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Article information:

To cite this document:
Christoph Fuchs, Daniel Beck, Bernhard Lienland, Florian Kellner, "The Role of IT in Automotive Supplier Supply Chains", Journal of Enterprise Information Management, https://doi.org/10.1108/JEIM-03-2017-0038
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The Role of IT in Automotive Supplier Supply Chains

Abstract

Purpose—This research explores the impact of IT on supply chain performance in the automotive industry. Prior studies that analyzed the impact of IT on supply chain performance report results representing the situation of the "average industry." This research focuses on the automotive industry because of its major importance in many national economies and due to the fact that automotive supply chains do not represent the supply chain of the average industry.

Design/methodology/approach—A research model is proposed to examine the relationships between IT capabilities, supply chain capabilities, and supplier performance. The model divides IT capabilities into functional and data capabilities, and supply chain capabilities into internal process excellence and information sharing. Data has been collected from 343 automotive first-tier suppliers. Structural equation modeling with partial least squares is used to analyze the data.

Findings—The results suggest that functional capabilities have the greatest impact on internal process excellence, which in turn enhances supplier performance. However, frequent and adequate information sharing also contributes significantly to supplier performance. Data capabilities enable supply chain capabilities through their positive impact on functional capabilities.

Practical implications—The findings will help managers to understand the effect of IT implementation on company performance and to decide whether to invest in the expansion of IT capacities.

Originality/value—This research reports the impact of IT on supply chain performance in one of the most important industries in many industrialized countries, and it provides a new perspective on evaluating the contribution of IT on firm performance.

Keywords: Information technology; Supply chain management; Automotive industry

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1. Introduction

1.1. Background

Information technology (IT) is widely recognized as a critical factor in the supply chain because IT can contribute to the performance of both independent firms and the supply chain as a whole (Jin, 2006). IT implementation, within the organization and in collaboration with business partners, is generally accepted as an important factor in improving supply chain management (SCM) (Gupta and Capen, 1996; Koh and Saad, 2006). In recent years, the advancement of IT has rapidly changed the requirements for global business relationships (Li *et al.*, 2009). With the provision of timely, accurate, and reliable information, IT has improved the conditions for doing business around the world. IT enables the sharing of large amounts of information all along the supply chain, including operational,

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planning, and financial data. Integrated IT infrastructures, which are characterized by common data definitions and integrated applications, allow flows of information and coordination activities across business divisions, geographic regions, and supply chain partners (Broadbent *et al.*, 1999). The availability of information along the supply chain supports joint production planning, inventory management, and distribution. Previous supply chain research has shown that the sharing of order-related information improves the forecasting of demand and reduces the bullwhip effect (Lee *et al.*, 2000; Klein and Rai, 2009). Thus, almost all companies in the supply chain have either implemented or are in the process of implementing IT in order to improve supply chain performance (Olhager and Selldin, 2004; Liu *et al.*, 2005).

Since more and more companies are investing in IT, there is an increasing need for research investigating its impact on supply chain performance. The debate on the "productivity paradox" and on the payoff from investing in IT suggests that the impact of IT on firm performance is not unchallenged (Wu *et al.*, 2006; Li *et al.*, 2009; Brynjolfsson, 1993). Many studies have analyzed the impact of IT from different perspectives (cf. Table 1). Li *et al.* (2009), Rai *et al.* (2006), Wu *et al.* (2006), Bharadwaj (2000), and Prajogo and Olhager (2012) have contributed some interesting insights. Li *et al.* (2009) examined the impact of IT implementation on supply chain integration (SCI) and performance. They found that the positive effect is mediated by SCI. Rai *et al.* (2006) showed that integrated IT infrastructures enable firms to develop the higher-order capabilities of supply chain integration, which results in significant and sustained performance gains. Wu *et al.* (2006) explained how IT implementation can create a sustained competitive advantage for a company. The study demonstrates that supply chain capabilities are a key mediator between IT investment and firm performance. Adopting the resource-based view, Bharadwaj (2000) illustrated the association between IT capability and business performance. In an empirical analysis, he revealed a positive relationship between IT capability and firm performance. In a recent study, Prajogo and Olhager (2012) investigated the integration of information and material flows between supply chain partners and their effect on operational performance. They found that logistics integration and long-term relationships with supply chain partners have a significant effect on operational performance. In Table 1, the relevant research is classified into a) research investigating the value of IT for firm performance, b) research investigating the impact of IT on different supply chain capabilities, and c) research combining the aforementioned classes to analyze supply chain capabilities as a mediator between IT capabilities and firm performance. Our approach is in line with the third group of papers, i.e., it analyzes the impact of IT capabilities via supply chain capabilities on firm performance. We start with the assumption that this approach allows for a more differentiated analysis of the impact of IT investments on firm performance (see below).

[Table 1 near here]

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1.2. *Research objective*

When looking in detail at the applied data of the stated studies, one can observe that these studies consider “average industries.” The underlying data basis is, for example, a representation of companies in a certain region or a mix of multiple company types, such as manufacturing and retail (cf. Li *et al.*, 2009; Rai *et al.*, 2006). Therefore, one might question whether IT also has an impact on supply chain performance when considering *one* single industry. To verify such a relationship, we decided to analyze the automotive industry due to its predominant role in society (Verband der Automobilindustrie e. V., 2012) and due to the fact that this industry represents one of the most complex sectors, (Olin *et al.*, 1999) with thousands of individual suppliers of different component complexity and relevance (Hyun, 1994; Lienland *et al.*, 2013). Today, a large proportion of control over quality, cost, and delivery has been transferred from original equipment manufacturers (OEM) to first-tier suppliers. The latter have assumed responsibility for the design and improvement of components and subassemblies (Choi and Hartley, 1996; Spekman, 1988; Turnbull *et al.*, 1993). It is the suppliers who provide for the OEM key components that guarantee quality, reduced inventory, and a continual focus on research and the development of specific components (Tuunainen, 1998; Richardson, 1993). Such development results in close cooperative relationships between the OEM and the suppliers (Dyer and Ouchi, 1993; Cusumano and Takeishi, 1991; Helper, 1991). Despite all cooperation, suppliers still have to face strong price pressure and an increasing demand for flexibility in the supply of materials, as examined by Childerhouse *et al.* (2003). Standard IT-systems in SCM, such as enterprise resource planning (ERP) and advanced planning systems (APS), are essential for supporting the procurement, production, and distribution processes. Thus, we consider the automotive supply chain with its described complexity to be different from the “average industry” supply chains. As a consequence, the role of IT in the automotive supply chain is not necessarily the same as in other industry sectors.

The contribution of this research is twofold. (1) Our study contributes to the existing research investigating the impact of IT on supply chain and firm performance by focusing on one specific industry. The objective is to learn whether the general findings presented by Li *et al.* (2009) and Rai *et al.* (2006) also apply to one of the most important industries in many industrialized countries, such as France, Germany, and the UK. Studying the automotive industry is particularly interesting because many characteristics of automotive supply chains differ from the “average” industry. Therefore, the general findings of prior research may not be valid. (2) Prior research analyzed empirically the effect of IT on company and/or supply chain performance and proved that supply chain capabilities have a mediating effect on the influence of IT on firm performance (Table 1). Our study extends the understanding about the mediating role of supply chain capabilities because, in contrast to existing work, we analyze the role of supply chain capabilities by sub-dividing them into two sub-constructs, namely internal process excellence and information sharing. The research question this article answers

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is: *How does IT implementation have an impact on the supply chain performance of automotive first-tier suppliers?*

The answer to this question is relevant for both research and practice as it provides a new perspective on evaluating the contribution of IT on firm performance in the automotive sector. This will help, e.g., automotive managers to understand the effect of IT implementation on company performance and to decide whether to invest in the expansion of IT capacities.

To answer the research question, we base our data purely on the automotive industry. By doing so, we ensure that no "diluting effects" occur, which would then just represent "average industry" results. Furthermore, we adopt a research model from the literature to develop constructs and relationships associated with IT capabilities, supply chain capabilities, and supplier performance. Specifically, we focus on the constructs of functional capabilities, data capabilities, internal process excellence, information sharing, and supplier performance. We test our model by developing and validating measures for the constructs und examine empirically the validity of the relationship between the constructs.

The paper is organized as follows. In Section 2, we review the theoretical background, develop the research model, and derive our hypotheses. In Section 3, we describe the research methodology. In Section 4, the empirical results are presented. In Section 5, we discuss our findings and identify opportunities for future research, before drawing conclusions in Section 6.

2. Theoretical background and research hypotheses

2.1. Research framework

The research model used to analyze the relationships between IT capabilities, supply chain capabilities, and supplier performance is presented in Figure 1.

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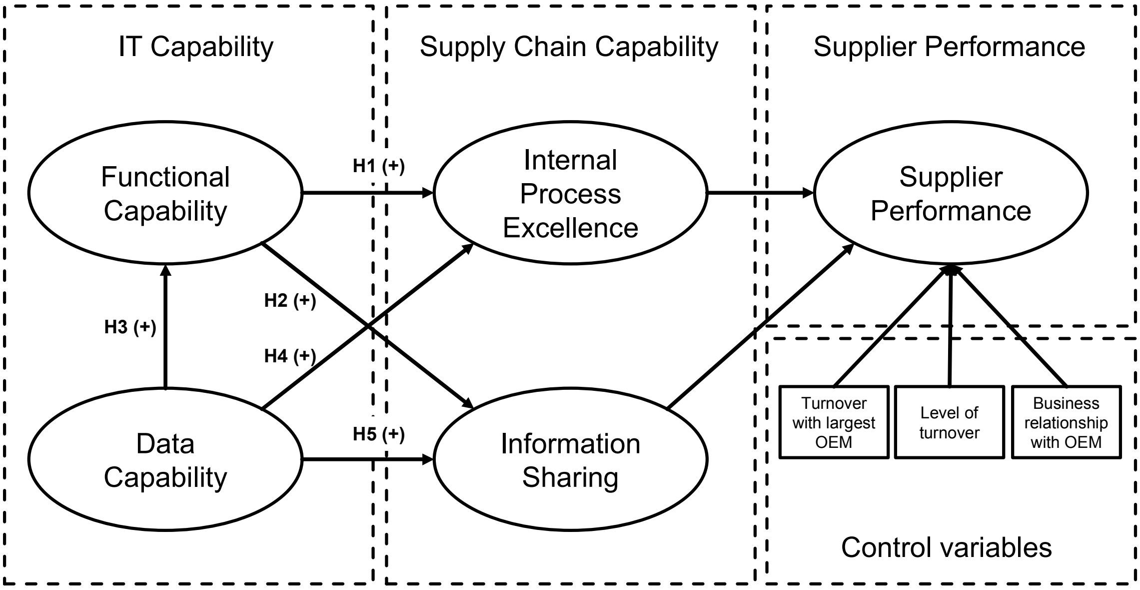

Figure 1. Research model.

The foundations for this model were laid by Li *et al.* (2009), who detected causal relationships running from IT implementation to supply chain integration, and from supply chain integration to supply chain performance. Our model extends the construct of supply chain integration from Li *et al.* (2009) by using two sub-constructs: internal process excellence and information sharing. Furthermore, our model divides IT implementation into functional and data capabilities (cf. Rai *et al.*, 2006). In the following, we specify the constructs in terms of their various items.

2.1.1. IT capabilities

From a user perspective, IT has two main dimensions: functionality (e.g., Swafford *et al.*, 2008; Fasanghari *et al.*, 2007; Subramani, 2004; Singh *et al.*, 2007; McLaren *et al.*, 2004) and data (e.g., Rai *et al.*, 1997; Wong *et al.*, 2011; Li *et al.*, 2009). Technical considerations of software and hardware, IT organizational, or IT service perspectives are the basis for functional IT capabilities. The widely used supply chain domain models (Stewart, 1997; Cooper *et al.*, 1997; Stadtler, 2005) are based on three main business processes: purchasing, production, and sales. These business processes have tasks extending over two time horizons: planning and execution. Consequently, there are, on the one hand, three functional modules for planning tasks: material requirements, production, and demand planning. On the other hand, there are three modules for execution tasks: material, production, and customer order management. The construct of functional capability describes the ability of functional IT modules to support the above named business processes. IT support is defined by functional breadth, which refers to the breadth of the tasks in a business process supported by IT functionality (quantity of functionalities), and by functional depth, which refers to how well a single task is supported (quality of functionalities).

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Functional modules require high quality data to improve business process performance. Data quality can be measured by various metrics. The most relevant are accuracy, reliability, timeliness, and relevance (Wand and Wang, 1996; Wang and Strong, 1996). Rai *et al.* (2006) used three items to measure data consistency: automatic data capturing, common data definitions, and data consistency across multiple data bases. Systems for automatic data capturing include bar codes, radio frequency identification (RFID), and electronic data interchange (EDI). The benefits are fewer mistakes through manual entries and more frequent data capturing, which leads to increased accuracy, reliability, and timeliness. Common data definitions of the main data entities (such as product descriptions, part numbers, suppliers, and customers) along the entire supply chain facilitate a correct information flow, which results in improved reliability and relevance of the data. Finally, data consistency across multiple data bases ensures the accuracy and the reliability of the data.

2.1.2. Supply chain capabilities

There are two groups of supply chain capabilities: internal (e.g., Fasanghari *et al.*, 2007; Swafford *et al.*, 2008; Byrd and Davidson, 2003) and external (e.g., Kaipia, 2007; Kelle and Akbulut, 2005; Klein and Rai, 2009; Prajogo and Olhager, 2012). The internal capabilities surface in the internal supply chain processes: purchasing, production, and sales. Within *purchasing*, there are two major process quality indicators: procurement efficiency (Gunasekaran *et al.*, 2001; Fasanghari *et al.*, 2007) and inventory management (Rai *et al.*, 2006; Li *et al.*, 2009). Procurement efficiency is defined by the ability to source required input materials of high quality, on time, and at low cost. Low inventory levels and a high availability of required materials are the diametrical characteristics of good inventory management. In the *production* domain, efficiency and flexibility are the main metrics in which IT capabilities can have an impact. Flexible manufacturing is the ability to react to changes in volume, production mix, product, or process with low changing costs and without major organizational adjustments (Toni and Tonchia, 1998). Finally, the process *sales* is driven by the ability to incorporate customer demand forecast information into production planning (Helms *et al.*, 2000).

External supply chain capabilities deal mainly with information sharing. As the bullwhip effect is a serious danger for first-tier suppliers, communication capabilities are becoming more and more important (Lee *et al.*, 1997). Information sharing can help to mitigate demand uncertainties (Chen and Lee, 2009). There are four major information flow directions: towards second-tier suppliers, from second-tier suppliers, towards customers (OEMs), and from customers (OEMs). The information flow upstream (towards second-tier suppliers and from OEMs) is typically composed of forecast information and order releases (Kaipia, 2007). The information flow downstream (from second-tier suppliers and towards OEMs) consists of order confirmations, dispatch notifications, and delivery confirmations (Klein and Rai, 2009). The quality and frequency of shared information in all four directions defines the communication capabilities.

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2.1.3. Supplier performance

Finally, we explain supplier performance in the automotive supply chain by means of nine items: lead time, order fill capacity, logistics costs, delivery reliability, order flexibility, delivery time flexibility, advanced shipment notification, advanced problem notification, and process innovation (Savitskie, 2007). *Lead time* is a crucial factor for measuring supplier performance (Li and O'Brien, 1999) and refers to the time elapsed between the receipt of the customer´s order and the delivery of the desired product (Gunasekaran *et al.*, 2004). The item lead time is important for the customer's production planning and scheduling, particularly for just-in-time delivery processes (Verma and Pullman, 1998).The *order fill capacity* indicates the quantity and size of orders that can be fulfilled. Another important aspect of measuring supplier performance is total *logistics cost* (Gunasekaran *et al.*, 2004). Stewart (1995) divides the total logistics costs into four major components: order management costs; material acquisition costs; inventory carrying costs; and supply chain finance, planning, and management information system costs. *Delivery reliability* denotes whether an order is delivered on-time and in the right quantity (Savitskie, 2007). According to Beamon (1999), flexibility is vital to the success of the supply chain because of the high degree of uncertainty along many different dimensions. In an automotive production plant, various problems can occur, for instance, variations in the assembly of cars, depletion of parts, or quality problems, that require order flexibility from suppliers. This *order flexibility* is defined as the ability to meet changing customer orders in terms of quantity, place, delivery mode, or packaging (Savitskie, 2007). *Delivery time flexibility* refers to the speed or agility of companies to respond to changes along the supply chain (Swafford *et al.*, 2008). In the automotive industry, the forecast delivery schedule determines the date and quantity of deliveries. To react to fluctuations in production, the car manufacturer sends daily release orders to suppliers. The automaker needs to be informed about the status of an order and the estimated arrival time of delivery. An *advanced shipment notification* (ASN) from the supplier supports the OEM's inventory control. Whenever a full truck leaves the supplier, the production plant should receive information about the loaded components, the delivery note, and the estimated arrival time. Providing online information is an important element of customer service and underlines the delivery reliability of the supplier (Gunasekaran *et al.*, 2001). Lancioni *et al.* (2000) showed that the most popular use of the internet in this area is the communication of stock-outs between customer and vendor or the *advanced problem notification* by suppliers. The advanced notification of suppliers about imminent stock-outs or problems enables the automaker to take measures such as contacting an alternative supplier or altering the production program. Finally, *innovation* is a driver of company success and fundamental to gaining a competitive advantage over other automotive suppliers (Corsten and Felde, 2005). Hence, innovation is a prerequisite for long-term business relationships. Suppliers contribute with their research to the development of vehicles and so reduce the R&D expenses of the car manufacturer.

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2.2. IT capability and supply chain capability

Two IT systems provide the functional capabilities for supporting the business processes of purchasing, production, and sales: enterprise resource planning (ERP) systems and advanced planning systems (APS). The ERP system manages the entire information flow on the supply chain execution layer: materials, production, and customer order management (Akkermans *et al.*, 2003). Well supported material management creates transparency on inventory levels across the organization (Kelle and Akbulut, 2005). Production management deals with the efficient use of production resources, such as staff, equipment, and materials. Within customer order management, it is important to keep track of the full lifecycle of a customer order and to provide input information for the production process. APS software modules support the supply chain planning process from demand planning and production planning to material requirements planning (Stadtler, 2005). The primary function of demand planning is to forecast customer demand, which is the fundamental input for production planning. In the automotive industry, the OEM usually provides short- and long-term forecast delivery schedules to their first-tier suppliers. Thus, demand planning should support the integration of this forecasting information. Finally, the production planning should not only enable efficient manufacturing, but also create flexibility in manufacturing if crucial parameters such as customer orders or the availability of resources have changed. From a combination of all these causal relationships, we formulate our first research hypothesis:

H1: Functional IT capabilities foster internal supply chain process excellence.

Technology is an indisputable enabler of information sharing (Savitskie, 2007; Li *et al.*, 2009; Li and Lin, 2006). While Dell Computers and Wal-Mart have successfully implemented IT systems for external coordination (McLaren *et al.*, 2004), it is not necessary to implement an inter-organizational information system for supply chain management, as described in Humphreys *et al.* (2001). Common APS and ERP systems are also able to share relevant information directly (Rai *et al.*, 2006). These systems facilitate the integration of order releases and forecast information, and provide information such as order confirmations, dispatch notifications, and delivery confirmations in a format that is easily accessible using the supply chain partners' IT systems. Accordingly, the transaction costs of information sharing are reduced by the quality of functional IT capabilities (Li *et al.*, 2009), which leads to an increase in external communication capabilities. Therefore we state the second research hypothesis:

H2. Functional IT capabilities support information sharing.

Data quality is a critical issue for the implementation of an ERP system (Xu *et al.*, 2002). The wrong data can cause functional errors, and information inconsistencies can be multiplied throughout the organization. Inaccurate attribute values can make whole data records inaccessible (Madnick *et al.*, 2009). An example where data quality is vital is forecasting. Historical sales volumes are the critical

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input for the demand forecasting algorithm. Wrong or incomplete data sets will either stop the algorithm or generate inaccurate demand forecasts. Functional IT capabilities can be limited by low data capabilities, which leads to the third research hypothesis:

H3. Data capabilities drive functional IT capabilities.

Data and information quality are playing an increasingly critical role in our data and knowledge-intense business world (Madnick *et al.*, 2009). Poor data quality can jeopardize the effectiveness of organizational strategies and business processes (Redman, 1998). Fisher and Kingma (2001) analyzed two disasters (outside the supply chain area), namely the explosion of the space shuttle Challenger and the shooting down of an Iranian Airbus by the USS Vincennes, and came to the conclusion that data quality issues were the fatal factors in a conglomerate of causes. In supply chain processes, there are many tasks where operational decisions have to be taken on a daily basis. The size of order quantities in material requirements planning and production schedules in production planning are just two examples from many. The quality of these decisions directly drives process performance. Slone (2006) found a strong correlation between data quality and organizational outcome in a cross-industry study. As we expect no differences for the automotive supplier industry, we formulate the fourth hypothesis as follows:

H4. Data capabilities lead to internal supply chain process excellence.

Data quality not only facilitates internal supply chain processes, but also supports the information flow with supply chain partners. Rai *et al.* (2006) demonstrated the positive impact of data consistency on information flows between the focal firm and its suppliers and customers. In this study, information flows were defined as demand-related information, inventory and sales positions, production and delivery schedules, and performance metrics. These information artifacts comprise the basis of communication between a first-tier supplier and a second-tier supplier on the one hand, and a first-tier supplier and OEMs on the other. In addition to functional IT capabilities, data capabilities also contribute to a reduction in the transaction costs of information sharing (Li and Lin, 2006). If the first-tier supplier has relevant and accurate data about demand and production plans, it can share this information with its suppliers in a timely manner. Correspondingly, the first-tier supplier will ask for information from the second-tier suppliers if capabilities are available to quickly process the information into its own information systems. Hence, we derive our fifth research hypothesis:

H5. Data capabilities support information sharing.

2.3. Supply chain capability and supplier performance

In our research model, we consider two supply chain capabilities: internal process excellence and information sharing. The role of internal process excellence in supplier performance (often referred to as supply chain performance) has been analyzed in several studies (e.g., Li *et al.*, 2009; Subramani, 2004; Swafford *et al.*, 2008). Li *et al.* (2009) investigated the positive impact of demand forecasting

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and inventory management on supply chain performance. Both processes reduce overproduction, which results in lower costs and stock levels. A company with flexible manufacturing is able to react rapidly to changing customer orders. Correspondingly, procurement and manufacturing efficiency are responsible for the ability to fulfill customer orders, to provide short lead times, and to be cost-efficient. Companies that provide a high level of customer service at reasonably low cost are expected to be efficient and flexible in their main business processes, namely procurement, manufacturing, and sales.

The degree and quality of information sharing determines how efficiently an entire supply chain network performs (Yu *et al.*, 2001). A company can speed up the information flow in the supply chain, improve its efficiency and effectiveness, and respond to changing customer needs quicker if information is shared rapidly and in the right quantity and quality (Li and Lin, 2006). The automotive supply chain is threatened by the bullwhip effect because of fluctuations in the production program. Information sharing is the crucial measure for reducing its negative effects (Yu *et al.*, 2001; Chen and Lee, 2009). Streamlining and making all information flows throughout the chain visible is a strong enabler for an integrated and effective supply chain (Childerhouse and Towill, 2003). Strategic information flows provide optimized planning, control, and flexibility of resources, which leads to improved asset management, reduced costs of operations, and enhanced productivity (Klein and Rai, 2009). Thus, communication drives a supplier's flexibility when changes in customer orders and delivery dates arise. In addition, it helps to reduce the cost impact of the bullwhip effect and implicitly enables the supplier to provide timely advanced shipment and problem notifications.

3. Methodology

We test our hypothesis using data from an online survey of automotive suppliers in Europe. For the analysis, we used the partial least squares (PLS) approach.

3.1. Data collection

Data for this study was obtained through a survey of 1,823 automotive suppliers in Europe. The sample was provided by a German car manufacturer. The invitation to participate in the online survey was sent out by the OEM to all of its suppliers across the OEM's complete value chain and it was not limited to a certain series, model, product, or material, which means that the whole spectrum of different parts suppliers was covered in this sample (e.g., drive unit, chassis, and electronic parts). Thus, a great and representative number of responses were to be expected, and the sample does not imply that the findings are only valid for a certain product, material, or for a certain group of suppliers. Target respondents for the survey were managers or employees who are responsible or in contact with supply chain activities (e.g., supply chain management, logistics, or procurement) or information technology. Since all of our respondents were familiar with supply chain activities or IT processes, it is reasonable to expect the respondents to provide insight into internal processes and to be

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knowledgeable about the content of the inquiry. We published the survey online and invited the respondents via e-mail to participate in our study. We promised data confidentiality and emphasized the benefits of the study to the participants. After one week, we sent reminders. A total of 343 questionnaires were ultimately returned, which corresponds to a response rate of 18.8%. The characteristics of the automotive suppliers who participated in the survey are displayed in Table 2.

[Table 2 near here]

To assess non-respondent bias, we compared the responses of early and late respondents to test for significant differences (Armstrong and Overton, 1977). The first 75% (n = 257) of the responses were classified as "early respondents" and the remaining 25% (n = 86) as "late respondents." This approach is based on the notion that late respondents are similar to non-respondents. At the 5% significance level, we detected no differences between early and late respondents for the following firm characteristics: level of turnover, number of employees, product category, period of relationship with OEM, and turnover with largest OEM. Based on this, we suggest that non-response bias was not evident with regard to data collection.

3.2. Measures

Initially, we conducted an extensive literature review and adopted items from previous research to improve the reliability and validity of the measures. Subsequently, we adapted the items in the questionnaire for the automotive supply chain in cooperation with logistics experts from the car industry. Items and scales used in the questionnaire were selected based on suggestions from Dillman (2000). A 7-point Likert scale was used as the answer option. The scales ranged from 1 (strongly disagree) to 7 (strongly agree), with the exception of the item delivery reliability. This particular item was measured as the ratio of satisfactory deliveries to all deliveries in the range of <75%, 75-85%, 85-90%, 90-95%, 95-98%, 98-99%, and >99%. Furthermore, we included turnover with the largest OEM, the level of turnover, and duration of business relationship with an OEM as control variables because larger suppliers could benefit due to their size and because they have already been working intensively with the OEM for a long time and have more resources to invest in information technologies (Hitt *et al.*, 2002; Zhu, 2004). When creating the questionnaire, the following aspects were considered to prevent common method biases (cf. Podsakoff *et al.*, 2003): an appealing and varied survey layout, guarantee of anonymity for the respondents, separation of the questions on independent and dependent variables, and no item-ambiguity. Furthermore, we used a mail/online-survey, which has the advantage of no interviewer bias, a wider reach, and cost and time savings (Sittimalakorn and Hart, 2004). Before starting the survey, we conducted a pilot test with two suppliers, resulting in slight modifications in the wording of some items. The full questionnaire can be found in Appendix A.

3.3. Data analysis

We used the PLS approach, a structural equation modeling technique, to test the model and hypotheses in this article. PLS is recommended primarily for predictive research models where the focus is on

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theory development (Chin, 1998). PLS path modeling can estimate highly complex models with many latent and manifest variables (Henseler *et al.*, 2009). In addition, we chose PLS because it allows us to include formative items (Chin *et al.*, 2003). The software used for the analysis was SmartPLS, Version 2.0 M3 (Ringle *et al.*, 2005).

For the decision on whether the constructs should be modeled as reflective or formative, we followed the guidelines of Jarvis *et al.* (2003). Constructs should be modeled as formative under the following conditions: (1) the direction of causality is from indicators to construct, (2) the indicators need not be interchangeable, (3) there is no need for indicators to covary with each other, and (4) the nomological net of indicators can differ. Based on these criteria, all constructs in this study were modeled as formative. Table 3 summarizes the constructs with the corresponding indicators.

[Table 3 near here]

4. Results

4.1. Measurement model

Traditional statistical evaluation criteria for reflective scales that test for reliability and validity cannot be used with formative constructs (Bagozzi, 1994). At the indicator level, the question arises of whether each indicator delivers a real contribution to the formative index by conveying the intended meaning. We examine whether or not an indicator should be included in the construct in two ways. First, the weights of the indicators have to be considered in a component analysis. Weights approaching 1 or -1 suggest a strong correlation, while values close to 0 assume a weak correlation. The statistical significance of weights can be used to determine the relative importance of indicators in describing a construct. If any of the item weights is non-significant, it may be appropriate to remove non-significant items until all paths are significant (Diamantopoulos and Winklhofer, 2001). When removing indicators, it is important that the construct still measures the complete meaning. For this reason, it is generally recommended that non-significant indicators be retained to maintain content validity (Bollen and Lennox, 1991). An overview of indicator weights is provided in Table B.1 in the appendix. In addition to the indicator's weight, the loadings should also be considered (Hair *et al.*, 2011). Table C.1 in the appendix provides an overview of the indicator loadings. When both weight and loading are non-significant, there is no empirical support for the indicator's relevance in providing content to the formative index (Cenfetelli and Bassellier, 2009). Since no indicator has both a non-significant weight and a non-significant loading, we keep all indicators in the research model.

Furthermore, formative indicators have to be examined for multicollinearity. High multicollinearity occurs if there is a strong linear dependency between indicators. While high multicollinearity is preferable for reflective measures, it is adverse for formative measures because it can result in non-significant indicators (Diamantopoulos, 2006). If measures are highly correlated, this implies that multiple indicators explain the same aspect of a construct. The variance inflation factor (VIF) is a useful statistic for ensuring that there is no multicollinearity. A VIF statistic greater than 3.3

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indicates multicollinearity (Diamantopoulos and Siguaw, 2006). The VIF values for our formative measures are 1.39 for functional capability, 1.47 for internal process excellence, 1.48 for information sharing, and 2.28 for supplier performance. These values indicate no multicollinearity for our indicators.

4.2. Structural model

The results of the analysis for the structural model are presented in Figure 2.

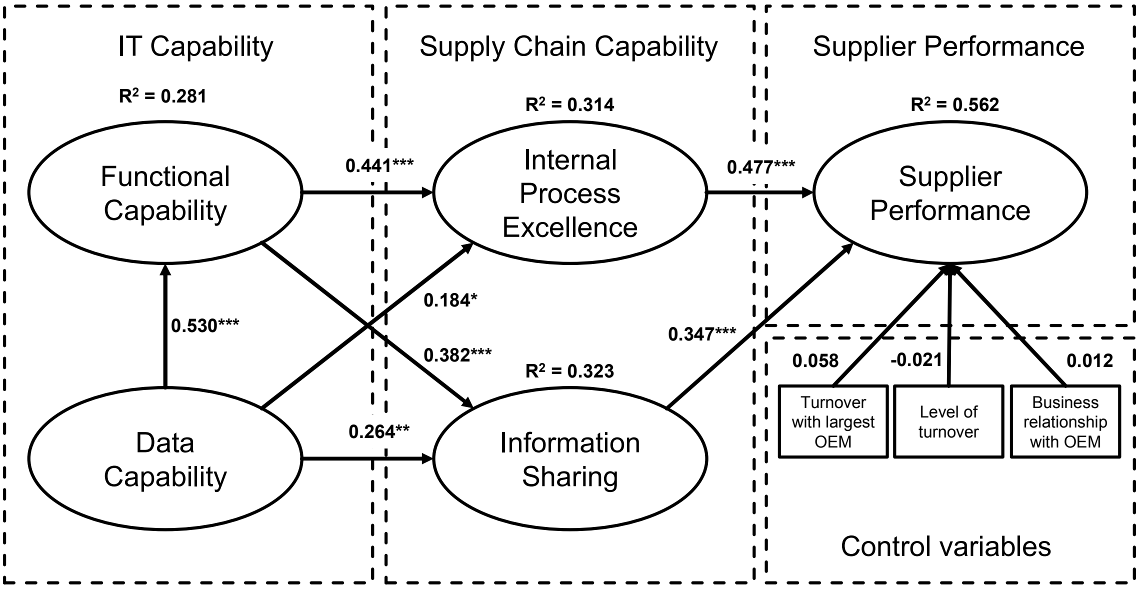

Figure 2. Results of path analysis (* $p < .10$, ** $p < .05$, *** $p < .01$).

The results support our research model and all five hypotheses. R^2 values are used to indicate the power of path models (Chin and Gopal, 1995). They reveal the amount of variance in the construct that is explained by the path model (Barclay *et al.*, 1995). The results show that the model explains 56.2% of the variance in supplier performance. Similarly, 28.1% of functional capabilities are explained by data capabilities, while 31.4% of internal process excellence and 32.3% of information sharing are explained by functional capabilities and data capabilities. R^2 values of 0.75, 0.50, or 0.25 for endogenous latent variables in the structural model can be described as substantial, moderate, or weak, respectively (Hair *et al.*, 2011).

A bootstrapping technique was used to estimate the significance of path coefficients. The bootstrap analysis was conducted with 2,000, 5,000, and 10,000 subsamples and 343 cases to test the reliability of our results. With t-values for a two-tailed test above 2.58, all path coefficients in our research model are significant ($p<.01$). The strongest correlations are from data capabilities to functional capabilities (0.530), from functional capabilities to internal process excellence (0.441), and from internal process excellence to supplier performance (0.477). Medium correlations are from functional capabilities to information sharing (0.382) and from information sharing to supplier

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performance (0.347). Finally, weak, but still significant, correlations are from data capabilities to internal process excellence (0.184) and information sharing (0.264).

To test the mediation effect, we compared the research model that proposes full mediation against a competing and partially mediated model. The latter model has one additional path from functional capabilities to supplier performance. The R^2 for supplier performance in the partially mediated model is 0.562, compared to 0.570 in the fully mediated research model. The f^2-statistic is a procedure of measuring the effect size and significance of the change in R^2 between models. The formula for computing f^2 is (R^2 partial mediation – R^2 full mediation) / (1-R^2 partial mediation). f^2 values from 0.02 indicate a low, 0.15 a medium, and 0.35 a strong impact on the endogenous variable (Cohen, 1988). Based on the R^2-values of our two models, the f^2 is 0.018, which suggests that the additional path from functional capabilities does not significantly add to the variance explained of supplier performance.

We found that all specific paths between constructs in our research model have significant path coefficients. Since the structural equation model is satisfactory, it serves as the basis for evaluating our hypotheses (Table 4).

[Table 4 near here]

5. Discussion

5.1. Contributions to theory

This research contributes to the information systems and management literature as it is, to the best of our knowledge, the first to study the impact of IT on supply chain performance in the context of automotive supply chains. In fact, supply chains in the automotive industry differ substantially from other industries (e.g., consumer goods or high tech; see above). Therefore, it is uncertain whether the general findings of prior research (Rai *et al.*, 2006; Li *et al.*, 2009), which didn't take the supply chain specificities of certain industries into account, are also valid in the automotive case. In the following, we summarize the major contributions of this study to theory, namely (1) the analysis of the linkage between IT capabilities, supply chain capabilities, and supplier performance in automotive supply chains and (2) the proposed research model.

5.1.1. The linkage between IT capabilities, supply chain capabilities, and supplier performance

Our findings indicate that in the automotive industry, supply chain capabilities mediate the impact of IT capabilities on supplier performance. This is basically in line with the research outcomes presented by Li *et al.* (2009), Liu *et al.* (2013), Prajogo and Olhager (2012), Rai *et al.* (2006), and Wu *et al.* (2006), all of whom did not focus on a specific industry sector. It is interesting to observe that even though there are many characteristics of automotive supply chains that differ from the "average" industry, the results of the prior studies are, generally, also valid in the automotive case.

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In contrast to the aforementioned studies, however, our research provides additional insights into the mediating role of supply chain capabilities in the impact of IT investment on firm performance because we analyze the role of supply chain capabilities by differentiating between "internal process excellence" and "information sharing." Li *et al.* (2009) showed that supply chain capabilities serve as a mediator between IT and firm performance: however, they did not sub-divide this construct. Liu *et al.* (2013) based their research on the dynamic capabilities perspective and interpreted supply chain capabilities as a combination of absorptive capacity and supply chain agility. Prajogo and Olhager (2012) considered the aspect "information sharing," but they did not take into account the effect of IT investment on internal process excellence. Rai *et al.* (2006), in contrast, did not consider the mediating role of information sharing, and finally Wu *et al.* (2006) did not sub-divide supply chain capabilities (same as Li *et al.*, 2009). Therefore our approach is novel and allows for new and deeper insights into the impact of IT on firm performance.

The results of our research indicate a strong and significant influence of functional IT capabilities on both internal process excellence and information sharing. Automotive first-tier suppliers with functionally rich and adequate IT systems have efficient internal processes and communicate effectively with supply chain partners. The results indicate that the processes of demand forecasting, manufacturing and procurement planning, and production and inventory management are too complex to be managed manually or semi-manually. Although many first-tier suppliers are relatively small and provide only a few products and components to a few automotive OEMs, we found no evidence of a size effect in our study. Smaller suppliers also perform better if they use suitable IT systems, such as less complex ERP suites or web-EDI. While it is logical that IT systems have an impact on process excellence, the influence on information sharing requires some explanation. IT systems provide companies with the right information at the right time and the right place. The barrier to sharing information with supply chain partners is lower if managers have high quality information at their disposal. This extends the view of Li and Lin (2006), who focused more on communication technologies such as EDI and the internet as enablers of information sharing.

The impact of data capabilities on internal process excellence and information sharing is lower, but still significant. Core business processes can be performed more effectively with data that is accurate, reliable, timely and relevant. If the right information is available, demand forecast information can be translated more precisely into production plans, material requirements planning is better able to meet the production needs, and manufacturing can react to changes more quickly. Data capability contributes the missing link in effective information sharing by providing high quality information. While the IT system safeguards the availability of the information, data quality measures ensure that the information is precise and appropriate for the supply chain partner. But at this point, the interdependence between functional and data capabilities becomes obvious. Our results indicate that functional capabilities mediate the impact of data capabilities on supply chain capabilities. Data capabilities influence functional capabilities more strongly than supply chain capabilities. This

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suggests that data quality is a significant driver of how IT systems support business processes. Good data quality alone is not sufficient for internal process excellence; its direct impact is weak. IT systems, which directly affect the internal business processes, are in turn dependent on the data quality.

Our results suggest that both internal process excellence and information sharing have a positive and significant effect on supplier performance. Those companies that are more effective and efficient in procurement, manufacturing, and demand forecasting perform better as suppliers in terms of customer order fill rates, reliability, flexibility to order changes, quality, and costs. The degree of information sharing also has a positive impact on supplier performance. Automotive suppliers that regularly exchange high quality information with suppliers and customers are particularly more flexible and reliable, and achieve higher performance results than first-tier suppliers that are less open towards information sharing (cf. Klein and Rai, 2009). However, in contrast to Klein and Rai (2009), we transferred their results to the specific characteristics of the automotive supply chain (cf. Childerhouse *et al.*, 2003).

In summary and in contrast to the work of other researchers, our study enables a comparison of the effect of internal process excellence and information sharing on supplier performance. The results indicate that the impact of internal process excellence is stronger than that of information sharing. A look at the whole research model shows that the most significant path starts at data capabilities and leads via functional capabilities and internal process excellence to supplier performance.

5.1.2. The research model

For the analysis of the relationships between IT capabilities, supply chain capabilities, and supplier performance in the automotive sector, we proposed an extended version of the research models suggested by Li *et al.* (2009), Rai *et al.* (2006), and Wu *et al.* (2006). Our model extends the constructs of "supply chain integration" from Li *et al.* (2009) and "supply chain capabilities" from Wu *et al.* (2006) by using the sub-constructs "internal process excellence" and "information sharing." In comparison to Rai *et al.* (2006), we added the component "information sharing" to the research model and, in contrast to Prajogo and Olhager (2012), we added the effect of IT investment on internal process excellence to our model. Furthermore, our model divides IT implementation into functional and data capabilities. These subdivisions allow for a more differentiated analysis of the impact of IT on supply chain performance, as our research shows. At the same time, the proposed model is general enough to be applied for the analysis of the role of IT in other industries. We tested our model by developing and validating measures for the constructs und examined empirically the validity of the relationship between the constructs.

5.2. Contributions to management / practice

Several managerial implications can be derived from the results presented above. According to our model and our results, the most effective way for an automotive first-tier supplier to improve supplier

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performance is to increase internal process excellence. Internal processes improve when the corresponding functional IT capabilities are expanded. In other words, IT systems for supporting the core supply chain processes should be introduced, enhanced, or replaced by new ones. These IT systems primarily encompass enterprise resource planning (ERP) and advanced planning systems (APS), but more specialized systems such as supplier relationship management (SRM) or customer relationship management (CRM) should also be taken into consideration. Functionally rich and suitable IT systems are only one side of the coin for supporting business processes effectively. Data capabilities for achieving and maintaining high data quality are essential on the path to superior supplier performance. Common data definitions, systems for automatic data capturing (such as bar coding, EDI, and RFID), and data transparency across the whole enterprise are the key prerequisites for high data quality. In addition, the mediating role of functional capabilities in the impact of data capabilities on supply chain capabilities serves as a strong indication that the effect of functional and data capabilities is complementary. Effective data management should always accompany a functional improvement of IT systems. Although the role of internal process excellence on supplier performance seems to be dominant, information sharing should not be neglected. Effective information sharing is an additional driver of improved supplier performance. Many first-tier suppliers have invested greatly in internal processes and are now seeking the next leap forward in performance. Expanding and intensifying communication with customers and suppliers can be a strong performance driver.

Although our results do not point to any size effects indicating that the influence of IT via supply chain capabilities on supplier performance is lower for smaller first-tier suppliers, we wish to note that suppliers should be careful in selecting the IT system. An excessively large and sophisticated IT system can paralyze an organization with a complex implementation project and result in inordinately strict and bureaucratic processes. There are ERP and APS solutions in the market that address the requirements of small and medium enterprises quite adequately.

5.3. Limitations and future research

Our study is subject to some limitations: (1) The questionnaire consisted of subjective questions with 7-point Likert scales. We have only limited possibilities to verify the quality of the information that our participants provided, but we assume that the supply chain and IT managers who participated know their company and the industry. Moreover, the large sample size of 343 should eradicate some issues of imprecise survey answers. (2) As participation in our study was voluntary, our sample might be slightly biased in that it may only contain those suppliers that are particularly open, leaving those that are not underrepresented. (3) The survey was conducted with first-tier suppliers in Europe. A comparison of our results with other cultural regions would be beneficial. For instance, in Japan, the relationship between an OEM and its suppliers is more cooperative. (4) The sample of the automotive suppliers surveyed was provided by one German car manufacturer. Therefore, the generalizability of the findings may be seen as a concern because the results may only be representative of one OEM and its suppliers. The car manufacturer, however, is among the leading automakers in the world. The

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suppliers with whom it collaborates and that took part in the survey are located throughout Europe and cover the whole spectrum of different parts. Most of them are not supplying only one OEM but are serving several car manufacturers. As the OEM and its suppliers represent a great share of the European automotive industry, it is assumed that this survey allows for representative insights into the role of IT in automotive supplier supply chains. (5) The group of respondents is not homogenous, ranging from chief executive officers and plant and supply chain managers to computer personnel (Table 2). This diversity may also cause generalizability concerns because the daily experiences and the involvement in supply chain activities and IT processes certainly vary depending on the position of the respondents. In this research, the automotive suppliers were asked to select the person in their company who is most familiar with the supply chain activities and IT processes to answer the questionnaire. The goal was to get information from the person with the broadest and deepest knowledge about the supply chain activities and IT processes at the single suppliers, independently of the position held. Certainly, it would be interesting to see whether the perceptions vary depending on the respondents' positions. However, due to the fact that the job designations vary from one company to another (in some companies all supply chain employees are referred to as "supply chain managers" while some companies do not have a designated chief information officer;…), we desisted from such analyses but present the positions of the respondents in Table 2 to give an idea about the composition of the sample. (6) We did not differentiate between the various IT systems that apply to supply chain management. An interesting direction for future research would therefore be to compare the impact of ERP and APS solutions on supply chain capabilities. We identified only one enabler of functional capabilities, namely data capabilities. Further antecedents could be investigated. Finally, we encourage researchers to examine additional IT enablers of information sharing as functional and data capabilities do not fully explain this construct.

6. Conclusion

With the growing awareness of the advantages of IT implementation, it is important to understand what impact IT has on performance. The provision of timely, accurate, and reliable information has enhanced the conditions for business relationships worldwide. The present study focused on the relationships among IT capabilities, supply chain capabilities, and supplier performance using empirical data from automotive suppliers in Europe. Our findings show a strong relationship between these three perspectives. Data capabilities contribute to supply chain capabilities through a positive impact on functional capabilities. Internal process excellence has the strongest impact on supplier performance, but the effects of regular and adequate information sharing should not be underestimated. These findings contribute to our understanding of the impact of IT implementation on firm performance, for instance, that the impact of IT within specific automotive supply chains is comparable to the impact of IT on "average firm" supply chains. Furthermore, the findings underline the value for automotive suppliers of promoting IT implementation as a performance enabler.

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Appendix A. Questionnaire

If not otherwise specified, all questions are based on a 7-point Likert scale: 1 (strongly disagree), 2 (disagree), 3 (somewhat disagree), 4 (neutral), 5 (somewhat agree), 6 (agree), 7 (strongly agree).

A1 Functional capability

Our IT systems provide comprehensive functionality to support:

1. Demand planning (long-term demand forecasting and planning, integration of order releases, etc.)
2. Material requirements planning (calculation of order sizes, bill of material explosion, transmission of order releases, etc.)
3. Production planning (long-term planning of production orders, installation of production tools, etc.)
4. Material management (goods receiving, warehousing, pick and pack, etc.)
5. Production management (shop floor control, etc.)
6. Customer order management (order intake, etc.)

A2 Data capability

1. Automatic data capture systems are used (e.g., bar code, EDI, RFID) across the supply chain.
2. Definitions of key data elements (e.g., customer, order, part number) are common across the supply chain within the organization and with supply chain partners.
3. Our data are accurate, reliable, up-to-date, and available across the organization.

A3 Internal process excellence

1. We have optimized the degree of capacity utilization of our manufacturing.
2. We are able to react quickly in the manufacturing process to changes in the demand.
3. Our procurement processes ensure a smooth supply for production needs.
4. We integrate forecast information into our production planning.
5. We have low inventory levels and high availability of materials (raw materials, components, and finished goods).

A4 Information sharing

1. We provide our suppliers all necessary information accurately and comprehensively so they can effectively plan and execute their production.
2. We receive (and use) from our suppliers all necessary information accurately and comprehensively so we can effectively plan and execute our production.
3. We receive (and use) from our OEMs all necessary information accurately and comprehensively so we can effectively plan and execute our production.

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4. We provide our OEMs with all necessary information accurately and comprehensively so they can effectively plan and execute their production.

5. The information exchange with our suppliers is timely and is automatically executed in fixed intervals.

6. The information exchange with our OEMs is timely and is automatically executed in fixed intervals.

A5 Supplier performance

1. Our lead time fulfills the requirements of our OEMs.

2. We are able to fulfill the required order quantities of our OEMs.

3. Our supply chain costs are low compared to the industry average.

4. What is the share of on-time deliveries (according to order releases)? [Answer options (in percent): < 75; 75 – 85; 85 – 90; 90 – 95; 95 – 98; 98 – 99; > 99]

5. We are able to change order items and quantities on short notice.

6. We are able to antedate or delay single deliveries.

7. We are able to implement new processes with our suppliers or OEMs.

8. We are always able to notify our OEMs about date and time of the deliveries.

9. We are able to recognize, communicate, and solve problems early.

A6 Control variables

1. What is the share of your largest OEM compared to the total turnover of your company? [Answer options (in percent): < 10; 10 – 25; 25 – 50; 50 – 75; > 75]

2. What is the total turnover of your company? [Answer options (in million EUR): < 100; 100 – 500; 500 – 1.000; > 1.000]

3. How long do you have a continuous business relationship with your largest OEM? [Answer options (in years): < 1; 1 – 5; 5 – 10; > 10]

A7 Other firm characteristics

1. How many employees does your company have? [Answer options: < 250; 250 – 1.000; 1.000 – 5.000; > 5.000]

2. What is your position in your company? [Answer options: Chief Executive Officer; plant manager; logistics manager; logistics employee; Chief Information Officer; computer personnel; other]

3. The products of your company are mainly part of which product category? [Answer options: Power train; car body; interior; chassis; infotainment; other]

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Appendix B. Indicator weights

[Table B.1 near here]

Appendix C. Indicator loadings

[Table C.1 near here]

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Table 1.
Empirical research investigating the impact of IT (investment) on company and/or supply chain performance.

Perspective	Source	Object of analysis
Value of IT for firm performance	Bharadwaj (2000)	Linkage between IT capabilities and firm performance
	Hendricks *et al.* (2007)	Impact of investments in Enterprise Resource Planning (ERP), SCM, and Customer Relationship Management systems on stock price and profitability
	Ko and Osei-Bryson (2006)	Impact of IT investments using regression and data mining techniques
	Yang and Su (2009)	Relationship between benefits of ERP systems implementation and its impacts on firm performance
	Saleh Shatat and Mohamed Udin (2012)	Relationship between ERP systems and SCM performance in manufacturing companies
Impact of IT on supply chain capabilities	Ceric (2016)	Interactions between IT and organizational resources in manufacturing organizations
	Fuchs and Otto (2015)	Value of IT in supply chain planning
	Panda and Rath (2016)	Linkage between IT capability and organizational agility
	Parida *et al.* (2016)	Influence of information and communication technology (ICT) capabilities on the dynamic capabilities of firms
	Su and Yang (2010)	Impact of ERP benefits on SCM competencies
Supply chain capabilities as a mediator between IT capabilities and firm performance	Li *et al.* (2009)	Impact of IT implementation on supply chain integration and performance
	Liu *et al.* (2013)	Examination of how IT capabilities affect firm performance through absorptive capacity and supply chain agility
	Prajogo and Olhager (2012)	Integrations of information and material flows between supply chain partners and their effect on operational performance
	Rai *et al.* (2006)	Development of a research model to investigate the hierarchy of IT-related capabilities and their impact on firm performance
	Wu *et al.* (2006)	Impact of IT-related company resources on firm performance

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Table 2.
Participant characteristics.

Level of turnover (in million Euro)	Number (share in total)	
< 100	156	(45.5%)
100 – 500	128	(37.3%)
500 – 1000	27	(7.9%)
> 1000	32	(9.3%)
Number of employees		
< 250	100	(29.2%)
250 – 1000	134	(39.1%)
1000 – 5000	76	(22.2%)
> 5000	33	(9.6%)
Position of respondent		
Chief Executive Officer	12	(3.5%)
Plant manager	16	(4.7%)
Supply chain manager	98	(28.6%)
Supply chain employee	127	(37.0%)
Chief Information Officer	4	(1.2%)
Computer personnel	7	(2.0%)
Other (e.g. sales manager, project manager, quality manager)	79	(23.0%)
Product category		
Power train	42	(12.2%)
Car body	80	(23.3%)
Interior	89	(25.9%)
Chassis	36	(10.5%)
Infotainment	12	(3.5%)
Other (e.g. operating supply items, auxiliary items, chemical products)	84	(24.5%)
Period of business relationship with OEM		
< 1 year	13	(3.8%)
1 – 5 years	28	(8.2%)
5 – 10 years	71	(20.7%)
> 10 years	231	(67.3%)
Turnover with largest OEM		
< 10 %	14	(4.1%)
10 – 25 %	100	(29.2%)
25 – 50 %	107	(31.2%)
50 – 75 %	58	(16.9%)
> 75 %	63	(18.4%)

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Table 3.
Measurement of constructs.

Construct	Type	Indicator	Mean	Stand. Dev.
Functional capabilities	Formative	Demand planning	5.12	1.53
		Material requirements planning	5.72	1.30
		Production planning	5.29	1.42
		Material management	5.67	1.28
		Production management	5.23	1.53
		Customer order management	6.05	1.18
Data capabilities	Formative	Automatic data capturing	5.26	1.61
		Common data definitions	5.55	1.51
		Data transparency across applications	5.46	1.40
Internal process excellence	Formative	Manufacturing efficiency	5.29	1.37
		Manufacturing flexibility	5.39	1.24
		Procurement efficiency	5.29	1.24
		Forecast information integration	5.96	1.42
		Inventory management	4.77	1.43
Information sharing	Formative	Information sharing quality to suppliers	5.65	1.28
		Information sharing quality to OEMs	5.99	1.06
		Information sharing quality from suppliers	4.98	1.25
		Information sharing quality from OEMs	5.27	1.34
		Information sharing frequency with suppliers	5.33	1.39
		Information sharing frequency with OEM	5.67	1.35
Supplier Performance	Formative	Lead time	5.66	1.25
		Order fill capacity	5.96	1.04
		Logistics costs	4.66	1.18
		Delivery reliability	4.95	1.48
		Order flexibility	5.53	1.23
		Delivery time flexibility	5.79	1.13
		Process innovation	5.63	1.19
		Advanced shipment notification	5.96	1.18
		Advanced problem notification	5.64	1.25

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Table 4.
Evaluation of hypotheses.

Hypothesis		Path coefficient	t-value	Sig. level	Supported
H1:	Functional Capabilities → Internal Process Excellence	0.441	7.792	0.01	+
H2:	Functional Capabilities → Information Sharing	0.382	5.366	0.01	+
H3:	Data Capabilities → Functional Capabilities	0.530	11.481	0.01	+
H4:	Data Capabilities → Internal Process Excellence	0.184	2.954	0.01	+
H5:	Data Capabilities → Information Sharing	0.264	4.367	0.01	+
	(Internal Process Excellence → Supplier Performance	0.477	8.583	0.01	+)
	(Information Sharing → Supplier Performance	0.347	6.056	0.01	+)

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Table B.1
Indicator weights.

Indicator	Constructs				
	Functional Capabilities	**Data Capabilities**	**Intern. Process Excellence**	**Information Sharing**	**Supplier Performance**
Demand planning	.309*				
Material requirements planning	.294**				
Production planning	.169				
Material management	-.081				
Production management	.237**				
Customer order management	.299**				
Automatic data capturing		.133			
Common data definitions		.394*			
Data transparency across applications		.627*			
Manufacturing efficiency			.432*		
Manufacturing flexibility			.135		
Procurement efficiency			.279*		
Forecast information integration			.275*		
Inventory management			.291*		
Information sharing quality to suppliers				.356*	
Information sharing quality to OEMs				.291*	
Information sharing quality from suppliers				.018	
Information sharing quality from OEMs				.040	
Information sharing frequency with suppliers				.257*	
Information sharing frequency with OEM				.333*	
Lead time					.353*
Order fill capacity					.231
Logistics costs					.206**
Delivery reliability					.123
Order flexibility					-.107
Delivery time flexibility					.055
Process innovation					.159
Advanced shipment notification					.354
Advanced problem notification					.354**

* significant at p<0.05; ** significant at p<0.01

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Table C.1
Indicator loadings.

Indicator	Constructs: Functional Capabilities	Data Capabilities	Intern. Process Excellence	Information Sharing	Supplier Performance
Demand planning	0.819*				
Material requirements planning	0.871*				
Production planning	0.815*				
Material management	0.691*				
Production management	0.796*				
Customer order management	0.756*				
Automatic data capturing		0.695*			
Common data definitions		0.821*			
Data transparency across applications		0.931*			
Manufacturing efficiency			0.837*		
Manufacturing flexibility			0.577*		
Procurement efficiency			0.705*		
Forecast information integration			0.645*		
Inventory management			0.644*		
Information sharing quality to suppliers				0.790*	
Information sharing quality to OEMs				0.782*	
Information sharing quality from suppliers				0.529*	
Information sharing quality from OEMs				0.579*	
Information sharing frequency with suppliers				0.750*	
Information sharing frequency with OEM				0.789*	
Lead time					0.801*
Order fill capacity					0.744*
Logistics costs					0.539*
Delivery reliability					0.455*
Order flexibility					0.559*
Delivery time flexibility					0.593*
Process innovation					0.641*
Advanced shipment notification					0.646*
Advanced problem notification					0.785*

* significant at p<0.01

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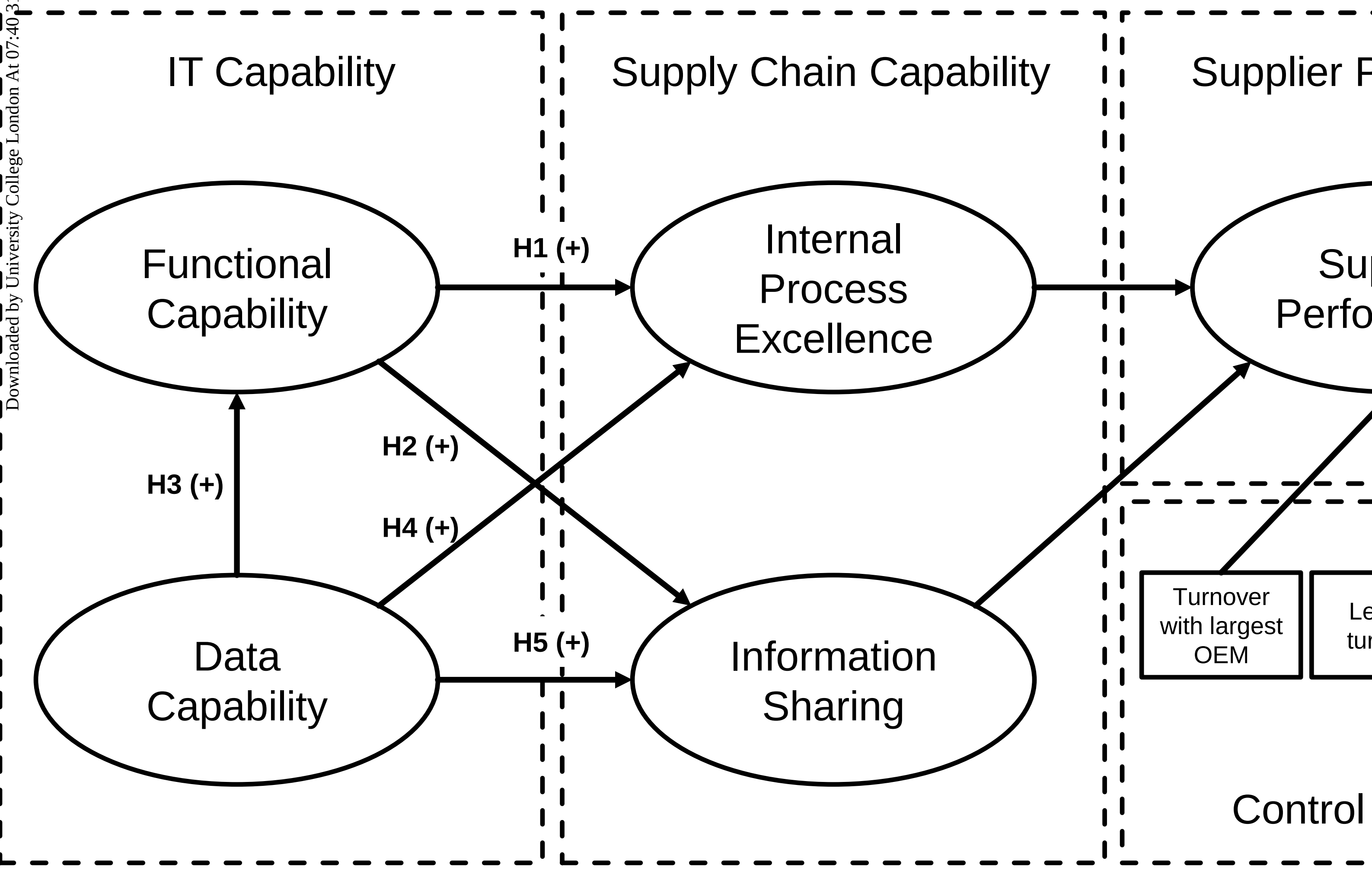

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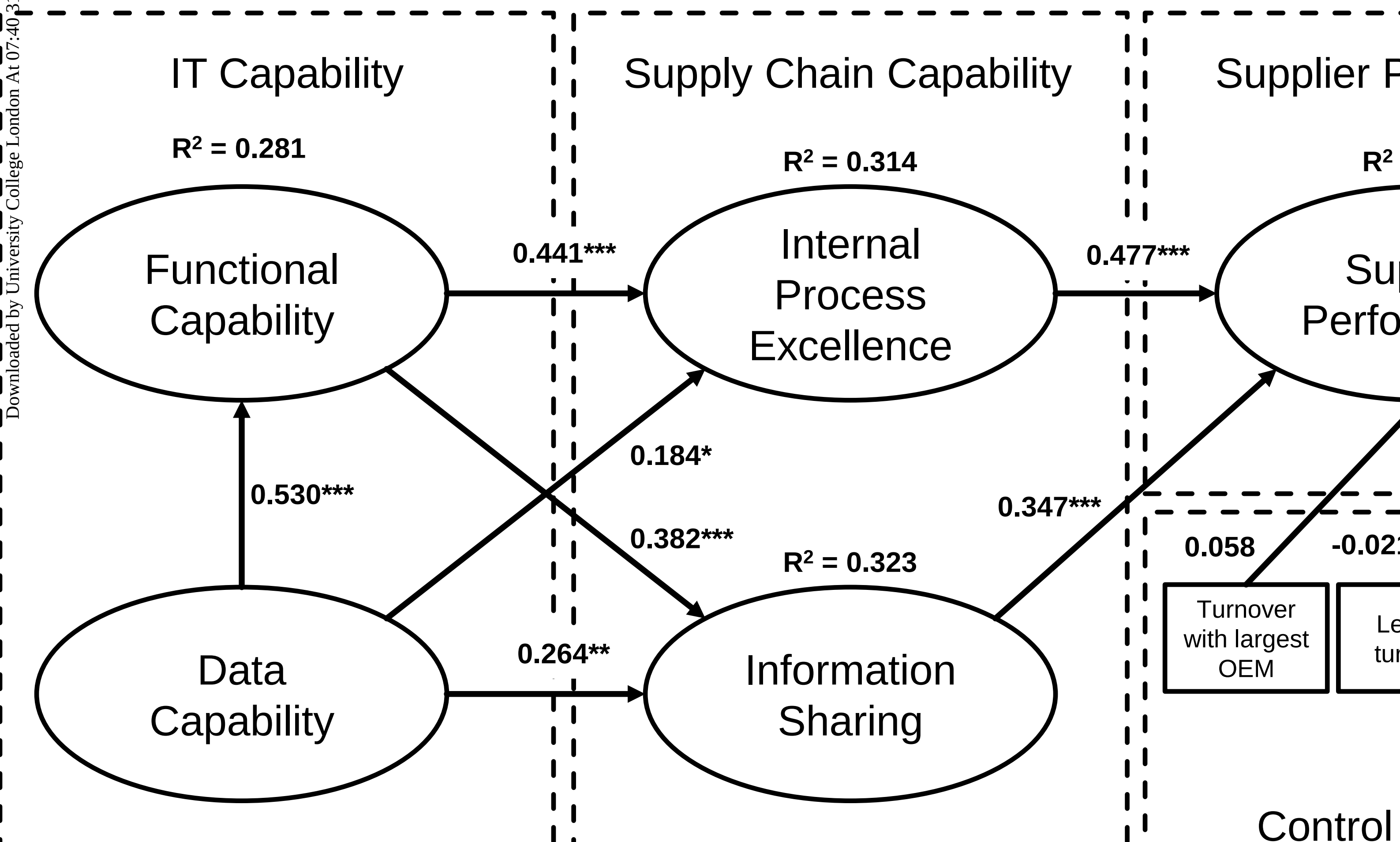

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<u>Response to Reviewers</u>

The Role of IT in Automotive Supplier Supply Chains

Dear Professor Irani, Editorial Team Members, and Referees,

Thank you again for your feedback and the efforts you have taken in reviewing our submission! We are happy to hear that you are satisfied with the modifications that we have made in the course of the revision.

In the following, we will describe how we have incorporated your comments to improve the paper. We will use the same scheme as that used in the last response letter: We will address the specific concerns and suggestions of the two referees. Each concern is repeated in *italics*. Our comments are presented right after each concern.

We would be very happy if the revised manuscript could be considered for publication in the Journal of Enterprise Information Management.

Referee #1

Recommendation: Minor Revision

Comments:
I still think Hypotheses 6 and 7 should be eliminated.
Authors propose: "we will remove them (lines 16 and 40 on page 9) and carry out the modifications in Figure 1." Doing this, the paper is suitable for publication.

In the revised version of the manuscript, we eliminated the Hypotheses 6 and 7. Furthermore, we carried out the corresponding modifications in Figure 1 and Table 4.

Additional Questions:
1. Originality: Does the paper contain new and significant information adequate to justify publication?: See comments to the Author

Thank you for your feedback!

2. Relationship to Literature: Does the paper demonstrate an adequate understanding of the relevant literature in the field and cite an appropriate range of literature sources? Is any significant work ignored?: See comments to the Author

Thank you for your feedback!

3. Methodology: Is the paper's argument built on an appropriate base of theory, concepts, or other ideas? Has the research or equivalent intellectual work on which the paper is based been well designed? Are the methods employed appropriate?: See comments to the Author

Thank you for your feedback!

4. Results: Are results presented clearly and analysed appropriately? Do the conclusions adequately tie together the other elements of the paper?: See comments to the Author

Thank you for your feedback!

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5. Practicality and/or Research implications: Does the paper identify clearly any implications for practice and/or further research? Are these implications consistent with the findings and conclusions of the paper?: See comments to the Author

Thank you for your feedback!

6. Quality of Communication: Does the paper clearly express its case, measured against the technical language of the field and the expected knowledge of the journal's readership? Has attention been paid to the clarity of expression and readability, such as sentence structure, jargon use, acronyms, etc.: See comments to the Author

Thank you for your feedback!

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Referee #2

Recommendation: Accept

Comments:
Comments addressed

Additional Questions:
1. Originality: Does the paper contain new and significant information adequate to justify publication?: Comments addressed

Thank you for your feedback!

2. Relationship to Literature: Does the paper demonstrate an adequate understanding of the relevant literature in the field and cite an appropriate range of literature sources? Is any significant work ignored?: Comments addressed

Thank you for your feedback!

3. Methodology: Is the paper's argument built on an appropriate base of theory, concepts, or other ideas? Has the research or equivalent intellectual work on which the paper is based been well designed? Are the methods employed appropriate?: Comments addressed

Thank you for your feedback!

4. Results: Are results presented clearly and analysed appropriately? Do the conclusions adequately tie together the other elements of the paper?: Comments addressed

Thank you for your feedback!

5. Practicality and/or Research implications: Does the paper identify clearly any implications for practice and/or further research? Are these implications consistent with the findings and conclusions of the paper?: Comments addressed

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