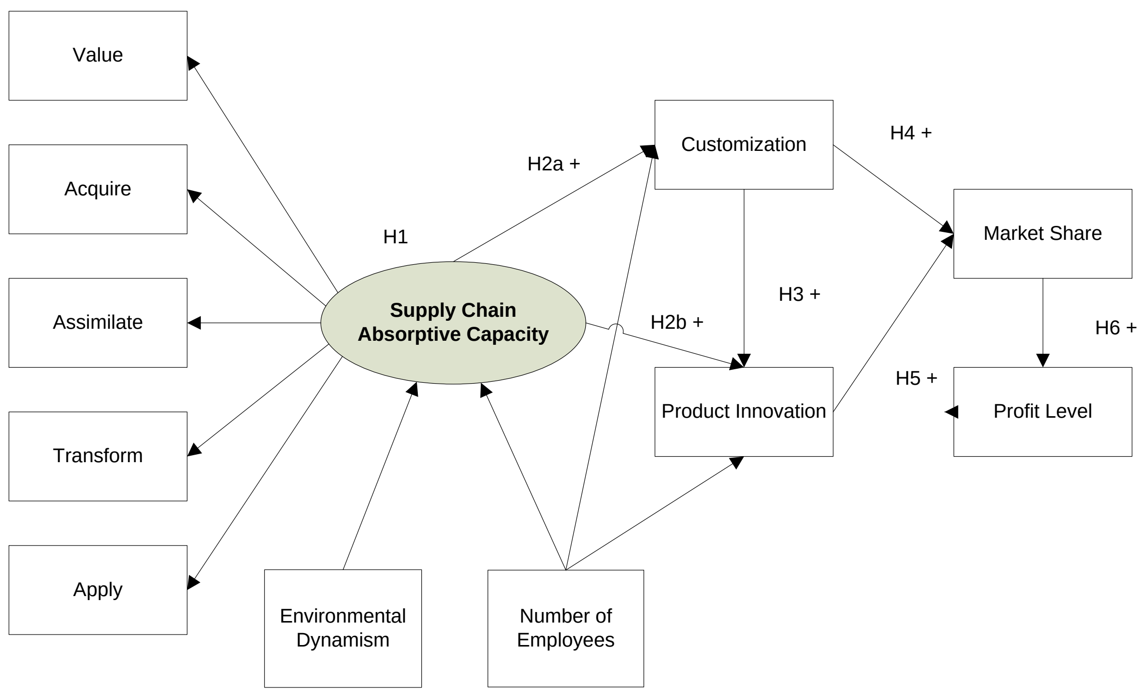
Table 5. Theoretical Model: Direct, Indirect, and Total Effects of Exogenous Variables: Standardized Maximum Likelihood Estimates (N = 174)

	Value	Acquire	Assimilate	Transform	Apply	S.C. Absorptive Capacity	Customization	Product Innovation	Market Share	Profit Level
Environmental Dynamism										
Total Effect (T.E)	0.22^{***}	0.18^{***}	0.21^{***}	0.20^{***}	0.24^{***}	0.27^{***}	0.07	0.30^{***}	0.12^{***}	0.11^{***}
Direct Effect (D.E)	---	---	---	---	---	0.27^{***}	-0.02	0.20^{***}	---	---
Indirect Effect (I.E)	0.22^{***}	0.18^{***}	0.21^{***}	0.20^{***}	0.24^{***}	---	0.09^{***}	0.10^{**}	0.12^{***}	0.11^{***}
Number of Employees										
Total Effect (T.E)	0.10	0.08	0.10	0.09	0.11	0.12	0.07	0.22^{***}	0.09^{***}	0.08^{****}
Direct Effect (D.E)	---	---	---	---	---	0.12	0.02	0.17^{***}	---	---
Indirect Effect (I.E)	0.10	0.08	0.10	0.09	0.11	---	0.04	0.06	0.09^{***}	0.08^{***}
S.C. Absorptive Capacity										
Total Effect (T.E)	0.82^{***}	0.68^{***}	0.78^{***}	0.74^{***}	0.88^{***}	---	0.34^{***}	0.40^{***}	0.19^{***}	0.17^{***}
Direct Effect (D.E)	0.82^{***}	0.68^{***}	0.78^{***}	0.74^{***}	0.88^{***}	---	0.34^{***}	0.26^{***}	---	---
Indirect Effect (I.E)	---	---	---	---	---	---	---	0.13^{***}	0.19^{***}	0.17^{***}
Customization										
Total Effect (T.E)	---	---	---	---	---	---	---	0.39^{***}	0.28^{***}	0.24^{***}
Direct Effect (D.E)	---	---	---	---	---	---	---	0.39^{***}	0.14	0.02
Indirect Effect (I.E)									0.14^{***}	0.22^{***}
Product Innovation										
Total Effect (T.E)	---	---	---	---	---	---	---	---	0.36^{***}	0.35^{***}
Direct Effect (D.E)	---	---	---	---	---	---	---	---	0.36^{***}	0.13
Indirect Effect (I.E)	---	---	---	---	---	---	---	---	---	0.22^{***}
Market Share										
Direct Effect (D.E)	---	---	---	---	---	---	---	---	---	0.61^{***}

Table 6. Post-Hoc Analysis: Alternative Theoretical Model: Direct, Indirect, and Total Effects of Exogenous Variables: Standardized Maximum Likelihood Estimates (*N* = 174)

	Value	**Acquire**	**Assimilate**	**Transform**	**Apply**	**Customization**	**Product Innovation**	**Market Share**	**Profit Level**
Environmental Dynamism									
Total Effect (T.E)	0.22***	0.14***	0.09***	0.06***	0.06***	0.03	0.25***	0.09***	0.09***
Direct Effect (D.E)	0.22***	---	---	---	---	0.01	0.23***	---	---
Indirect Effect (I.E)	---	0.14***	0.09***	0.06***	0.06***	0.02	0.03	0.09***	0.09***
Number of Employees									
Total Effect (T.E)	0.17**	0.11**	0.07**	0.05**	0.05**	0.06	0.22***	0.09***	0.08***
Direct Effect (D.E)	0.17**	---	---	---	---	0.05	0.18***	---	---
Indirect Effect (I.E)	---	0.11**	0.07**	0.05**	0.05**	0.01	0.04	0.09***	0.08***
Value									
Total Effect (T.E)	---	0.62***	0.40***	0.26***	0.28***	0.08***	0.10***	0.05***	0.04***
Direct Effect (D.E)	---	0.62***	---	---	---	---	---	---	---
Indirect Effect (I.E)	---	---	0.40***	0.26***	0.28***	0.08***	0.10***	0.05***	0.04***
Acquire									
Total Effect (T.E)	---	---	0.65***	0.41***	0.46***	0.12***	0.16***	0.07***	0.07***
Direct Effect (D.E)	---	---	0.65***	0.07	---	---	---	---	---
Indirect Effect (I.E)	---	---	---	0.34***	0.46***	0.12***	0.16***	0.07***	0.07***
Assimilate									
Total Effect (T.E)	---	---	---	0.53***	0.65***	0.18***	0.22***	0.10***	0.09***
Direct Effect (D.E)	---	---	---	0.53***	0.40***	---	---	---	---
Indirect Effect (I.E)	---	---	---	---	0.25***	0.18***	0.22***	0.10***	0.09***
Transform									
Total Effect (T.E)	---	---	---	---	0.48***	0.13***	0.16***	0.08***	0.07***
Direct Effect (D.E)	---	---	---	---	0.48***	---	---	---	---
Indirect Effect (I.E)	---	---	---	---	---	0.13***	0.16***	0.08***	0.07***
Apply									
Total Effect (T.E)	---	---	---	---	---	0.27***	0.34***	0.16***	0.14***
Direct Effect (D.E)	---	---	---	---	---	0.27***	0.23***	---	---
Indirect Effect (I.E)	---	---	---	---	---	---	0.11***	0.16***	0.14***
Customization									
Total Effect (T.E)	---	---	---	---	---	---	0.42***	0.29***	0.25***
Direct Effect (D.E)	---	---	---	---	---	---	0.42***	0.14	0.02
Indirect Effect (I.E)	---	---	---	---	---	---	---	0.15***	0.23***
Product Innovation									
Total Effect (T.E)	---	---	---	---	---	---	---	0.35***	0.35***
Direct Effect (D.E)	---	---	---	---	---	---	---	0.35***	0.13
Indirect Effect (I.E)	---	---	---	---	---	---	---	---	0.22***
Market Share									
Direct Effect (D.E)	---	---	---	---	---	---	---	---	0.61***

Figure 1 – Model 1
Supply Chain Absorptive Capacity as a 2nd Order Construct
Effects on Customization, Product Innovation and Business Performance



Control Variables

Figure 2 – Model 2 (Post-Hoc Analysis)
Supply Chain Absorptive Capacity (Todorova & Durisin, 2007)
Effects on Customization, Product Innovation and Business Performance