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Reconceptualization of information technology flexibility for supply chain management: An empirical study

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ABSTRACT

IT flexibility is an increasingly important factor in today's dynamic business environment. However, earlier research lacks 1) an integrated framework that corresponds to diverse processes for supply chain management and 2) an explanation of how IT flexibility affects firms' performance in the supply chain context. To fill these gaps, our study theorised a research model by integrating disparate streams of IT flexibility research with three types of IT flexibility, namely, operational, transactional, and strategic, and tested both the direct and indirect effects of the three IT flexibility types on firm performance. Our theoretical model uses an extended resource-based view to highlight the role of IT flexibility in managing interdependent firm relationships in supply chains.

Using a partial least squares approach to structured equation modelling analysis on 162 questionnaires from supply chain practitioners, we found two significant relationships: (1) transactional IT flexibility affects operational IT flexibility, and (2) operational IT flexibility affects strategic IT flexibility. Transactional IT flexibility also affects strategic IT flexibility, thus playing a pivotal role in the effectiveness of the other two flexibility types. In addition, it was identified that transactional and operational flexibilities affect firm performance indirectly, via process integration capability, while strategic flexibility directly affects firm performance. By classifying diverse IT flexibility attributes into three types, a comprehensive and explicit concept of IT flexibility in inter-organisational relationships is attained, which allows practitioners to target key resource investments to realise the full potential of IT in the supply chain.

1. Introduction

Flexible Information Technology (IT) can simultaneously deliver rapid results and support sustainable growth in an increasingly dynamic market environment, while inflexible IT could have detrimental effects on organisational performance – for instance, freezing the organisation into patterns of behaviour and operations that resolutely resist change (Allen and Boynton, 1991; Biloslavo et al., 2013). The concept of IT flexibility is not new. It is often perceived as an antecedent to one type of organisational or supply chain capability, such as firm agility (Tallon and Pinsonneault, 2011; Lee et al., 2015), supply chain agility (Duclos et al., 2003; Ngai et al., 2011), supply chain responsiveness (Bush et al., 2010), or inter-firm strategic alliance (Tafti et al., 2013; Lioukas et al., 2016).

However, the IT flexibility literature is dominated by a focus on IT infrastructure flexibility, as evidenced by our comprehensive literature review and also supported by the work of Kumar and Stylianou (2014). Seen from the ambidexterity perspective, this stream of research emphasises the 'exploiting' role of IT flexibility to allow firms to leverage and (re)configure their existing and proven portfolio of IT assets in different business activities for incremental operational gains (Duncan, 1995; Byrd and Turner, 2000; Ray et al., 2005; Zhang et al., 2009; Bhatt et al., 2010; Tallon and Pinsonneault, 2011; Kumar and Stylianou, 2014). Another stream of research with notably fewer articles investigates the 'exploring' role of IT flexibility to enable firms to develop innovative offerings to their existing and/or new customers for radical and strategic gains with direct attention towards the emerging technologies and practices (Saraf et al., 2007; Bush et al., 2010; Tian et al., 2010; Tafti et al., 2013; Cheng et al., 2014). There is a clear consensus in the literature that ambidexterity is critical to sustained competitive advantage, i.e. combinative capability of exploitation and exploration ensures both current and future viability, and simultaneous pursuit of both exploration and exploitation tends to lead to longer-term sustainability of the firm, through better financial performance, learning and innovation (Gibson and Birkinshaw, 2004; He and Wong, 2004; O'Reilly and Tushman, 2011; Yang et al., 2014). Yet the alignment between exploration and exploitation has not been explicitly addressed by extant IT flexibility literature.

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Further, the ambidexterity of IT flexibility need not reside only in single firms but can be extended to supply chains. Flexible information linkages between companies could allow a focal firm to exploit its existing cross-company operations, such as using online purchasing order and supplier management system to streamline procurement processes, to enhance efficiency. In addition, IT flexibility could enable supply chain exploration practices such as deploying big data analytics systems across business entities to detect customer trends and develop new product offerings. However, the notion of ambidexterity of IT flexibility for supply chain management (SCM) has not received much attention in the literature either. This is no surprise given the lack of efforts in exploring the combinative capability in IT flexibility in general. For instance, Kristal et al. (2010), from a comprehensive survey of manufacturers in the USA, provide evidence that when manufacturers' ambidexterity extends to their supply chain practices, the outcome is improved performance. Within their conceptual model development they note that IT plays a significant role in extending ambidexterity capabilities inter-organisationally, but unlike our study, do not focus on the detailed characteristics of IT flexibility.

The clear divide in the IT flexibility literature on exploitation and exploration, plus a biased single-organisational focus, leads to two limitations that we address in this paper;

a) For scholars, the lack of a comprehensive synthesis of IT flexibility for supply chain management (SCM) underpinned by appropriate theories prohibits the further advance of the knowledge in this field. The dominant infrastructure-focused view reflects the historical origin of the IT flexibility from information systems (IS) and the IT discipline, but it is unhelpful for supply chain researchers who have seen the increasing importance of IT flexibility in supporting elastic supply chain relationship configuration and linking chains of activities (business processes) for competitive advantages (Power, 2005; Burgess et al., 2006; Wong et al., 2012). Where there is empirical evidence, such research is dominated by the theoretical lens of resource-based view (RBV) as indicated by our literature review in Section 1. Most empirical research looks at intra-organisational issues of IT flexibility using RBV (e.g. Ray et al., 2005 and Bhatt et al., 2010). While RBV is appropriate in examining issues of IT flexibility within a firm, it has its limitations in an inter-organisational supply chain setting (Barney et al., 2011; Holweg and Pil, 2008).
b) For practitioners, the existing literature offers little detailed investigation about how firms can actually build the ambidexterity of IT flexibility for superior performance, although there is a clear need to do so. In particular, current efforts examining IT flexibility are mainly at the organisational level, and there is a lack of insight on how IT flexibility can be developed, not only within but also across companies. This is important because companies can no longer work in isolation, and they and their associated supply chain partners have to work together to develop a viable competitive advantage and sustain it in an increasingly hostile market (Frohlich and Westbrook, 2001; Kamal and Irani, 2014).

Therefore, the purpose of this study is to take the first step towards the development of a synthesised IT flexibility framework via alternative theoretical lens, to explore how IT flexibility should be executed for effective SCM. The synthesised model we developed was based on a comprehensive literature review and was further tested empirically using a large-scale survey. For the purposes of this study, we refer to SCM as the management of an extended enterprise as a network of processes, relationships and technologies that creates an interdependence and shared destiny for competitive advantages (Power, 2005). Our focus is on a focal firm's internal and external integration with its suppliers and customers, as these are vital to overall supply chain performance (Gunasekaran and Ngai, 2004; Teller et al., 2012; Braziotis et al., 2013). Our work contributes to the literature in three ways. First, we develop and test a theoretical extension of RBV that explains IT flexibility in a supply chain setting while prior research has largely emphasised the part played by IT infrastructure in enabling organisational level IT flexibility. Second, our model focuses on the execution of IT flexibility for SCM whereas existing models fail to articulate a route of causality from IT flexibility to firm performance. Third, our model tested and clarified that there are both direct and indirect effects of IT flexibility on firm performance while prior studies offer conflicting evidence. Our major practical contribution is that we provide much needed empirical evidence on what constitutes IT flexibility for SCM and how it leads to positive impact on firm performance.

The next section reports our literature research and provides a summary of IT flexibility definitions to illustrate how the concept has been progressively developed. We then present the key literature of IT flexibility derived from both the operations management/supply chain and IT/IS fields, which led to the development of our integrated conceptual model. Research hypotheses were then articulated, with main constructs operationalised for the benefits of our survey research. Survey results were reported and analysed subsequently. We conclude the paper by highlighting our contributions and limitations.

2. Literature review

To review a wide range of aspects of IT flexibility systematically, keyword searches were conducted through several databases, namely, the ABI/Inform Global Proquest, EBSCO and Emerald. Since IT is an extensively applied concept, several keyword combinations of IT-related flexibility were deployed, such as information technology flexibility, information and communication technology flexibility, ICT flexibility, information systems flexibility, technology flexibility and IT infrastructure flexibility. We are also aware that considerable literature from the OM/SCM field did discuss the enabling or supporting role of IT to a firm or supply chain performance but did not treat IT flexibility as their primary account (such as Setia and Patel, 2013; Jin et al., 2014). Therefore, the above keywords research would not allow us to identify those 'hidden' studies. Meanwhile, the same problem exists in the field of IT/IS, too, where IT flexibility tends to be treated explicitly or implicitly, as one of prerequisites to support other organisational capabilities, such as organisational agility (Overby et al., 2006; Chakravarty et al., 2013), improvisational capability (Pavlou and Sawy, 2010) and information management capability (Mithas et al., 2011; Youn et al., 2014). Compared to the rich literature on manufacturing and supply chain flexibility, IT flexibility is far less developed. Therefore, it seemed necessary to widen our literature research, using more generic terms than the ones used at our preliminary screening stage of the literature. Our literature review approach is in line with the recommendations provided by Bryman (2012) and Tranfield et al. (2003).

First, IT-related research was selected by searching for 'information' OR 'IT' OR 'ICT' OR 'e-'. In order to narrow the research scope to supply chains, articles including only 'logistic*', 'supply chain*', 'demand chain*' and 'value chain*' were identified. Moreover, to widely select articles that examined capabilities supported by IT, articles including the terms 'performance*', 'impact*','affect*','improve*' or 'increase*' were captured. The combination of keywords provided above generated 613 search results from the ABI/INFORM GLOBAL database. ABI/INFORM GLOBAL was used because it returned the largest number of search results, compared to EBSCO, Emerald Library and Science Direct. In order to ensure quality and increase credibility, only peer-reviewed scholarly articles were captured and analysed; in all, 200 articles were analysed. In order to capture any previously identified impact of IT flexibility on firm competitiveness, only those articles, which empirically tested their IT flexibility models, were included. In this way, we focused on the gaps highlighted in the introduction – namely, research that has made not only scholarly

Table 1
Empirical studies on IT flexibility.

Research streams	Reference	IT flexibility constructs	Major arguments and findings	Theoretical lens	IT flexibility impact on firm competitiveness
Infrastructure focused view (exploitative)	Armstrong and Sambamurthy (1999)	Client/server computing, LAN, imaging technology, computer aided software, data base management system, EDI, graphical user interface	IT flexibility directly affects IT assimilation for firm strategies and value chain activities.	RBV	Direct impact
	Bhatt et al. (2010)	Scalability, compatibility, sharing, modularity, capability to handle multiple applications	IT flexibility is positively linked to firm competitive advantage. It is mediated by market orientation capabilities (information generation and dissemination).	RBV	Indirect impact
	Byrd and Turner (2000)	IT connectivity, applications functionality, IT compatibility, data transparency, technology management, business knowledge, management knowledge	Integrated and modularised information systems have a potential to contribute to the organisational flexibility and firm competitive advantages.	Implicit but similar to RBV	–
	Duncan (1995)	Platform compatibility, network connectivity, data modularity	An organisation with high levels of connectivity, compatibility and modularity will have high IT infrastructure flexibility.	RBV	–
	Fink and Neumann (2009)	Modularity, compatibility, connectivity, technical knowledge, behavioural knowledge, business knowledge	Based on Duncan (1995)'s IT flexibility model, connectivity is positively associated with physical flexibility (range of information-sharing-related service diversification).	DC	Indirect impact
	Liu et al. (2013)	Connectivity, compatibility, modularity	IT flexibility indirectly affects firm performance. It is mediated by IT assimilation and firm absorptive capacity.	DC	Indirect impact
	Nelson and Ghods (1998)	Modularity, change acceptance, consistency, rate of response, coordination of action	IT flexibility is positively associated with firm structural flexibility and process flexibility.	Implicit but similar to RBV	–
	Ngai et al. (2011)	Connectivity, compatibility, modularity	IT flexibility is a component of IT competence that directly affects supply chain agility.	RBV	Indirect impact
	Ravichandran and Lertwongsatien (2005)	Network, platform, data and core applications	IT flexibility positively affects firm operational performance. It is also mediated by IS capabilities and IT supports for core competencies.	RBV	Indirect impact
	Ray et al. (2005)	Hardware compatibility, data identification, accessibility, standardised data, data shareability	IT flexibility directly affects customer satisfaction related process performance.	RBV	Direct impact (Not significant)
	Tallon and Pinsonneault (2011)	Hardware compatibility, software modularity, network connectivity	IT flexibility facilitates the level of firm agility.	RBV	Moderating impact (Not significant)
	Tafti et al. (2013)	Open communication standards, cross-functional transparency, modularity	IT flexibility affects the formation of inter-firm collaborative alliance.	Implicit but similar to RV	Direct impact
	Zhang et al. (2009)	Compatibility, connectivity, modularity, IT personnel competency	Compatibility and connectivity affect firm performance indirectly as a resource, but modularity as a capability directly affects IT responsiveness.	RBV	Direct and indirect impact
Value creation view (explorative)	Gosain et al. (2004)	Standardised interface, modular interconnected processes, structured data connectivity, quality of information-sharing, breadth of info sharing, deep coordination-related knowledge	IT infrastructure characteristics such as modularity of processes and structured data connectivity has a positive effect on offering and partnering flexibility.	CT	Direct impact
	Bush et al. (2010)	Changing communication and reporting linkages, scaling transaction processing up and down, changing partners, redesigning supply chain process	IT flexibility moderates the link between product design modularity and supply chain responsiveness. It also positively affects chain responsiveness.	MST	Direct impact & moderating
	Cheng et al. (2014)	Compatibility, standardisation, access, external integration for rapid change, support new business, design for quick response to changes	IT flexibility is positively associated with innovative performance. It is mediated by dynamic capabilities.	DC	Direct and indirect impact
	Saraf et al. (2007)	Scalability, IT integration for rapid changes, supporting new business, accommodation of new changes	IT flexibility affects business performance. It is mediated by integration with customer and channel partners.	RV	Indirect impact
	Tian et al. (2010)	Responsiveness to changes, customisation, reaction to competitors, new application launching, expand to new market, change of application, new technology adaption, switch to new suppliers	(Strategic) IT flexibility is positively associated with firm competitive advantage.	RBV	Direct impact

Abbreviations: RBV: resource-based view, COA: components-oriented approach, CT: Coordination theory, RV: Relational View, MST: Modular Systems Theory, DCT: dynamic capability theory.

contributions but that also has practical evidence and/or relevance. In total, 18 articles are retained and summarised in Table 1.

2.1. Defining IT flexibility for SCM

Flexibility has been an important topic of interest to researchers in the field of OM and SCM. In general, flexibility refers to the ability to react to a wide range of possible environments with few penalties in terms of time, effort, cost or performance (Sethi and Sethi, 1990; Upton, 1995). Much of the literature related to flexibility originated and concentrates on manufacturing operations, including Slack's (1987) and Gerwin's (1987) early, notable work. Later studies on flexibility have extended from a manufacturing system to a supply chain level (Duclos et al., 2003; Lummus et al., 2005; Sanchez and Perez, 2005; Stevenson and Spring, 2007). For a comprehensive review of manufacturing and supply chain flexibility, one can refer to the work of Stevenson and Spring (2007), Bernardes and Hanna (2009), Seebacher and Winkler (2013), Mishra et al. (2014) and Tiwari et al. (2015).

IT flexibility has a critical impact on a firm's ability to manage its supply chains when operating under conditions of high environment munificence, dynamism and complexity (Wade and Hulland, 2004; Tiwari et al., 2015). It supports rapid knowledge-sharing, flexible processes and relational coupling with supply chain partners and enables data-driven innovation (Saraf et al., 2007; Tafti et al., 2013). In the existing literature, however, there is no single definition of IT flexibility that has been uniformly accepted. Terms such as IT-enabled flexibility, e-business flexibility, IT flexibility, Information System (IS) flexibility and IT infrastructure flexibility are often used interchangeably in the literature without much consistence, which causes ambiguity and difficulties in further developing valid and reliable measures for the concept. Table A (Appendix A) shows some representative definitions identified in our literature review from both the OM/supply chain and IT/IS literature that exhibit an explicit definition of IT-related flexibility and demonstrate the progression in understanding and scope of the concept. Definitions from the OM/SCM field are from papers which normally treat IT flexibility as one of the enablers for a higher-level organisational capability, without much devoted attention, while definitions extracted from the IT/IS field usually position IT flexibility more as a core construct and the centre of their discussions.

From Table A, we can see that the IT flexibility is mostly examined from the infrastructure perspective. These definitions depict that IT flexibility is dynamic because the specific routes a company takes to achieve IT flexibility have to be constantly adjusted in order to respond to a rapidly changing environment. It is context-specific, as the environmental (such as technological development and market conditions), organisational (such as size, strategy and financial condition) and IS (such as IT resources and staff, architecture and IT vendors) factors all influence the level of needed flexibility. Finally, it is growth- or value-oriented because it is often perceived as one antecedent to one type of organisational or supply chain capability, which ultimately leads to either incremental or radical improvement in performance.

One of the earliest efforts in exploring IT flexibility was Duncan (1995), who established that the technological components of IT infrastructure include platform, networks/telecomm, data and applications and that IT infrastructure flexibility is characterised by connectivity, compatibility and modularity. Her research serves as the starting point for a large number of authors who have subsequently explored properties of IT infrastructure flexibility. The most comprehensive model so far is the one developed by Kumar and Stylianou (2014) on IS flexibility. Although they did not explicitly provide an overarching definition of IS flexibility, their proposed conceptual model outlines the steps one needs to undertake in order to manage IS flexibility: understanding the context, recognising why there is a need for flexibility, evaluating what needs to be flexible, identifying IS flexibility categories and analysing the synergies as well as trade-offs between different flexibilities, then finally prescribing into management action. Their study also distinguishes seven types of IS flexibility (volume, operating, input/output, integration, development, new technology deployment, financial, sourcing and staffing), and each is offered with an explicit definition. The most relevant definition for SCM is by Bush et al. (2010), but their definition only considers the external aspect of flexible IT linkages.

We agree with Duncan (1995) and Golden and Powell (2000) that trying to develop a single, exclusive definition of IT flexibility would be almost impossible since it is multi-dimensional and context-dependent, nor is it necessary, due to its polymorphous nature (Kumar and Stylianou, 2014). However, it seems necessary to at least offer a working definition of IT flexibility in the context of our research, i.e. supply chains. This is because most definitions do not explicitly consider inter-firm IT flexibility at the supply chain level and are heavily skewed towards the technological capability, ignoring the importance of and necessity for appropriate processes and relational couplings in order for flexible IT alignment in supply chains (Byrd and Turner, 2000; Fink and Neumann, 2009; Guillemette et al., 2012; Wong et al., 2012; Lee et al., 2014; Williams et al., 2013).

Hence, we propose IT flexibility for SCM as ‘a focal firm's capability to use IT elastically to configure or reconfigure its information, process and relational linkages within the company and with its supply chain partners in response to a changing business environment’. Building IT flexibility is a more complex and challenging task at the supply chain level because a focal company usually exhibits divergent co-existing supply chain partnerships in practice, and this requires significant efforts to integrate information linkages/flows, to deal with different forms of information transmission and sharing process and to co-ordinate the changing interests of the participating firms.

2.2. Emerging IT flexibility research streams

Our literature review has identified 18 articles as the key empirical studies on IT flexibility. They can be categorised into two main research streams (Table 1): the first focuses on infrastructure flexibility, seeing the role of IT flexibility as exploitative, and the second emphases value creation, considering the utility of IT flexibility as explorative.

We recognise that Duncan's (1995) approach to IT flexibility has been the backbone of IT flexibility research. Duncan claimed that key determinants of IT flexibility are 1) platform connectivity to attach any technology components to other components, 2) network compatibility to share various types of information across other technical components and 3) application modularity to add and modify any technical components with low cost and penalties. She argued that IT flexibility can enhance external cooperation, cost-efficient innovation and strategic system redesign to respond to a changing market. Although this infrastructure-oriented approach is criticised for being a partial examination (Fink and Neumann, 2009; Kumar and Stylianou 2014), the three constructs have been adopted by a large number papers in the subsequent literature as the core constructs of IT flexibility. For example, Zhang et al. (2009) found that connectivity, compatibility and modularity significantly supported a firm's process improvement and service changes for customer requirements. Ngai et al. (2011) also identified that these constructs positively affect supply chain agility by allowing the firms to make changes on IT infrastructure effectively. In Liu et al.'s (2013) study, they were positively associated with IT assimilation, which covered improved business processes and flexible partnering. This research stream, therefore, asserts that IT infrastructure flexibility is determined by the extent of reach and range upon which a network is configured.

In the later literature, new constructs were added to the original three proposed by Duncan (1995) to account for the IT developments for more flexible information-sharing in inter-organisational relationships. For example, constructs such as data and core application sophistication (Ravichandran and Lertwongsatien, 2005), data identification/standardisation, accessibility, shareability (Ray et al., 2005), electronic data interchange (EDI) (Armstrong and Sambamurthy, 1999) and information-sharing capability to handle multiple applications (Bhatt et al., 2010) were tested. This focus on information-sharing addresses the fact that flexible information-sharing supports a firm's ability to improve various types of competitiveness through activity coordination and streamlined process management. However, their approach is not significantly different from the conventional infrastructure approach, as they are still standing on the technological advancements in which the network reach and rage are the central idea of IT flexibility. This stream posits that the role of IT flexibility is exploitative, i.e. IT flexibility will allow a firm to utilise existing resources within and between its partners for efficiency gains.

Although there is a strong tendency towards maintaining a primary focus on IT infrastructure flexibility, there is another stream, which views IT flexibility as an enabler of potential value creation. In the former stream, the ways in which IT flexibility attributes are used to respond to market changes are primarily related to adjusting technical resources within the current configuration. On the other hand, the latter stream, which focuses on the exploratory capabilities of IT, contains types that measure to what extent IT resources are reconfigurable (Grewal and Tansuhaj, 2001; Fredericks, 2005) and partnerships are renewable through IT alignment (Gosain et al., 2004; Rai and Tang, 2010) in order to actively respond to the market requirement to seek potential value. These constructs include the IT ability to handle new business requirements (Saraf et al., 2007; Cheng et al., 2014), introduce new technology (Tian et al., 2010), support the redesign of supply chain processes (Bush et al., 2010), support new offerings, and implement an elastic configuration with new partners, as well as offer reconfiguration with existing supply chain partners (Gosain et al., 2004). This potential value creation perspective takes into consideration the fact that firms will effectively utilise IT resources to meet the dynamic requirements of the market through resource and partnering configuration and reconfiguration. Therefore, the role of IT flexibility is more innovation-oriented and explorative.

It is important to note that the two research streams are not mutually independent. The value-seeking activities become feasible only if firms acquire the proper level of infrastructure and information-sharing capabilities. For example, having an effective inter-organisational system (i.e. proper infrastructure) enables firms to have a smooth information flow directing the flow of materials. It also increases information visibility to multiple firms for continuous process improvement (Simatupang and Sridharan, 2005). Firms with sufficient information-sharing capabilities should then be able to alter or modify their operations according to customer and market requirements (i.e. value-seeking activities). In so doing, firms can develop long-term planning and evolve their approaches to create potential value and overall performance improvement in a supply chain (Stank et al., 1999).

Based on the comprehensive literature review, we conceived an opportunity to reconceptualise IT flexibility for SCM. There is a need to integrate and restructure the existing IT flexibility constructs into a more comprehensive concept due to problems highlighted in Section 1. There is a particular opportunity to combine the value creation perspective with the infrastructure-based approach. Furthermore, with the current two inconsistent approaches to IT flexibility, it is not clear how IT flexibility affects firm performance. As can be seen from Table 1, the majority of the papers show that IT flexibility had some effect on firm performance: a direct effect (such as Armstrong and Sambamurthy, 1999; Gosain et al., 2004; Tian et al., 2010), an indirect effect (Saraf et al., 2007; Fink and Neumann, 2009; Bhatt et al., 2010), and a moderate effect (Bush et al., 2010; Tallon and Pinsonneault, 2011). Only two articles tested both direct and indirect relationships between IT flexibility and firm performance (Zhang et al., 2009; Cheng et al., 2014). The model we propose later aims to test both the direct and indirect pathways to have an impact on performance in order to add clarity to the confusing literature.

3. Theory development of IT flexibility for SCM

As evidenced in Table 1, the RBV is the dominant theory in the literature. RBV asserts that a firm's competitive advantages lie in its ability to manage a bundle of resources that are valuable, rare, inimitable and non-substitutable (Penrose, 1995; Wernerfelt, 1984; Barney, 1991; Teece et al., 1997). RBV is appropriate for examining the implications of flexible IT capabilities by conceptualising IT as one type of internal resources affecting organisational capability creation (Hsu et al., 2009; Zhang et al., 2011). However, as RBV argues that the resources for a competitive advantage must be confined within the firm's boundaries, it is not sufficient to justify the mutual benefits realised by widely shared IT components and systems in the inter-organisational supply chain setting (Wade and Hulland, 2004; Lavie, 2006; Kraaijenbrink et al., 2010). Eisenhardt and Martin (2000) also criticised that RBV's path-dependent logic of leveraging *existing* resource configurations for competitive advantage are not applicable in a market with high velocity because a volatile market would require firms to build *new* resource configurations and move into fresh, competitive positions using a path-breaking logic of change.

Given the aforementioned limitations of RBV, researchers have added relational (Lavie, 2006; Jin et al., 2014) and dynamic (Teece et al., 1997; Teece, 2007; Fawcett et al., 2011) extensions of RBV to increase its applicability in an inter-organisational setting. The relational extension argues that in networked environments, such as supply chains, firms' capability to form and maintain valuable interactive relationships with alliance partners plays an important role in gaining and sustaining competitive advantages (Lavie, 2006). This argument was informed and closely related to the theory of Relational View (RV). According to RV, a firm's critical resources may span firm boundaries and may be embedded in inter-firm routines and processes, such as information-sharing and IT system integration (Dyer and Singh, 1998). Collaborative relationships between firms lead to the generation of relational value, a source of inter-organisational competitive advantages (Dyer, 1996; Dyer and Singh, 1998; Rai et al., 2012). With a focus on dyadic/network resources and capabilities, extended RBV and RV are more suitable to explain differential firm performances in a supply chain context (Chen and Paulraj, 2004; Devaraj et al., 2007). For instance, Wang et al. (2013) found that IT-enabled planning and control can contribute to the realisation of mutual adaptation by motivating relation-specific investments, leading to modification flexibility (the ability of buyers and suppliers to adjust their behaviours or the terms of the agreement in response to environmental changes and the needs of their partners).

The dynamic extension of RBV, known as dynamic capabilities, also underpins our theorising of IT flexibility for SCM because it emphasises the need to integrate, build and reconfigure internal and external competencies in order to remain competitive under market volatility (Eisenhardt and Martin, 2000; Teece, 2007). Teece (2007) pointed out that operational competences (known as operations management), such as order entry, billings, purchasing, inventory control, marketing and sales, will only help to sustain the technical fitness but is not sufficient for long-term competitive success, while dynamic capabilities will allow companies to build evolutionary fitness via strategic sensing, seizing and transformational/reconfiguring activities. For instance, with big data and advanced analytic tools, companies are increasingly able to sense subtle shifts in customer preferences and customise products/services via the real-time monitoring of online customer feedback, blogs, news reports and Tweets. These strategic activities may include shaping the ecosystem a firm occupies, developing new products and processes and designing and implementing new business models. Companies with dynamic capabilities will be able to successfully innovate and capture sufficient value to deliver superior long-term performance (Agarwal and Selen, 2009; Wu, 2010).

3.1. Conceptual model

While traditional RBV explains the infrastructure-based approach of IT flexibility, the relational and dynamic extensions need to be added to articulate IT flexibility in a supply chain context. Synthesising these extensions of extended RBV, we propose a three-type model of IT flexibility for SCM (transactional, operational and strategic) reflecting the themes that emerged from the literature accordingly: IT infrastructure for network connectivity, IT alignment that facilitates information-sharing, and the strategic use of IT for potential value-seeking. As our research is interested in exploring the impact pathways of IT flexibility on firm performance, our focus is not on supply chain conditions (though these are very important), but on how the flexible deployment of IT resources (internally and externally) and process and relational configurations could lead to improvement in a focal firm's performance. Although we recognise that IT flexibility is contingent on the supply chain context, we are more interested in how IT flexibility gets executed in a dyad supply chain.

It is worth noting that while a firm's strategy for IT flexibility is typically crafted in a top-down fashion (i.e. a firm's strategy defines its operations practices and subsequently determines its tactical implementation), its execution normally takes a bottom-up approach in order to translate strategy into action (Muckstadt et al., 2001). This is in line with classic systems engineering approaches where IT systems are specified top-down but implemented bottom-up (Croxton et al., 2001; Sage and Rouse, 2009; Buede, 2016; Kossiakoff et al., 2011). To elaborate, a firm's strategy will articulate the nature of inter-organisational relationships with its various partners (from arms-length to strategic) and what relationship-specific investment should be made with each of them. This will then dictate, at the operational level, how multi-functional IT interfaces should be built in order to fit the nature of partnership and business needs. Operational-level activities will then guide the decisions on IT physical infrastructures and network connectivity at the transactional level – for instance, whether to use a hosted IT service or build one in-house. Once the strategy is developed, its execution to operationalise the strategy will follow the reverse order, i.e. one should build essential IT infrastructure and appropriate connectivity at the transactional level, then proceed to establish operational level alignment on business processes. Both transactional IT flexibility and operational IT flexibility will then enable strategic IT flexibility to allow flexible partnering and innovative product or service offering.

Transactional (TR) IT flexibility embodies the infrastructure view in the literature. It represents the idea that IT flexibility for elastic networking and connectivity with a firm's supply chain partners is critical for competitive advantages. TR flexibility leverages the advancement of infrastructure and connectivity to support changes in business requirements driven by market conditions or strategy. We contend that organisations' decisions regarding how they invest and use their IT infrastructure resources affect their productivity because TR flexibility is a critical means to elastic intra- and inter-organisational integration and effective supply chain management (Henderson and Venkatraman, 1999; Paulraj et al., 2008; Mithas et al., 2011). The importance of TR flexibility to a supply chain is well illustrated by Collins et al. (2010), using a trading company example. This company serves retailers around the world with clothing and other products manufactured in Asia, Africa and America: '*Each order requires orchestration of a variety of services, from design and sourcing through production, logistics, quality management, finance and billing, all within a customised worldwide workflow that may exist only for the duration of that specific order' (p. 436–437)*. The firm's ability to serve customers depends heavily on its ability to deploy and flexibly integrate its IT infrastructure across organisational boundaries on an as-needed basis to support business processes and managerial decisions. We argue that the infrastructure in itself is exploitive, however TR flexibility goes beyond the mere hardware and software themselves by developing a capability that also allows the use of infrastructure for explorative purposes. For instance, the modularity of IT architecture would enable the rapid reconfiguration of business processes, particularly when a new operating entity is formed as a result of a partnership (Mithas et al., 2011). Modularity and open standards also help to reduce the switch or exit costs when a partnership ceases to exist (Tafti et al., 2013). In both scenarios, TR flexibility allows firms to adapt to the changing environment for sustained business viability. In contrast, TR flexibility could also enable supply chain partners' joint pursuit of efficiency out of existing supply chain practices. For instance implementing a supply chain visibility system improves operational performance in terms of cost efficiencies and profitability (Lee et al., 2014). Therefore TR flexibility has a dual purpose of exploitation and exploration, depending on how it is being deployed.

Operational (OP) IT flexibility is derived from the literature to depict the role of IT flexibility for efficient/quality information-sharing and process improvement. With the support of OP IT flexibility, resources can be designated for process enhancement, especially with regards to streamlining shared business processes, such as ordering, inventory, transport and distribution management (Turban and Volonino, 2010). Improved automation and coordination can contribute to cost savings and reduced lead times and also contributes to better alignment of complementary decision-making processes in the chain, resulting in the overall performance improvement of participating firms and the whole chain (Chandra and Kumar, 2001). Corresponding to the technical (operational) fitness argument by theory of dynamic capability, we identified that the purpose of OP IT flexibility is exploitation, i.e. firm's elastic utilisation of existing IT resources and practices embedded and shared in a supply chain will support continuous process improvement and greater control over process execution (Lee et al., 2015). OP IT flexibility hence serves as catalyst and stimuli to support an existing inter-organisational relationship portfolio and is efficiency-driven (March, 1991; Subramani, 2004; Im and Rai, 2013).

Strategic (STR) IT flexibility refers to the ability of a firm to proactively invest in its own and its supply chain partners' IT proficiency to create new, future-oriented business capabilities under uncertainty and market shifts. This represents the value-creation-focused research stream in our literature review and also incorporates the idea of dynamic and relational extension to RBV that STR flexibility allows a firm to configure new or reconfigure existing inter-organisational relationships for innovative product and service offering. Namely, it impacts firm performance with regard to revenue growth by supporting flexible partnering (the ability to build and alter linkages with different supply chains) and flexible offerings (the ability of inter-firm relationships to back changes in product/service offerings for value creation) (Gosain et al., 2004; Rai and Tang, 2010). For example, the study of Wang et al. (2011) illustrates how three multinational manufacturers explore collaboration opportunities by establishing an innovative consortium electronic logistics marketplace to jointly manage their transport provision and execution. Therefore, the purpose of STR flexibility is viewed as explorative and is innovation driven (March, 1991; Williams et al., 2002; Subramani, 2004). Table 2 summarises the classification of the IT flexibility types identified and their characteristics.

We further propose that the execution of IT flexibility in a supply chain may rely on intra- and inter-organisational process integration. Process integration capability (PIC) represents the magnitude of both intra and inter-firm process integration measured from a viewpoint of a focal firm. Owing to the requirements of SCM to coordinate the material flows within and between firms, the level of process integration is considered as one of the normative ways of achieving competiveness in supply chains (Bagchi et al., 2005). There is a plethora of literature on supply chain integration with a predominance of process view, i.e. describing SCM as a series of connected input-process-output chain of activities (Gunasekaran and Ngai, 2004; Power, 2005; Droge

Table 2
The classification of IT flexibility types and their characteristics.

Types	Purpose of IT use	Focus	Flexibility attributes
OP IT flexibility	Exploitation	Supply chain routines & operations	Capability for - Information sharing - Process automation & synchronization - Process coordination
TR IT flexibility	Dual - Purpose	Network configuration & connectivity	Capability to use - A wide range of IT infrastructure - High level of IT applications - Internet connections and access - High interoperability
STR IT flexibility	Exploration	Market & innovation	Capability to - Reconfigure partnerships, according to changing customer needs - Support changes in product or services - Develop new business models

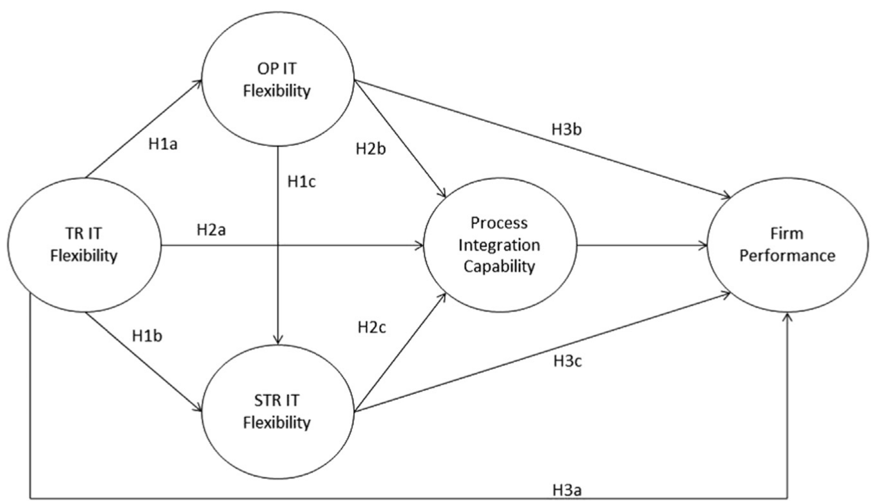

Fig. 1. A conceptual model of IT flexibility and the associated hypotheses.

et al., 2012; Schoenherr and Swink, 2012; Maiga et al., 2015; Rahimi et al., 2016; Titah et al., 2016). The necessity of taking a process view for execution is also recognised by scholars from IT/IS field (Rai et al., 2006; Kamal and Irani, 2014). Process integration is evidenced as an indispensable element of successful supply chain execution (Frohlich and Westbrook, 2001; Zailani and Rajagopal, 2005) because it is the processes which transform inputs (resources/assets) into outputs (competitive performance) (Teller et al., 2012). PIC is also perceived as a relational competency that is required to mediate firms to achieve relational rent in collaborative relationships (Paulraj et al., 2008). Our rationale for using PIC as mediator is further supported by the empirical evidence presented by Rai and Tang (2010) and Fink and Neumann (2009) that the role of IT flexibility in establishing process capabilities, which then have a positive impact on competitive performance. Following this rationale, we propose process integration capability as a mediating construct. We present our conceptual model in Fig. 1.

3.2. Structuring an IT flexibility model and hypothesis development

3.2.1. Relationships between IT flexibility types

As shown in Table 2, we propose that TR flexibility is pivotal in supporting other two flexibilities because IT infrastructure can serve more than one purpose in inter-firm business network (Henderson and Venkatraman, 1999; Hong, 2002; Vickery et al., 2003). TR IT flexibility has dual purposes: it provides a foundation to achieve OP flexibility by facilitating quality information-sharing and flexible process alignment, and it is an enabler to strategic IT flexibility by allowing partnership, (re)configuration and innovative product/service offerings.

The impact of TR IT flexibility on OP IT flexibility can be identified in the context of electronically enabled business processes. It is argued that IT capabilities for inter-firm relationships is a precursor of supply chain information alignment via compatible information-sharing and quality inter-frim communication (Tan et al., 2010), so it can be interpreted that IT advancement and compatibility for inter-firm business reflects the degree of IT diffusion in supply chain processes (Wu et al., 2006). In a similar vein, Jayaram and Vickery (2000) identified that information systems' infrastructure and software interacts with supply chain process improvement tools, and Byrd et al. (2008) showed that superior IT infrastructure positively affects the performance of business information systems.

TR IT flexibility enables current or new strategy initiatives of a firm and thus supports STR IT. For example, IT infrastructure, such as networks and platforms, support firms' IT use for market-related competence (Ravichandran and Lertwongsatien, 2005). Inter-operable IT infrastructure positively affects the use of web technology to leverage its potential business strategies (Ranganathan et al., 2011). Moreover, customers' and trade partners' strategic needs can be shared by adopting compatible information systems (Tan et al., 2010). For instance, using cloud computing, a focal company of a supply chain could quickly scale up/down its IT infrastructure when market demand rises or cools down. Cloud computing concepts such as infrastructure as a service or software as a service offer the much needed flexibility but without incurring high setup or exist cost which often accompanies with a traditional IT deployment with supply chain partners (Battleson et al., 2015).

The same logic applied to the role of OP IT flexibility and to STR IT flexibility. Open-standard, higher-level information-sharing and process improvements could allow firms to achieve strategic communication with new or existing partners (Hong, 2002). According to Zhang and Dhaliwal (2009), the use of shared IT for diverse supply chain operations by key trade partners leads to technology diffusion in external collaborations. The utilisation of IT such as Radio-Frequency Identification for operational efficiency encourages quick response to customers along the supply chain by enabling firms to synchronously share information with partner suppliers and customers (Zelbst et al., 2010). Qrunfleh and Tarafdar (2014) confirm that IT flexibility supports supply chain strategic goals such as agility. Agile supply chain needs IT to be deployed relatively quickly and reconfigured frequently and easily in response to changing customer demand. Flexible operational IT systems such as market information system helps in tracking customer preferences and facilitating fast response in terms of new product offering. The paper cites Zara, a well-known Spanish clothing retailer, as an example for successfully utilising IT systems at both transactional and operational levels to design, produce and make available a new garment in store worldwide in just 15 days.

Thus, in accordance with the extant literature, we expect that TR, OP and STR IT flexibilities are related as indicated in the following hypotheses:

H1a. TR IT flexibility positively affects OP IT flexibility.

H1b. TR IT flexibility positively affects STR IT flexibility.

H1c. OP IT flexibility positively affects STR IT flexibility.

3.2.2. Impact of IT flexibility on organisational capabilities

Process integration is often considered a primary goal of IT application adoption, such as enterprise resource planning (ERP) or electronic data interchange (EDI) (Themistocleous and Corbitt, 2006; Berente et al., 2009). This study proposes that PIC mediates the effect of the three types of IT flexibility on a focal firm's performance. The associated role of IT flexibility with PIC has not been investigated explicitly in existing IT flexibility research, although there are generic studies investigating the mediated relationship between ICT and SC performance (see recent research by Zhang et al., 2011). For instance, Vickery et al. (2003), via a survey conducted in the automotive sector, found that integrative ICT impacts both internal process integration by increasing the flow of relevant information among process participants and external integration with suppliers and customers by forging closer supplier and customer relationship. Based on a survey of 127 companies in China, Peng et al. (2016) also empirically confirmed that a firm's capability to manage both internal and external business processes fully mediate the impact of IT on firm performance.

Achieving internal process integration is a first step towards overall process integration at the supply chain level (Lambert et al., 2005; Narayanan et al., 2011). The role of IT in *internal* process integration is in facilitating cross-functional information-sharing and collaboration (Schoenherr and Swink, 2012; Williams et al., 2013). Internal integration removes the functional silo effect characterised by individual functions having their own agendas with limited interaction and resulting in high unit costs, high levels of inventory, and poor customer service (Stevens, 1989; Stevens and Johnson, 2016). A typical IT solution to the aforementioned problem is the widespread adoption of (ERP) system in companies. An ERP system improves firm's capability to integrate its business processes (such as marketing, finance, manufacturing and logistics) seamlessly to respond swiftly to customers and suppliers (Su and Yang, 2010). The impact of TR IT flexibility on internal PIC was evidenced by the study of Kim et al. (2011). Their study confirms that IT infrastructure flexibility has a direct influence on process oriented dynamic capability, empowering a firm to innovate its own business process continuously and faster than its competitors. This capability enhances the firm's ability to adapt resiliently to changes in business environment and leads to sustainable competitive advantages.

The impact of OP IT flexibility on internal PIC can be observed in the research by Sanders (2007), which identified that internal integration is a critical mediator of supply chain IT use for improved organisational performance. They found that web-based IT use positively affect intra-organisational database integration, information-sharing and strategic planning. OP IT Flexibility supports internal PIC mainly via processes streamlining and information-sharing across functions. For example, effective deployment of enterprise social media supports instant intra-organisational communication and flexible information-sharing, which improves cross team collaboration and productivity (Leonardi et al., 2013).

STR IT flexibility stresses the capability to support flexible relational configurations with supply chain partners as well as new product/service offering. By engaging in inter-organisational collaboration companies automatically force higher levels of internal integration (Droge et al., 2004). For example, Subramani (2004) argued that IT for operational efficiencies between trade partners enables a focal firm's capability to integrate its production and inventory management processes. Similarly the sharing of demand and production related information between a manufacturer and a supplier would allow the supplier to make segment specific forecast and align its production closely with actual demand (Seidmann and Sundararajan, 1998; Barratt and Barratt, 2011).

There seems to be a consensus in the literature regarding the role of ICT as an enabler in *external* process integration (Zhang et al., 2016). For instance, at the infrastructure level, Prajogo and Olhager (2012) explored the positive impact of an information-sharing network on external supplier integration. Mithas et al. (2011) identified that IT infrastructure and information management plays a foundational role in building process management capability for improved inter-organisational performance. TR IT flexibility supports external process integration by providing flexible information linkages and ensuring interoperability between systems. Rai et al. (2006) show that IT infrastructure integration at the supply chain level enables the transformation of fragmented, functional, silo-oriented supply chain processes to integrated, cross-functional inter-firm supply chain processes. Flexible IT infrastructure allows smooth information flow along the supply chain, facilitates timely decision-making and leads to improvements in operational coordination and performance (Liu et al., 2013).

With respect to OP IT flexibility's impact, we need to focus on the advantages obtained via IT services for process improvement. For instance, Saeed et al. (2011) identified that integration and process optimisation IT applications affect operational integration with external supply chain members. Wiengarten et al. (2013) identified that e-business applications for integration have a significant positive effect on buyer-supplier collaboration. STR IT flexibility is also expected to have an impact on PIC. Devaraj et al. (2007) identified the positive impact of information system capability (with its focus on strategic use, such as customer involvement, supplier selection and forecasting scheduling) to supplier and customer integration. Saraf et al. (2007) also argued that IT in new business and market requirements handling supports firms in integrating processes with customers and channel partners. Finally, Rai and Tang (2010) confirmed that flexible IT configuration for external resource management has a direct influence on competitive process capabilities for external resource management, which then leads to competitive performance.

Based on the above reasoning, we propose the following hypotheses:

H2a. TR IT flexibility positively affects PIC.

H2b. OP IT flexibility positively affects PIC.

H2c. STR IT flexibility positively affects PIC.

3.2.3. Impact of IT flexibility on firm performance

With regard to firm performance, we deployed performance indicators based on Zhang et al. (2011), who mainly viewed IT as inter-organisational technologies affecting firm performance such as cost, service, speed, quality and value. Apart from the indirect impact of IT flexibility on firm performance through PIC, we also expect that there could be a direct impact of IT flexibility on firm performance in the form of a series of performances. Therefore, we test the impact of IT flexibility on the performance with the support of the following research findings.

Regarding the impact of TR IT flexibility on firm performance, Ray et al. (2005) and Bhatt et al. (2010) insisted that infrastructure resources positively affect customer satisfaction including speed, accuracy and identification of service. Fink and Neumann (2009) confirmed that IT infrastructure positively affects the cost efficiency of firms, and Jayaram and Vickery (2000) identified the positive impact of IT infrastructure on time performance. With regard to OP IT flexibility's impacts, Zhang et al. (2009) found that information quality affects cost performance. Wiengarten et al. (2013) insisted that applications for shared process coordination affect cost and quality-related performance. Bharadwaj (2007) claimed that the information system capability of focusing on data and process integration is positively associated with cost performance. STR IT flexibility's impact is also discussed in the literature. Cheng et al. (2014) investigated how IT designed for quick response to change can support new business and affect the speed and quality of service. Tan et al. (2010) argued that EDI for supplier management affects overall firm performance, such as cost and overall level of quality and service. Based on the discussion above, this research offers the following hypotheses:

H3a. TR IT flexibility positively affects firm performance.

H3b. OP IT flexibility positively affects firm performance.

H3c. STR IT flexibility positively affects firm performance.

3.2.4. Impact of the firm's PIC on firm performance

We argue that a firm's ability to integrate process, which is enhanced by IT flexibility, will positively impact firm performance. Studies as discussed in Section 3.2.2 focusing on either internal or external PIC or both largely agree that there is a positive relationship between PIC and firm performance. Rai et al. (2006) identified that internal and external process integration with customers and suppliers was positively associated with firm performance. Hafeez et al. (2010) found that organisational integration in supply chains also positively affects firm performance. In order to examine the impact of IT flexibility on firm performance, through the mediator PIC, we propose the following hypothesis:

H4. PIC positively affects firm performance.

Our conceptual model (shown in Fig. 1) indicates that there are potential relationships between the three types of IT flexibility and their impact on firm performance. Furthermore, our research tests whether IT flexibility affects firm performance directly or indirectly via the mediating role of PIC.

4. Research method

4.1. Data collection

Targeting senior executives as key informants is a typical sampling technique to ensure credibility of response. However, as our model examines activities at transactional, operational and strategic levels, we targeted our respondents at all levels for a balanced view of IT flexibilities, i.e. employees conducting transactional activities (usually clerk/junior level employees), employees conducting operational activities (usually by middle managers) and employees responsible for strategic activities (senior managers or executives). We also feel that senior executives, though they understand strategic issues well, may not have hands-on experience with IT systems. An experienced respondent such as a transport/production planner often knows much better how IT affects the key performance indicators (KPIs) than senior executives because he/she deals with such IT activities on a daily basis. Indeed, during our pilot stage, we found that practitioners valued the involvement of respondents at all levels. Our strategies to ensure that informants are reliable to provide credible responses are as follows:

1) We used the professional network of the authors' university, which included industrialists whom we have known for a number of years through joint research projects and knowledge transfer projects, as well as the academic advisory board and established alumni.
2) To assess the appropriateness of informants and to determine whether they met the criteria of involvement, an additional formal check was administered with a part of the questionnaire to measure the competency of informants in conservative manner (Kumar et al., 1993). Specifically, three questions in the first part were designed to assess explicitly the informants' familiarity with IT use for transactional, operational and strategic activities. Only respondents able to fully answer those three questions were retained for data analysis.

Prior to its full implementation, the survey was piloted with ten practitioners in logistics/SCM and three academics from the same field. Pilot respondents were asked to examine the contents of the questionnaire and to suggest areas of improvement. As a result, several items and questions were modified for improved content validity and clarity. For example, examples of specific technologies in TR and OP IT flexibility were given. A definition of the reconfiguration of information linkages was also provided. Questions were measured using a seven-point scale from 'strongly disagree' to 'strongly agree'. Firm performance was measured using a similar seven-point scale from 'much worse' to 'much better'.

Given the exploratory nature of this study and increased difficulties in accessing different levels of informant groups, convenience sampling is considered as a practical solution to collect reliable data (Thomas, 2004). Initially, 93 people were contacted to answer our questionnaire. They were encouraged to circulate the questionnaire to their colleagues or business partners. As a result, 162 valid responses were collected after discarding unusable responses. As the survey was completed by a single informant, concerns of common method bias should be addressed. Typical remedies include procedural control in designing and conducting the survey and statistical control after the survey (Podsakoff et al., 2003; Conway and Lance, 2010). The procedural remedies include creating a proximal separation between the dependent and independent variables, protecting respondent anonymity, reducing evaluation apprehension and improving scale items. The statistical remedies typically include Harman's single factor test, one of the most widely used techniques to address common method variance issue. We have paid attention to both approaches in our research setting. At the questionnaire design stage, we have deliberately assigned the independent and dependent variables in different sections, assured the respondents of their anonymity and conducted a pilot test to remove ambiguous items and keep questions simple, specific and concise. After the survey, Harman's single factor test (Podsakoff and Organ, 1986; Podsakoff et al., 2003) was performed to determine if the majority of the variance could be explained by a single factor. The non-rotated solution exploratory factor analysis extracted four factors with eigenvalues above 1.0 which accounted for 67% of the total variance. Since several factors, as opposed to a single factor, were identified and the first factor did not account for a majority of the variance (24%), a substantial amount of common method variance does not appear to be present. However, Harman's single factor test is increasingly contested for its ability to identify common methods bias (Podsakoff et al., 2003). So we also conducted a second test in which the construct correlation matrix computed with partial least squares (PLS) (Table 4) was used to examine if any construct correlated highly because extremely highly correlated (more than 0.90) variables indicate the possibility of common method bias (Pavlou et al., 2007; Siponen and Anthocy, 2010). In our case, no constructs were highly correlated. Our third test follows the recommendation of Lindell and Whitney (2001) and Craighead et al. (2011) to use a theoretically unrelated marker variable (in our case, 'years of the firm established') to perform correlation analysis. We found that the marker variable is not correlated with any other variables. Therefore, we conclude that common method bias is not a significant problem in this study.

A non-response bias test was conducted, as suggested by Armstrong and Overton (1977), which compared the early and late respondents over a number of parameters. The *t*-tests for differences between early and late responses across the key research constructs and company size (number of employees) did not indicate significant differences at the 5% significance level, indicating no evidence of non-response bias. By allowing respondents to choose multiple answers, we found that the firms in our sample provide many types of supply chain related services which are fairly distributed across the industry: warehousing (19%), freight transport (19%), international logistics (16%), freight forwarding (13%), supply chain intermediaries (10%), manufacturing (10%), multimodal transport (8%), construction (3%), and other (2%). From the distribution of the level of responsibility (manager/assistant manager: 46%, clerk/operator: 20%, director/vice director: 16%, supervisor: 12%, vice president or above: 4%, other: 1%) and the number of employees (less than 100: 25%, 101–500: 37%, 500–1000: 13%, 1000–3000: 7%, more than 3000: 15%, non - response: 2%), we can conclude that our sample profile shows the data was obtained from heterogeneous groups of people and companies, which instills confidence in the survey findings.

4.2. Construct operationalisation

IT flexibility types are constructed with subordinate IT resources which support and enable inter-firm business processes in each level of flexibility. As discussed earlier TR IT flexibility's emphases are infrastructure and connectivity. To enable sound technical interconnection throughout the chain members we contend that the level of IT infrastructure can be measured by advancement of hardware, software (Lai et al., 2007), and of networks (Ray et al., 2005; Vickery et al., 2010; Tallon and Pinsonneault, 2011). The connectivity was measured by accessibility to network (Bharadwaj, 2007), length of reach and linkages to external firms (Devaraj et al., 2007) and interoperability (Mouzakitis et al., 2009).

Information-sharing and process improvement are key sub-dimensions of OP IT flexibility. Considering the requirements of inter-firm business networks, the quality (Wiengarten et al., 2013), visibility (Wang and Wei, 2007) and speed (Zhou et al., 2014) of information-sharing were considered as information-sharing's measurement indictors. In process handling and improvement, streamlining of business processes for better monitoring and control (Wiengarten et al., 2013) and process optimisation created by business intelligence (Qrunfleh and Tarafdar, 2014) were employed to mirror the role of IT flexibility in inter-firm business handling.

As introduced earlier, partnering and offering construct STR flexibility for strategic collaborative partnering and new serve/product offering for potential value creation. Partnering was measured with the capability to establish information linkages with existing partners (Gosain et al., 2004; Tan et al., 2010) and new partners (Gosain et al., 2004), Offering was measured with the ability to support offerings to customers (Gosain et al., 2004; Wiengarten et al., 2013).

In order to measure the levels of internal, external and customer integration, business PIC was measured with the ability to integrate sourcing, transport and service processes internally (Cooper et al., 1997); the ability to integrate sourcing, transport and service processes with external firms (Lambert et al., 1998; Wiengarten et al., 2013); and the ability to integrate processes with customers (Frohlich and Westbrook, 2001). We retained the original construct of supply chain execution from Teller et al. (2012) for PIC to ensure content validity.

In this research, performance measurement is defined as the process of quantification in which various aspects of a firm process or whole operations are measured and assessed against performance objectives (Slack et al., 2007). This study adopts the aggregated approach provided by Devaraj et al. (2007); Slack et al. (2007) which frequently appear in IT and SCM research (Zhang et al., 2011). They are transaction cost, speed of business process, quality of service. Moreover, the scale of the customer value (Wang et al., 2008) and service (Jayaram and Vickery, 2000) which represent external customer focused criteria is incorporated. A list of measures with the definitions we used in this study is provided in Appendix B.

The questionnaire was divided into five Sections (A–E). Section A is to provide the respondents' organisation and the types of ICT utilised. Section B provides a list of questions covering the three types of IT flexibility by which respondents have to provide responses via a 7-point Likert scale ranging from strongly agree to strongly disagree. In Appendix B we do not show the Likert scale but instead we give key references that support the development of each question. Similarly, this is also been done for Sections C and D. Questions in Section C are indicators of PIC while Section D is about performance. Finally Section E ask the general background information of the respondents themselves.

4.3. Partial least squares (PLS) method

This study used the PLS SEM method, which is recommended for the prediction and theory building exploratory approach (Gefen et al., 2000; Reinartz et al., 2009; Henseler et al., 2014), because the primary goal of this research is to evaluate the extent to which one part of research model (IT flexibility types in this study) influences values in other part of the model (firm performance in this study); as such, the work of Rai et al. (2006), Saraf et al. (2007), Klein and Rai (2009), and Teller et al. (2012) is relevant to IT-related inter-organisational research. On the other hand, LIRSEL (another type of SEM) is a parameter-oriented approach recommended for theory testing research, as it primarily seeks fit statistics to explain how well the data explains in a given research model (Fornell and Bookstein, 1982; Anderson and Gerbing, 1988; Henseler et al., 2009; Peng and Lai, 2012; Hair et al., 2013). In addition, PLS SEM uses ordinary least squares regressions, which are not sensitive to a small sample size (Gefen et al., 2011; Hair et al., 2011), thus, a relatively smaller sample size ($<$ 200) can be sufficient to acquire acceptable level of statistical power (Reinartz et al., 2009), as it is in the case of this study.

We adopted the PLS specific two-stage assessment procedures as recommended by Chin (1998), Henseler et al. (2009), Hair et al. (2011), Hair et al. (2012) and Hair et al. (2013). A construct level of analysis was conducted to assess the measurement model followed by a structural model assessment. This study deploys the SmartPLS 3.0 software. Missing values were treated with mean value replacement, as there were less than 5% of values missing per indictor. We used a bootstrapping technique to generate parameter coefficient estimates

Table 3
Result summary for measurement models.

Latent Variables	Number of Indicators	Internal consistency reliability		Convergent validity	Indicator Reliability
		Composite reliability	Cronbach's Alpha	AVE	Loadings
TR IT flexibility	6	0.898	0.863	0.597	0.628 to 0.852
OP IT flexibility	5	0.936	0.915	0.747	0.819 to 0.906
STR IT flexibility	3	0.911	0.854	0.775	0.826 to 0.913
Process integration capability	3	0.909	0.849	0.769	0.857 to 0.897
Firm performance	5	0.913	0.881	0.679	0.787 to 0.896

and t-values with 5000 subsamples from the original dataset and no sign changes, including mediating effecting analysis as per Preacher and Hayes (2008), Sattler et al. (2010) and Hair et al. (2013).

5. Empirical analysis and results

5.1. Measurement model assessment

Four types of validity tests were conducted in this step: internal consistency reliability, convergent validity, indicator reliability and discriminant validity. Tables 3 and 4 summarise the validity test results. Internal consistency reliability refers to a form of reliability used to determine the consistency of results across items on the same test. PLS uses composite reliability and the Cronbach's *alpha* for its criteria. Composite reliability and Cronbach's Alpha values over 0.60 are acceptable in exploratory research. Our composite reliability values satisfy the threshold.

Convergent validity is used to identify the extent to which a measure correlates positively with alternative measures of the same construct. Average variance extracted (AVE) measures convergent validity on the construct level with the criteria of 0.50 or higher. Our AVE values ranged from 0.597 to 0.775. Indicator reliability represents how many of the variations in an item are explained by the constructs. Outer loadings are the estimated relationships in a reflective model. They determine an item's absolute contribution to its assigned construct. Outer loadings of 0.708 or higher are desirable. In our case, every item's outer loading values are higher than 0.708, with the exception of interoperability (0.628) and access (0.685) in TR IT flexibility. However, if we consider that this research used an exploratory approach, a loading higher than 0.4 is also acceptable (Hulland, 1999).

We first verified the discriminant validity, which is used to measure the extent to which a construct is truly distinct from other constructs in two ways. First, as recommended by Fornell and Larcker (1981), the square root of the AVE for each construct should be greater than its highest correlation with any other construct. As Table 4 shows, all the square roots of AVE values satisfy the criteria.

Second, we looked at the cross loading, which states that each construct shares larger variance with its own measures than with other

Table 4
Fornell-Larcker criterion analysis.

Latent Variables	PIC	Firm performance	OP IT flexibility	STR IT flexibility	TR IT Flexibility
PIC	**0.877**				
Firm performance	0.618***	**0.824**			
OP IT flexibility	0.573***	0.594***	**0.864**		
STR IT flexibility	0.497***	0.588***	0.808***	**0.880**	
TR IT flexibility	0.530***	0.548***	0.749***	0.738***	**0.773**

*** $p < 0.01$(two–tailed).

Table 5
Variation Inflation Factor analysis result.

Latent variables	OP IT flexibility	STR IT flexibility	Process integration capability	Firm performance
TR IT flexibility	1.000	2.278	2.576	2.655
OP IT flexibility		2.278	3.383	3.623
STR IT flexibility			3.262	3.262
PIC				1.542

measures. Thus, an indicator's outer loadings should be higher than all its cross loadings with other constructs. Appendix C shows that our model meets the cross loading requirements.

Coupled with validity assessment, we examined the multicollinearity due to relatively high correlations among some variables. The variance inflation factor (VIF) values for all of the constructs are at acceptable levels, i.e. below 5, as presented in Table 5. As expected, all measures are significant in their outer loadings at the 0.01 level.

5.2. Structural model assessment: hypothesis testing

Following the validity tests on the measurement models, we conducted an assessment of the structured model. Table 6 summarises the structural model tested by PLS analysis. This table presents the explained variance (R^2), the standardised path coefficient, and the *t*-values produced with the level of significance using the bootstrapping technique. It also shows the results with and without the mediating effects of PIC to discuss the mediating role of PIC in the relationship between IT flexibility and firm performance (FP).

In the full mediation model, the test results support hypothesis H1a (β=0.749, $p < 0.01$), H1b (β=0.302, $p < 0.01$), and H1c (β=0.582, $p < 0.01$) for the IT flexibility types. It shows that TR IT flexibility is positively associated with OP IT flexibility and STR IT flexibility, and that OP IT flexibility is also positively linked to STR IT flexibility. Regarding the effect of IT flexibility on PIC, the test supports H2a (β=0.226, $p < 0.05$) and H2b (β=0.395, $p < 0.01$), representing the positive influence of TR IT flexibility and OP IT flexibility on PIC. On the other hand, the link between STR IT flexibility and PIC, i.e. H2c (β=0.011) is not supported.

In terms of the impact on firm performance, TR IT flexibility and OP IT flexibility do not have a direct impact on firm performance; i.e. H3a (β=0.071) and H3b (β=0.119) are not supported, while STR IT flexibility affects firm performance significantly, i.e. H3c (β=0.246, $p < 0.05$). Finally, PIC affects firm performance positively, thus, H4 (β=0.390, $p < 0.01$) is supported. Fig. 2 illustrates the results of the

Table 6
Effects and variance explained for all endogenous variables.

Effects on endogenous variable with hypotheses	Path coefficient β (*t* value)		Variance explained (R^2)	
	Non-mediated model	Mediated Model	Non-mediated model	Mediated model
Effects on OP IT flexibility			0.562	0.561
H1a: TR → OP	0.750*** (19.316)	0.749*** (19.238)		
Effects on STR IT flexibility			0.694	0.693
H1b: TR → STR	0.301*** (4.178)	0.302*** (4.14)		
H1c: OP → STR	0.584*** (8.883)	0.582*** (8.846)		
Effects on PIC				0.351
H2a: TR → PIC		0.226** (2.088)		
H2b: OP → PIC		0.395*** (3.160)		
H2c: STR → PIC		0.011(0.086)		
Effects on FP			0.398	0.496
H3a: TR → FP	0.155(1.558)	0.071(0.710)		
H3b: OP → FP	0.274** (2.119)	0.119(0.934)		
H3c: STR → FP	0.254** (2.183)	0.246** (2.406)		
H4: PIC → FP		0.390*** (3.901)		

** $p < 0.05$.
*** $p < 0.01$.

impact path analysis of the mediated model.

6. Discussion of results

6.1. IT flexibility types

Our empirical testing of the model suggests that TR IT flexibility significantly affects OP IT flexibility, which explains 56.1% of the OP IT flexibility variance indicating strong prediction accuracy (Hair, 2013). This indicates that a firm's investment in TR IT flexibility will increase the level of OP IT flexibility. Both TR IT flexibility and OP IT flexibility affect STR IT flexibility significantly, accounting for 69.3% of STR IT flexibility variance. This represents strong prediction accuracy (Hair et al., 2013). This implies that a firm's investment in TR and OP IT flexibility will affect STR IT flexibility, where the reconfiguration of relationships and IT resources are emphasised as critical factors. These findings support our proposition that TR IT flexibility is a pivotal construct for two other flexibility types. The findings also support the structure of IT flexibility we proposed in the conceptual model.

6.2. IT flexibility and PIC

TR IT flexibility and OP IT flexibility significantly affect PIC, explaining 35.1% of variance, which indicates a reasonable level of prediction accuracy (Hair et al., 2013). An advanced level of infrastructure and connectivity is positively associated with the capability of a firm to integrate business processes internally and externally with customers and suppliers. Although IT flexibility in process improvement was not well addressed in prior research, our analysis indicates that there is a clear positive impact of OP IT flexibility on a firm's PIC. On the other hand, STR IT flexibility is positively supported by the other two types, but it does not show a significant level of impact on PIC. However, the STR IT flexibility firm performance directly. We will discuss this issue in the next section.

6.3. IT flexibility, PIC and firm performance: The indirect and direct impact

The test identified that 49.6% of variances of firm performance are explained by IT flexibility and PIC, which indicates strong prediction accuracy (Hair et al., 2013). Although STR IT flexibility is not associated with PIC, the model shows that it significantly affects firm performance directly. TR IT flexibility and OP IT flexibility do not affect firm performance directly; however, they do affect firm performance via PIC. This indicates that TR and OP IT flexibility indirectly affect firm performance. Yet, the impact of STR IT flexibility is directly associated with firm performance. This model suggests that TR and OP flexibility do need an intermediary to achieve the impact on firm performance because they operate at a lower level with the supply chain. But STR flexibility has a direct impact that does not need an intermediary support because it operates at a high level and aims to continuously re-align the supply chain with the demand.

To clearly address this issue, we tested the unmediated model to obtain fit statistics for comparison with the fully mediated model as

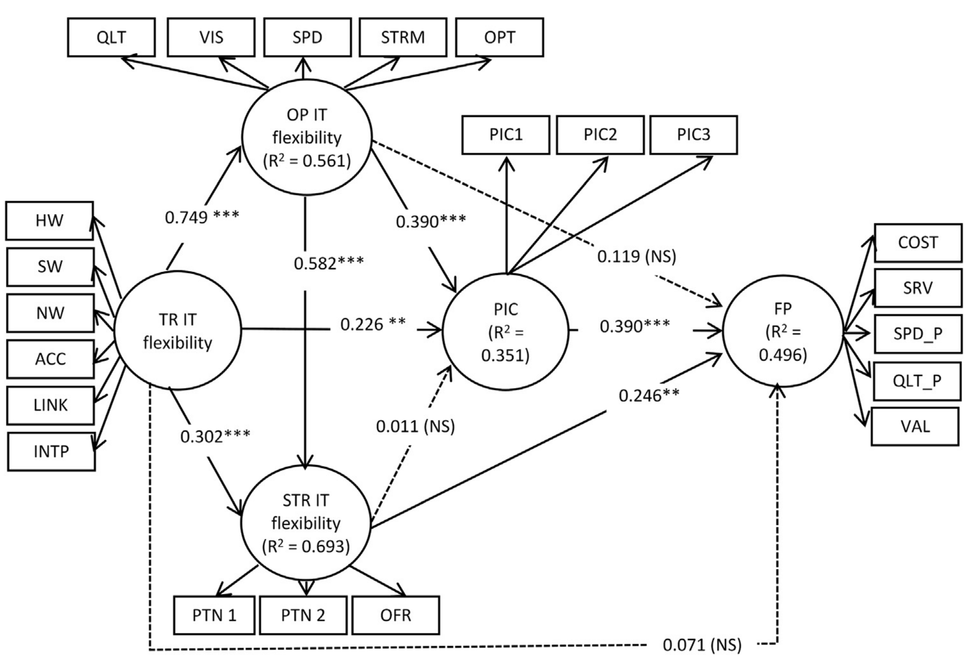

Fig. 2. Result of path analysis ** $p < 0.05$, *** $P < 0.01$ NS: Non-Significant.

suggested by Iacobucci et al. (2007) and results are presented in Table 6. Bootstrapping technique provided by the SmartPLS 3.0 software is used for mediating effect analysis as per Preacher and Hayes (2008), Sattler et al. (2010) and Hair et al. (2013). The direct effect of TR IT flexibility on firm performance decreased (β=0.155 to β=0.071) in the full mediation model. Moreover, its effect on PIC (β=0.226, $p < 0.05$) and PIC's effect on firm performance (β=0.390, $p < 0.01$) are significant. This implies that TR IT flexibility is positively associated with firm performance but only via PIC. In terms of OP IT flexibility, its direct effect on firm performance becomes insignificant (β =0.274 to β =0.119) in the mediated model, while the impact path of OP IT flexibility on PIC is significant (β=0.395, $p < 0.01$) as is the impact of PIC on firm performance (β=0.390, $p < 0.01$). Thus, the indirect impact of OP IT flexibility on firm performance through PIC is identified.

While comparing the direct impact and indirect impact of flexibility types on firm performance, we observed that the prediction accuracy of firm performance increased from 39.8% to 49.6% in the full mediation model. Thus, the proposed mediated model has strong predictive power with a high level of accuracy (Hair, 2013). The analysis shows that PIC affects firm performance significantly, which implies that a firm whose goal is greater firm performance in an inter-organisational setting cannot ignore PIC accumulation. In other words, a firm with a greater PIC to integrate shared business processes with trade partners will perform better.

7. Conclusion

7.1. Theoretical contributions

Our major contribution lies in the reconceptualization of IT flexibility for supply chain management. We did so via the development of a model through a comprehensive literature review. The model was further validated by a large-scale survey. The proposed model is different from the existing concepts or models of IT flexibility in three ways.

First, current studies on IT flexibility are largely biased towards infrastructure flexibility. Our model is more comprehensive as we integrate the two disparate research streams in the literature: infrastructure-based and value-seeking approaches. By doing so, we explore how IT flexibility should be pursued so that firms can develop the dual capability of exploration-exploitation at the supply chain level for enhanced performance. We draw on the traditional RBV theory but extend it to incorporate further relational and dynamic dimensions. The combined theoretical grounding proves effective in explaining why and how IT flexibility affects firm performance in a supply chain. Our findings suggest that to build IT flexibility for SCM, TR IT flexibility (i.e. infrastructure flexibility) plays a pivotal role. This is in line with most studies in the literature that deploy the theoretical lens of RBV in that flexible IT infrastructure can be considered as a bundle of strategic resources that are valuable, rare, and difficult to imitate and substitute. However, just building flexibility at the infrastructure level is not sufficient when a focal firm operates in a dynamic environment and is increasingly dependent on its supply chain partners for its long-term sustainability. For instance, a firm may be able to deploy cloud-based infrastructure for quick and flexible information provisions, but if this does not support flexible intra- and inter-information-sharing and process integration (OP IT flexibility) and flexible partnership configurations and innovative product/service offering (STR IT flexibility), then IT flexibility is still constrained within the focal firm's boundary and not operationalised for the supply chain. IT flexibility for SCM is a dynamic capability that can only be built upon if the relational, process and infrastructure linkages are aligned and integrated at the supply chain level.

Second, our model focuses on the execution of IT flexibility for SCM – a gap overlooked by the extant literature. Existing models fail to articulate a route of causality from IT flexibility to firm performance. For instance, some only consider IT flexibility as one of the antecedents to an organisational capability, e.g., supply chain responsiveness/flexibility (Ngai et al., 2011; Ravichandran and Lertwongsatien, 2005; Jin et al., 2014); others propose IT flexibility as a moderator to a higher order organisational capability, e.g., firm agility, which then affects performance (Bush et al., 2010). Therefore, they offer limited insights into how IT flexibility gets executed in a supply chain. Our model breaks down IT flexibility into three types – TR, OP and STR – and shows how the three types interact with each other and work with PIC to affect firm performance.

Third, our model tested and clarified whether there are both direct and indirect effects on firm performance. Existing literature offers conflicting evidence. For instance, the models proposed by Bhatt et al. (2010), Fink and Neumann (2009) and Ngai et al. (2011) confirm the *indirect* effects of IT flexibility on organisational performance. Gosain et al. (2004) and Tian et al. (2010), on the other hand, only identify *direct* effects of flexible IT on performance. There are also quite a few models that did not explicitly investigate the link between IT flexibility and performance but instead use other constructs, such as IT integration (Swafford et al., 2008) and IT-enabled information-sharing capabilities (Jin et al., 2014). Our research confirms that TR IT flexibility plays a critical role in supporting OP and STR IT flexibilities. OP IT flexibility, which focuses on mutual process handling, positively affects the STR IT flexibility by supporting partnering (re)configuration and new product/service offerings. TR and OP IT flexibility are first-order components that affect firm performance indirectly. In contrast, STR IT flexibility is identified as a second-order component having a direct impact on firm performance.

7.2. Practical implications

Our study offers a comprehensive view of IT flexibility and a clear pathway for constructing it for competitive advantages. This may lead to improved, prioritised IT investment and a better understanding of how to best extract value from such investments in organisations. Our findings stress the importance of building essential infrastructure flexibility at the transactional level that supports both operational and strategic flexibility. To build TR flexibility, firms need to establish a portfolio of hardware, software and network applications that facilitate flexible network connectivity with supply chain partners and support interoperability with a set of heterogeneous business applications in the supply chain. For example, if a firm's data transaction volume has large peaks and troughs throughout the year then a cloud-based infrastructure-as-a-service (IaaS) option could be a viable solution. This would be particularly helpful for small-medium sized companies as it saves firms from having to invest more on capability to cope with spikes and troughs, allowing quick scale up, and down, in response to changing opportunities and requirements.

However, having TR flexibility will not automatically lead to favourable performance, as our research findings indicate TR flexibility only affects performance indirectly. Our model indicates that there are two pathways for organisations to create value out of IT flexibility:

a) the exploitative path, where improvement in performance can only be achieved if TR flexibility and OP flexibility are coupled with PIC. This means intra- and inter-organisation process integration is the critical mechanism that helps to materialise benefits. OP flexibility builds on TR flexibility and emphasises the need for a focal company to share accurate information in a timely fashion and have a good visibility of partner companies' activities. These, combined with the company's efforts to integrate, automate and optimise existing supply chain processes, will lead to incremental cost savings and efficiency gains.
b) the explorative path to performance improvement does not tie companies in with PIC. It implies that for companies who wish to

explore more radical ideas and disruptive technologies, they might need to orchestrate a new set of IT resources, both internally and externally, and configure a new type of supply chain that structurally separate its exploration from exploitation – a concept known as structural ambidexterity (Raisch and Birkinshaw, 2008). The fact that STR flexibility does not rely on existing PIC to operationalise its impact suggests that spatial separation, namely establishing a separate set of supply chain process and information coordination structure, could be a viable mechanism for companies to strike the balance between exploration and exploitation. In practice, this could mean supply chain information systems and processes are loosely coupled, rather than tightly connected as seen in an exploitative only mode of operation. As explorative and exploitative paths for value creation compete for resources within and across companies, the challenge lies in how to create a strategic integration for a common set of values, a shared vision, and an overarching governance process (Gupta et al., 2006)

Our research also has implications for technology service providers (TSPs). TSPs should ensure that their products and service offerings are flexible enough in order to adapt to structural changes in supply chains, in particular when there is a need to dynamically and frequently configure and reconfigure inter-organisational information linkages. It is particular important that they can provide a portfolio of product and services that fulfil the diverse needs of a focal firm and its supply chain.

7.3. Limitations and further research

The first limitation of this study is that it tested the impact of IT flexibility on firm performance at an aggregate industry level. While it determines the causal relationship between variables, it does not offer a measurement tool per se. Future research could explore ways to determine the level of inherent IT flexibility within a firm and, hence, the resulting absolute or relative impact on firm performance. The second limitation of our study is that we have adopted perception-based firm performance measures in our survey. Future research should explore ways to conduct a sample check of actual performance, such as ROI and profits, against perception of performance. The third limitation of our study is our non-probability method of sampling. Though appropriate for the explorative nature of study, future research should adopt a more rigorous sampling technique in order to improve generalisability.

Our paper focuses on how IT flexibility gets executed in a supply chain, adopting the theory of extended RBV. Future research should explore how companies should adapt their IT flexibility to the supply chain context to improve firm performance. These decisions about resource and relational configurations with supply chain partners should be based on the context within which a focal company operates, as a 'one-sizes-fits-all approach' is unlike to be effective (Wong et al., 2011; Kembro et al., 2014). In this case, other theoretical lenses, such as contingency theory, would be more appropriate.

Extending the empirical testing research beyond our current scope of the dyad between the focus company and its customers/suppliers will provide further insights into how IT flexibility supports the reconfiguration of end-to-end supply chains and supply networks. Due consideration may also be given to the potential impact of technological trends, such as the greater adoption of crowdsourcing, online social media and the Internet of Things.

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Appendix A

see Appendix Table A.

Table A
IT flexibility definitions.

IT related flexibility	Definition	Reference
(Information) Technology flexibility	"The ability to adapt to both incremental and revolutionary changes in the business or business process with minimal penalty to current time, effort, cost, or performance. (p. 233)"	Nelson and Ghods (1998)
IT infrastructure flexibility	"IT infrastructure sophistication refers to the extent to which a firm has diffused key information technologies into its base foundation for supporting business applications. A sophisticated infrastructure provides the flexibility to later business strategies in response to competitiveness" (p. 309)"	Armstrong and Sambamurthy (1999)
IT infrastructure flexibility	"Is the ability to easily and readily diffuse or support a wide variety of hardware, software, communication technologies, data, core applications, skills and competencies, commitments and values within the technical physical base and the human component of the existing IT infrastructure (p172)".	Byrd and Turner (2000)
Information systems flexibility	Ability to align information system architectures and systems with the changing information needs of the organisation as it responds to changing customer demand. (p. 451)	Duclos et al. (2003)
E-business flexibility	"Is a function both of technology and of how effective an e-business system is managed. … It reflects an organisation's ability to react to those environmental variables that are particularly associated with information technology and new ways of doing business which are enabled by these technologies. (p. 415)	Shi and Daniels (2003)
IT infrastructure flexibility	"A flexible IT infrastructure facilitates rapid development and implementation of IT applications that enhance customer service process performance by enabling the organisation to respond swiftly to take advantage of emerging opportunities or to neutralize competitive threats." (p. 631)	Ray et al. (2005)
IS flexibility	"a flexible information system must be able to accommodate a certain amount of variation regarding the	Gebauer and Schober (2006)

(continued on next page)

Table A *(continued)*

IT related flexibility	Definition	Reference
	requirements of the supported business process." (p. 123) It incorporates both the *flexibility-to-use* and the *flexibility-to-change (conceptually related to infrastructure).*	
IT infrastructure flexibility	"ITI-enabled flexibility is defined here as the ability of ITI to adapt to new, different, or changing business requirements." (p. 91). ITI refers to IT infrastructure.	Fink and Neumann (2009)
IT infrastructure flexibility	"IT infrastructure flexibility depends on the degree to which the IT infrastructure is scalable, compatible, modular, and can handle multiple business applications." (p. 342)	Bhatt et al. (2010)
IT infrastructure flexibility	"we define IT infrastructure flexibility as the extent to which the focal firm can readily change the IT-based communication linkages across the supply chain, switch firms participating in a supply chain, redesign supply chain processes, and change the scale of the supply chain's operations upward or downward." (p. 245)	Bush et al. (2010)
Strategic IT flexibility	"Strategic IT flexibility is the organisational capability that facilitates the adaptation of the information systems to environmental changes by integrating new IT components into the existing information technology infrastructure or by changing the configuration of the existing information systems." (p. 241)	Tian et al. (2010)
IT flexibility	"IT flexibility is defined as the ability of IT infrastructure to adapt to both incremental and revolutionary change in the business or business process with minimal penalty to current time, effort, cost, or performance." (p. 237)	Ngai et al. (2011)
IT infrastructure flexibility	"IT infrastructure flexibility encompassing hardware, software, and networks could have a positive moderating effect on the link between alignment and agility. Two specific properties of a flexible IT infrastructure— scalability and adaptability" (p. 470)	Tallon and Pinsonneault (2011)
IT infrastructure flexibility	Flexible IT infrastructure refers to a firm's ability to establish a complete set of technological resources, which provides the foundation for the development of IT applications. (p. 1455)	Liu et al. (2013)
IT infrastructure flexibility	"Information technology infrastructure flexibility is defined as the set of resources for science and technology enterprises to provide rapid development and into the future application of information technology." (p. 175)	Cheng et al. (2014)

Appendix B. Survey items (measurement constructs)

Section A: Background information on the use of IT

Please tick or fill in the answer that best describes you and your organisation.

1. What types of operations/services do you provide? (Select all that apply)
☐ Manufacturing ☐ Warehousing ☐ Construction ☐ Freight transport ☐ Integrated logistics
☐ Multimodal transportation ☐ Freight forwarders ☐ Logistics brokers/intermediaries
☐ Other (please specify):

2. Which types of IT do you deploy to access your network? (Select all that apply)
☐ Integrated logistics portal/ E-market place ☐ RFID applications
☐ LAN (Local Area Network), GPS (Global Positioning System) , Satellite systems
☐ Web based e-mail and mobile messenger services
☐ Intranet ☐ Other (please specify):

3. Which types of IT do you deploy to manage your supply chain processes? (Select all that apply)
☐ Material Requirement Planning ☐ Enterprise Resource Planning
☐ Procurement and freight auctioning systems ☐ Warehouse Management Systems
☐ Transport Management Systems ☐ Decision support systems
☐ Real time Track and Tracing Systems ☐ Retail and sales management systems
☐ Enterprise Social network such as Yammer ☐ Electronic Invoice and Fund Transferring Systems
☐ Other (please specify):

4. Which types of IT do you deploy for external collaboration? (Select all that apply)
☐ Sales/demand Forecasting Systems ☐ Customer Relationship Management Systems
☐ Supplier Relationship Management Systems ☐ Vendor Managed Inventory Systems
☐ Collaboration portal ☐ Electronic logistics network/marketplaces
☐ Other (please specify):

Section B: IT and inter-firm information sharing

Please tick or fill in the answer that best describes you and your organisation.

5. How do you assess your ability to communicate with external firms at supporting by the current IT?

Items	IT flexibility dimension	Reference
We can effectively transact with external firms by using our advanced hardware (e.g. Computer, field devices, sensors, meters, servers etc.)	Transactional	Lai et al. (2007) Kim (2006)
We can effectively transact with external firms by using our advanced software and applications (e.g. Logistics portals, email systems, etc.)		Lai et al. (2007) (Tallon and Pinsonneault, 2011)
We can effectively transact with external firms by using our advanced network (e.g. internet, LAN, telephone, text, email)		Ray et al. (2005); Vickery et al. (2010)
We can effectively access our IT network properly and securely to communicate with external firms (e.g. internet/LAN access anytime anywhere)		Bharadwaj (2007) Closs and Savitskie (2003)
We can access a wide range of external firms through our IT network (e.g. *Number of external firms* we can access through our portal)		Devaraj et al. (2007) Savitskie (2007)
We can effectively transact with our external firms through standardized information format e.g. Excel, PDF, HTML, EDI		Mouzakitis et al. (2009) Devaraj et al. (2007)
We can share accurate and timely information	Operational	Wong et al. (2011) Wiengarten et al. (2013)
We can gain good visibility of supply chain processes		Wang and Wei (2007)
We can complete transactions rapidly		Zhou et al. (2014)
We can integrate and automate supply chain processes		Wiengarten et al. (2013)
We can optimise the supply chain processes with external firms		Qrunfleh and Tarafdar (2014)
We can easily build and alter our information linkages to our *existing* supply chain partners (e.g. customers, suppliers and third party logistics providers in response to changes in the business environment)	Strategic	Gosain et al. (2004) Tan et al. (2010)
We can easily build and alter our information linkages to *new* supply chain partners		Gosain et al. (2004)
We are actively exploring innovative ways of using ICT in offering new products or services to customers		Gosain et al. (2004) Wiengarten et al. (2013)

Section C. Process integration capability

Please circle one number on each scale, to indicate the level of you and your firm's capability to integrated business process internally and externally.

6. How is your firm's capability for process integration improved by using IT?

Items	Reference
Capability to integrate sourcing, transport, service process and other areas *internally*	Cooper et al. (1997) Wamba and Chatfield (2010).
Capability to integrate sourcing, transport, service process and other areas *with suppliers*	Lambert et al. (1998) Wiengarten et al. (2013)
Capability to integrate sourcing, transport, service process and other areas *with customers*	Frohlich and Westbrook (2001)

Section D. Firm performance

Please circle one number on each scale, to indicate the level of your firm's performance.

7. In the following areas how is your firm's performance improved by using IT?

Items	Reference
Transaction costs for your supply chain operations	Devaraj et al. (2007); Slack et al. (2007)
Level of service provided to customers	Jayaram and Vickery (2000)
Speed of supply chain operations	Devaraj et al. (2007); Slack et al. (2007)
Quality of service to customers	Devaraj et al. (2007); Slack et al. (2007)
Value creation in the supply chain	Wang et al. (2007); Wang et al. (2008)

Section E. General background information

Please tick or fill in the answer that best describe you and your organisation.

8. What is your level of responsibility within your company?
☐ Vice president or above
☐ Manager/assistant manager
☐ Director/vice director
☐ Supervisor
☐ Clerk/operator
☐ Other (please specify):

9. What is your area of responsibility within your company?
☐ CEO / Managing Director
☐ Logistics / Operations
☐ Supply chain
☐ ICT
☐ Marketing
☐ Other (please specify):

10. How long has your company been established?
☐ 1-5 years ☐ 6-10 years ☐ 11-15 years ☐ 16-20 years ☐ Over 20 years

11. Approximately, please indicate the number of employees in your company.
Total of ………………..employees

12. Please give an estimate of your annual revenue in 2013
Total of ……………….. revenue (in monetary unit in your country)

13. What types of ICT are you considering investing in, or implementing, in the next 3-5 years?
. ……………..……………...……………..……………...……………..……………..……………..………….

Appendix C. Cross loading analysis result

Indicators	TR IT flexibility	OP IT flexibility	STR IT flexibility	PIC	FP
HW	**0.852**	0.686	0.657	0.475	0.456
SW	**0.831**	0.638	0.627	0.370	0.414
NW	**0.813**	0.490	0.526	0.356	0.399
ACC	**0.685**	0.464	0.454	0.398	0.423
LNK	**0.801**	0.697	0.697	0.502	0.489
INTP	**0.628**	0.416	0.376	0.318	0.340
QLT	0.605	**0.852**	0.615	0.467	0.475
VIS	0.672	**0.867**	0.724	0.463	0.505
SPD	0.600	**0.874**	0.702	0.557	0.525
STRM	0.724	**0.906**	0.791	0.519	0.553
OPT	0.628	**0.819**	0.647	0.466	0.506
PTN 1	0.651	0.770	**0.900**	0.443	0.545
PTN 2	0.695	0.759	**0.913**	0.431	0.468
OFR	0.601	0.597	**0.826**	0.439	0.542
PIC 1	0.462	0.460	0.446	**0.857**	0.542
PIC 2	0.462	0.541	0.495	**0.897**	0.512
PIC 3	0.469	0.505	0.369	**0.876**	0.571
COST	0.491	0.536	0.586	0.512	**0.794**
SRV	0.454	0.447	0.431	0.514	**0.842**
SPD_P	0.382	0.495	0.475	0.472	**0.797**
QLT_P	0.489	0.486	0.471	0.527	**0.896**
VALUE	0.432	0.476	0.447	0.517	**0.787**

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