Interplant coordination, supply chain integration, and operational performance of a plant in a manufacturing network: A mediation analysis

Abstract

Purpose – The objective of this paper is to investigate the relationships at the level of plant in a manufacturing network, labelled as networked plant in the paper, between (1) inter-plant coordination and operational performance, (2) supply chain integration (SCI) and operational performance, and (3) inter-plant coordination and SCI.

Design/methodology/approach – This paper is developed based on the data obtained from the sixth version of International Manufacturing Strategy Survey (IMSS VI). Specifically, this paper uses a subset of the IMSS VI data set from the 606 plants that identified themselves as one of the plants in a manufacturing network.

Findings – This paper finds that external integration is significantly related to operational performance of networked plant, whereas internal integration is not. As an enabler for external integration, the influence of internal integration on operational performance of networked plant is mediated by external integration. This paper also provides evidence to the purported positive impact of internal integration on inter-plant coordination, as well as the positive impact of inter-plant coordination on external integration. It further suggests inter-plant coordination can influence operational performance of networked plant through external integration and also mediate the relationship from internal integration to performance through external integration.

Originality/value – This paper contributes to the SCI literature and extends our understanding of the impact of SCI on the operational performance by selecting networked plant as a unit of analysis. Besides, this paper distinguishes inter-plant coordination from SCI and investigates the relationship between SCI and inter-plant coordination for the first time.

Keywords: inter-plant coordination, supply chain integration, operational performance, manufacturing network

1. Introduction

During the last 20 years, multinational corporations (MNCs) have attempted to globalise their geographically dispersed plants and manufacturing system concepts have moved from a focus on the plant to one on the manufacturing network (Ferdows 1989; Rudberg and Olhager 2003; Cheng et al., 2015a). A manufacturing network is viewed as a coordinated aggregation of intra-firm plants located in different places, underlining the need for a wide perspective covering geographic dispersion and interdependent coordination rather than the traditional focus on separated manufacturing sites (Ferdows, 1989; Shi and Gregory, 1998; and Rudberg and Olhager, 2003). It seeks to extend traditional manufacturing system boundaries from a single factory towards a multi-plant system (Shi and Gregory, 2005), but it does not address inter-firm collaboration and is normally studied as a wholly owned and internal network in which all plants are under full financial control (Rudberg and Olhager, 2003; Cheng et al., 2015a)[1].

A plant, belonging to such a manufacturing network, is able to learn more about technology, customers, products or processes from other plants than it can learn by itself. It may also gain advantages in cost or flexibility from collaborating with other plants in the same network that it cannot achieve if it is managed as a stand-alone entity (Maritan et al., 2004). However, it has to face the complexity of inter-plant coordination (Prasad and Babbar 2000; Colotla et al. 2003). A plant must be coordinated to integrate material flows, management skills, product/process development, or other knowledge with other plants in the same network, in order to derive the above-mentioned benefits (Cheng et al., 2015a). Unfortunately, little attention has been devoted to coordination issues in the existing studies. There is a lack of research on the relationship between inter-plant coordination and performance of plant in a manufacturing network (Pontrandolfo and Okogbaa, 1999; Cheng et al., 2015a).

In addition to coordinate with other plants, a plant in a manufacturing network is also supposed to acquire, share, and consolidate strategic knowledge and information with internal and external partners, in order to achieve better alignment of objectives and business processes, coordination, and fit (Swink et al., 2007). The degree to which a manufacturer strategically collaborates with its supply chain partners and collaboratively manages intra- and inter-organisation processes (Flynn et al., 2010) is normally defined as supply chain integration (SCI), which has received increasing attention among academicians and practitioners alike in recent years (Zhao et al., 2008; Flynn et al., 2010; Zhao et al., 2011). However, the existing studies on SCI have seldom addressed plants in a manufacturing network and rarely considered the coordination among plants in the same network, as they mainly focus on the integration across internal functions and the integration with external suppliers and customers. The relationships between SCI and performance of plant in a manufacturing network as well as between SCI and inter-plant coordination have accordingly remained uninvestigated.

Therefore, the main objective of this paper is to investigate the relationships at the level of plant in a manufacturing network, which will be labelled as networked plant and used in the rest of this paper hereafter, between (1) inter-plant coordination and operational performance, (2) SCI and operational performance, and (3) inter-plant coordination and SCI. We use the data obtained from the sixth version of International Manufacturing Strategy Survey (IMSS VI) to explore these relationships. The remainder of the paper is organised as follows. First, the theoretical background is described and research hypotheses are developed in section 2. This is followed by an introduction of the research methodology in section 3. We then report and discuss our findings in section 4 and section 5 respectively. Finally, main conclusions are drawn, together with implications for research and managers, limitations of this study and suggestions for future research in section 6.

2. Theoretical background and hypothesis development

2.1 Inter-plant coordination and its relationship with operational performance of networked plant

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[1] A detailed analysis on the differences between manufacturing network and supply chain/network can be seen in Rudberg and Olhager (2003).

Designing a manufacturing network is like designing any operating system. Therefore, two types of decisions must be made: those concerning “configuration”, which primarily addresses structural decisions to design a network, and those related to “coordination”, which primarily addresses infrastructural links among plants (Colotla et al., 2003; Hayes et al., 2005). Thought of as an infrastructural process, inter-plant coordination specifically refers to the question for a networked plant about how to link or integrate with other plants in order to achieve the firm’s strategic objectives. Its aim is to achieve the efficient and effective planning of the physical and non-physical flows among the network’s plants (Pontrandolfo and Okogbaa, 1999).

While a considerable number of studies in operations management deal with configuration issue, less attention has been devoted to inter-plant coordination (Pontrandolfo and Okogbaa, 1999). Generally, three streams of studies on coordination can be identified from the existing literature (Cheng et al., 2015a). The first stream is about the introduction of practices related to inter-plant coordination. There exist many companies that have operated their manufacturing networks for years. Accordingly, they have accumulated much experience on inter-plant coordination and gradually formed their own practices in terms of structured tools, processes, and methods. Some of these practices have been introduced through specific case studies, such as Fletcher (1997), and Rudberg and West (2008). The second stream is related to the transfer and diffusion of production experience, knowledge and innovation among plants, as well as within-network learning (Flaherty, 1996). This is actually fundamental to ensure that a networked plant is able to benefit from belonging to a manufacturing network by learning more from other plants. Thus, the studies in this stream, e.g. Ferdows (2006), Cheng et al. (2010), Waehrens et al. (2012), Deflorin et al. (2012), Lang et al. (2014), attempt to explore how and when to transfer production experience, knowledge and innovation among geographically dispersed plants, specifically from the perspective of operations management. The last and the most dominant stream is the optimisation of physical distribution, which focuses on optimising the allocation of production among plants and the distribution of products between multiple plants and distribution centres or even customers within a manufacturing network. Nevertheless, the research in this stream has its origins in logistics management, materials management, demand management, order fulfilment, and procurement (Lambert and Cooper, 2000) and is mostly built on mathematical models (e.g. Tsiakis and Papageorgiou, 2008; Yuan et al., 2012).

A review of inter-plant coordination studies in three streams reveals different forms of inter-plant coordination, such as information sharing, knowledge transfer, and innovation diffusion, all of which are normally supported by the use of technology and the establishment of organisational infrastructure. Moreover, joint decision making among plants (Cheng et al., 2011; Cheng et al., 2014) and developing a comprehensive network performance management system (Cheng et al., 2015a) are also indicated to be important for inter-plant coordination. Nevertheless, past research provides little information regarding the contributions of inter-plant coordination to operational performance of networked plant. In fact, most of the existing studies, especially those in the third stream, tend to incorporate performance measures as objectives or constraints in their mathematical models to determine product or material flows across plants but do not explicitly consider the information, knowledge sharing and collaboration between networked plants (Tsiakis and Papageorgiou, 2008; Yuan et al., 2012). In contrast, only a few studies in the first two streams indirectly attempt to explore the relationship between inter-plant coordination and operational performance (Rudberg and West, 2008; Ferdows and Thurnheer, 2011). In these studies, a positive link between inter-plant coordination and operational performance of networked plant is suggested, which is however mostly built on case studies and is not empirically tested (Netland and Aspelund, 2014). In fact, inter-plant coordination enables the transfer of production experience, knowledge, and innovation across plants and thereby facilitates plants to simultaneously improve their product and process designs, which are instrumental to reducing product cost and improving product quality. Meanwhile, the mutual exchange of information about products, processes, schedules and capabilities allows for better coordination of production capacity to improve production flexibility and delivery performance. Therefore, in this paper, we aim to examine the relationship between inter-plant coordination and operational performance of networked plant, which is hypothesized as below:

H1: Inter-plant coordination is positively related to the operational performance of networked plants.

2.2 Supply chain integration and its relationship with operational performance of networked plant

The existing research on SCI is characterised by evolving definitions and dimensions (Van der Vaart and van Donk, 2008). Nevertheless, the diverse dimensions of SCI can be collapsed into two key dimensions: internal and external integration (Zhao et al., 2011).

In the existing literature, internal integration refers to the degree to which a manufacturer structures its intra-organisational practices, procedures and behaviours into collaborative, synchronised and manageable processes and systems across functions, in order to fulfil its customers' requirements and to efficiently interact with its suppliers (Chen and Paulraj, 2004; Schoenherr and Swink, 2012). It in essence involves information sharing between internal functions, strategic cross-functional cooperation, and working together (Zhao et al., 2011). Researchers have long articulated the need for studying internal integration and often mentioned it as a necessary step in supply chain integration process (Rosenzweig et al., 2003). For example, Zhao et al. (2011) analyse the influence of internal integration on external integration from the perspective of organisational capability and elaborate such influence in detail from the aspects of information sharing, strategic cooperation or alliance, and working together. Considered as part of a complete conceptualisation of supply chain integration (Swink et al., 2007; Flynn et al., 2010; Zhao et al., 2011), internal integration is further shown to be positively associated with operational performance (Swink et al., 2007; Flynn et al., 2010).

The other dimension of SCI, i.e. external integration, refers to the degree to which a manufacturer combines with its external partners to structure its inter-organisational strategies, practices, procedures and behaviours (Chen and Paulraj, 2004; Zhao et al., 2011). It further consists of supplier and customer integration. Supplier integration is related to coordination and information sharing with critical suppliers that provide insights into suppliers' processes, capabilities, and constraints. It is practised in manufacturing plants in order to enable more effective planning and forecasting, product and process design, and transaction management (Bowersox et al., 1999; Ragatz et al., 2002). Customer integration involves close collaboration and information sharing activities with key customers that provide insights into market expectations and opportunities (Bowersox et al., 1999; Wong et al., 2011). It enables manufacturing plants to develop a better understanding of customers' preferences, and to build relationships with customers (Swink et al., 2007). Researchers have long recognised the importance of a close integrated relationship between manufacturers and their supply chain partners (e.g. Lambert et al., 1978). Ever more research efforts have been made to examine the impacts of external integration on different operational performance (Rosenzweig et al., 2003; Jayaram et al., 2010; Wong et al., 2011; Schoenherr and Swink, 2012.)

In summary, SCI, in terms of internal and external integration, has been widely addressed in the relevant literature, but the existing studies on SCI have rarely taken the coordination among plants in the same network in to consideration, or vice versa. In fact, the existing literature on SCI has paid little attention to the manufacturing plant, not to mention networked plant. Their findings were normally developed based on samples of manufacturing firms. To our knowledge, there is only one study specifically discussing the relationship between SCI and the operational performance of manufacturing plant (Swink et al., 2007), but showing inconsistent results to other studies taking firm as the unit of analysis. Considering networked plant is also supposed to acquire, share, and consolidate strategic knowledge and information across internal functions and with external partners, we feel the necessity of specifying the relationships between internal and external integration for networked plant and further between SCI and the operational performance of networked plant, since optimal deployment of resources of a manufacturing firm must eventually be made at the plant (Swink et al., 2007). Nevertheless, various theoretical arguments proposed in the existing studies regarding to how internal integration influences external integration (e.g. Zhao et al., 2011) and how SCI impacts operational performance (e.g. Flynn et al., 2010; Wong et al., 2011) can still be viable when addressing networked plants. For example, internal integration breaks down functional barriers within a networked plant and is thereby expected to be related to the operational performance of networked plant. Meanwhile, external integration helps networked plants to resolve conflicting objectives. Supplier integration facilitates suppliers to understand and anticipate the networked plant's needs. This mutual exchange of information about products, processes, schedules and capabilities helps networked plant develop its production plans and produce goods on time. Similarly, customer integration offers opportunities for improving the accuracy of demand information, which reduces the networked plant's product design and production planning time and inventory obsolescence, allowing it to reduce costs, create greater value and detect demand changes more quickly. Therefore, we propose the following hypotheses:

H2: Internal integration is positively related to the operational performance of networked plant.
H3: External integration is positively related to the operational performance of networked plant.

Furthermore, as its external environment (in a supply chain, the characteristics of its customers and suppliers) changes, a networked plant should respond by developing, selecting and implementing strategies to maintain fit, not only among internal structural characteristics, but also with its external environment. In other words, external integration builds on a networked plant's internal integration. Although the other studies indicated that internal integration can be a precursor to external integration (Braunscheidel and Suresh, 2009; Zhao et al., 2011; Jayaram et al., 2011) and further provided empirical evidence to support this internal-external integration link (Koufteros et al., 2005, 2010; Zhao et al., 2011), there is still scarce research that goes further to link internal-external integration with performance and explores the possible mediation effect of external integration on the relationship between internal integration and operational performance. Instead, much of the extant literature on SCI explored the moderating effect of external integration on the relationship between internal integration and performance (Droge et al., 2004 and Flynn et al., 2010). To address this gap, we propose the following hypotheses:

H4: The relationship between internal integration and the operational performance of networked plant is mediated by external integration.

2.3 Inter-plant coordination and supply chain integration

According to the stage theory of SCI (Stevens, 1990; Zhao et al., 2011), internal integration is a relatively low level of SCI, where only the internal functions are integrated, while external integration is a relatively high level of SCI, where also external supply chain partners are integrated. In line with this thinking, inter-plant coordination can be viewed as a middle level of integration. It goes beyond internal integration and extends internal integration's elimination of functional silos to span across plants in the same manufacturing network, but it merely focuses on single firms and does not address inter-firm collaboration with external partners (Cheng et al., 2015a). In other words, internal integration, inter-plant coordination, and external integration represent a continuum of integration. It is thereby reasonable to speculate that inter-plant coordination is linked with internal and external integration, although the relationships between them have scarcely been discussed in the existing studies.

First, from the perspective of organisational capability, internal integration represents an absorptive capability for learning from external partners (e.g. Lane et al., 2006) and an internal communication and coordination capability for external coordination (Takeishi, 2001). It is thereby argued that when a networked plant has a high level of internal integration, it will be more capable to achieve a high level of inter-plant coordination. For example, Vereecke et al. (2006) indicate that plants with higher level of capabilities are true network players, which interact with other plants in the same manufacturing network more frequently. Cheng et al. (2010) show that the absorptive capability of a plant to disseminate, interpret, and utilise new knowledge is positively associated with the success of knowledge transfer among the plants in the same network. Thus, a plant with a high level of absorptive capability is more to likely learn from the other plants and understand their business to facilitate inter-plant coordination. Furthermore, inspired by Zhao et al. (2011), the influence of internal integration on inter-plant coordination can also be elaborated in terms of cross functional cooperation and information sharing. On the one hand, inter-plant coordination requires cooperation between different functional departments within the networked plant. For example, close cooperation between manufacturing and purchasing/sales/logistics functions seems to be necessary (Olhager et al., 2015) for supporting optimised allocation of production and accurate distribution of products among plants (Rudberg and Olhager, 2003). On the other hand, in the area of information sharing, it is less likely that a networked plant can share information and data with other plants if it does not have well-established internal systems and capabilities to integrate data and share information across internal functional departments. For example, if the plant does not have real-time visibility of inventory and operating data, it cannot share such data with other plants in the same network accurately in real time. If the plant does not have a good Enterprise Resource Planning (ERP) system that allows for cross-functional transparency of data for operational planning and control, data shared by other plants might not be fully utilised as well. Thus, we propose the following hypothesis:

H5: Internal integration is positively related to inter-plant coordination for networked plant.

Furthermore, combining hypotheses H5 and H1, we are able to propose a hypothesis regarding the mediation effect of inter-plant coordination on the relationship between internal integration and the operational performance of networked plant. This is related to the segmentation approach suggested by Rungtusanatham et al. (2014), i.e. developing hypotheses for the effect of X on M1 and the effect of M1 on Y, and concluding by stating the hypothesis for the mediation effect of M1.

H6: The relationship between internal integration and the operational performance of networked plant is mediated by inter-plant coordination.

Second, inter-plant coordination enables networked plants to better manage the flows of products and offers opportunities for improving the accuracy of information about products, processes, capabilities, and demands between plants. In turn, the accurate and timely information can facilitate external integration, since external uncertainties and linkages must be internally absorbed into the proper places in an organisation (Morash and Clinton, 1998). As its external environment (in terms of suppliers and customers) changes, a plant can respond by communicating with the other plants in the same manufacturing network, especially when it is not capable, e.g. for producing a large volume, exceeding its capacity. As mentioned in the introduction, this is actually one of benefits from managing a group of plants as a network (Maritan et al., 2004). Besides, inter-plant coordination provides access to resources, knowledge, and capabilities at other plants that otherwise may have been costly to develop internally at an individual plant. The more is the knowledge obtained, the higher is the possibility that a networked plant can manage its relationships with suppliers and customers. By doing so, a networked plant can further strengthen the relationship commitment, defined as a willingness to develop and maintain a stable, long-lasting relationship (Moore, 1998), with its suppliers and customers. Because external integration is created based on cooperative and mutually beneficial collaborations (Wisner and Tan, 2000), the networked plant and its suppliers and customers, with relationship commitment, will become more intrinsically tied to established goals, and more willing to share information and synchronise their processes (Chen and Paulraj, 2004; Zhao et al., 2011). Therefore, we hypothesize:

H7: Inter-plant coordination is positively related to external integration for networked plant.

Again, following the segmentation approach suggested by Rungtusanatham et al. (2014), we are able to combine hypotheses H7 and H3, and further propose a hypothesis regarding the mediation effect of external integration on the relationship between inter-plant coordination and the operational performance of networked plant:

H8: The relationship between inter-plant coordination and the operational performance of networked plant is mediated by external integration.

Figure 1 illustrates the relationships of the hypotheses formulated previously, forming the theoretical model that we sought to test in this study. Furthermore, other variables, like organisation size (Zhu and Sarkis, 2004; Swink et al., 2007) and demand-supply fluctuation (Kulkarni et al., 2004), are also included as controls for differences in operational performance that may be explained by scale effects.

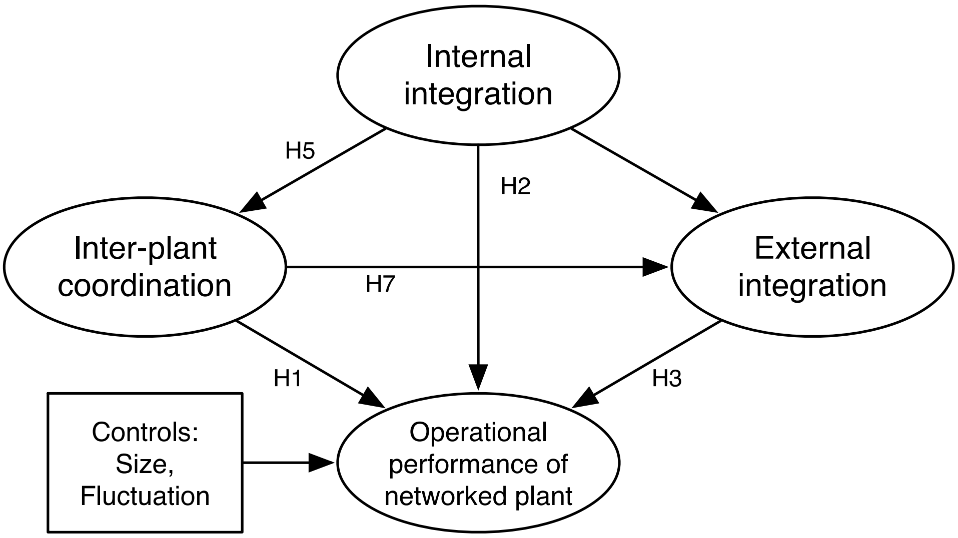

Figure 1: The relationships of proposed hypotheses

3. Research methodology

3.1 Sampling and data collection

In this paper the proposed hypothesis were tested by using the data from the sixth version of International Manufacturing Strategy Survey (IMSS VI). The IMSS is a global network of institutions that collaborate with each other and manufacturing companies to develop a common survey instrument and data collection protocol for the global study of manufacturing and supply chain management. The IMSS research network was first established in 1992 by the initiative of London Business School and Chalmers University of Technology. Today, the network is centrally coordinated by Politecnico di Milano.

The IMSS VI data was collected from June 2013 to June 2014 and the final data set was released in September 2014. The sample was designed to consider the population of assembly manufacturing plants with more than 50 employees. The sample companies were further selected from public or private local databases based on ISIC code (ISIC 25-30 classifications, i.e. machinery, electronics, metal products, transport equipment and motor vehicles industrial sectors). As a result, 7167 companies from the different countries were selected.

The original questionnaire was developed in English, and later translated by national researchers (e.g. French-, Spanish-, and Chinese-speaking countries), using double- and reverse-translation procedures, in a coordinated manner for countries with similar languages (Vanpoucke et al., 2014). Before the official launch, the questionnaire was extensively pre-tested with company managers. Their active involvement ensured the high levels of relevance of the instruments and content validity was thereby carefully addressed (Wiengarten et al., 2014). In addition, this research used IMSS data from sixth iteration, meaning the IMSS research instruments have already been verified and known to researchers as demonstrated by numerous research publications (e.g. Frohlich and Westbrook, 2001; Vanpoucke et al., 2014; Wiengarten et al., 2014) using different versions of the IMSS survey.

A common methodology was followed in each country to ensure that data was collected in the same way. In all countries, the survey respondent was usually operations, production, supply chain or plant manager/director, who was selected because of the knowledge and awareness this manager exhibited towards both operational and strategic decisions. The potential respondents were approached by the local research team through phone or email. If a respondent agreed to participate, the local researchers sent a questionnaire by ordinary mail, fax or email. If necessary, they also provided reminders after several weeks, in order to increase response rates (Zhao et al., 2008). The returned questionnaires were subjected to missing data controls, handled on a case-by-case basis but usually by contacting the plant again. Every local research group also controlled the gathered data for late respondent bias, company size and industry. Finally, quality checks (e.g., checking for errors, outliers) were conducted and all the data were summarised into a unique database through central coordination by the Politecnico Di Milano.

In total, 2586 questionnaires were distributed across the different countries. After excluding cases with much missing data or many errors, the final IMSS VI sample consisted of 931 companies from 22 countries situated in Europe, The Americas and Asia (see Table 1). The overall response rate was 36% (931/2586). Considering our goals to obtain a large sample and keep manufacturing practices relatively homogenous, IMSS VI offers an appropriate data set. Furthermore, while focusing on networked plants, this paper used a subset of the IMSS VI data set from the 606 plants that identified themselves as one of the plants in a manufacturing network. The profile of the sample used in this paper is shown in Table 1. This sample size is favorably comparable to other survey instruments employed in manufacturing and supply chain management research. Nevertheless, it should also be noticed that the sample tends to reflect more on large plants from European countries.

Table 1: The profiles of IMSS VI sample and the sample used in this paper

Demographic dimension		IMSS VI sample		Sample used	
		Number	Percentage (%)	Number	Percentage (%)
Personnel employed in the companies that the plants belong to					
	Small Companies (<250 employees)	409	43.93	197	32.51
	Medium companies (between 250 and 500 employees)	179	19.23	122	20.13
	Large companies (>500 employees)	341	36.63	285	47.03
	Missing	2	0.21	2	0.33
	Total	931	100.00	606	100.00
Industrial sector					
25	Manufacture of fabricated metal products, except machinery and equipment	282	30.29	176	29.00
26	Manufacture of computer, electronic and optical products	123	13.21	83	13.70
27	Manufacture of electrical equipment	153	16.43	103	17.00
28	Manufacture of machinery and equipment not elsewhere classified	231	24.81	139	22.90
29	Manufacture of motor vehicles, trailers and semi-trailers	93	10.00	74	12.20
30	Manufacture of other transport equipment	49	5.26	31	5.10
	Total	931	100.00	606	100.00
Regions and countries					
	Europe	479	51.45	327	53.96
	Asia	343	36.84	207	34.16
	North America	78	8.38	48	7.92
	South America	31	3.33	24	3.96
	Total	931	100.00	606	100.00

3.2 Non-response bias, late-response bias, and common method bias

To test for differences between respondents and non-respondents and between the early and late respondents, most of the local researchers started from an existing database, with information about all public firms in their country. These accessible secondary data was useful to reveal any significant difference between respondents and non-respondents and between the early and late respondents in their size, industry, sales or proprietary structure. If such databases were not available, non-response bias and late-response bias were then checked by using questionnaire items, such as size, industry, and operational performance. Nevertheless, in no cases evidence of non-response bias or late-response bias was found.

As is true for all studies that use data from a single source, Common Method Bias (CMB) may be a concern, which may be created due to common rater and item characteristic. The former might arise due to the respondents' perceived need to provide consistent or desirable answers and the latter due to social desirability or ambiguity in items. Addressing common methods bias must really start at the research design phase: most effective remedy is to be ex-ante smart about the issues (Guide and Ketokivi, 2015). Therefore, the survey included techniques described by Podsakoff et al. (2003) to minimise those biases during the data collection for this study. First, the questions on the constructs considered in this study were separated from each other. Specifically, the questions measuring the predictor and criterion variables were segmented into different sections of the survey (Dobrzykowski et al., 2015). Second, different scale anchors/formats were employed for items measuring independent and dependant variables. Such procedural remedies reduce the likelihood of CMB by making it difficult for respondents to link the targeted measures together (Podsakoff et al., 2003). Third, the anonymity of both the respondent and the firm are explicitly maintained, which eliminates incentives for socially favourable answers. Finally, to reduce ambiguity, the questions related to all the constructs incorporated objective concepts and explanations of the items. In addition, the data were also tested for the presence of CMB after data collection. The confirmatory single-method factor test advocated by Podsakoff et al. (2003) examined the effects of a latent method factor in the measurement model. The relationships among all the hypothesized measurement items and their respective constructs remained statistically significant, suggesting that CMB was not found to be problematic.

3.3 Measures

In this paper, to operationalise the constructs related to inter-plant coordination, SCI, and operational performance of networked plant, we used multi-item, reflective rather than formative indicators (Bollen, 1989). Thus we could identify items from the IMSS VI survey that correlated strongly with the constructs addressed in this paper. This approach is important, because IMSS VI includes a finite number of practices and routines related to coordination, integration and operational performance (Vanpoucke et al., 2014). The items for each construct were measured using five-point Likert scales, where higher values indicated stronger coordination and integration or better performance. More details about the items for each construct are presented in the appendix.

Inter-plant coordination is defined as the question for a networked plant about how to link or integrate with other plants (Pontrandolfo and Okogbaa, 1999). In order to reflect this definition and different elements of inter-plant coordination identified from the literature review, we in this study operationalised inter-plant coordination as current levels of implementation on a five item scale: 1) information sharing with other plants (Rudberg and Olhager; 2003), 2) joint decision making with other plants (Colotla et al., 2003), 3) innovation sharing/joint innovation with other plants (Ernst and Kim, 2002; Ferdows, 2006), 4) use of technology to support inter-plant communication with other plants (Clemmons and Simon, 2001), and 5) developing comprehensive network performance management system (Colotla et al., 2003, Rudberg and West, 2008).

In this study, internal integration was specifically measured by the current levels of implementation employed by networked plants on cross-functional integration between manufacturing and purchasing/sales. This decision was partially due to the fact that the existing literature only revealed the influence of close cooperation between manufacturing and purchasing/sales functions on inter-plant coordination (Rudberg and Olhager, 2003; Olhager et al., 2015). Furthermore, as indicated in the literature review, internal integration in essence involves information sharing between internal functions, strategic cross-functional cooperation, and working together (Zhao et al., 2011). In this research, it was therefore operationalised as a four item scale: 1) information sharing between manufacturing and purchasing, 2) joint decision making between manufacturing and purchasing, 3) information sharing between manufacturing and sales, and 4) joint decision making between manufacturing and sales.

In the existing literature, external integration is defined as the degree to which a manufacturer combines with its external partners (Chen and Paulraj, 2004; Zhao et al., 2011). A number of studies in the literature have advocated that it simultaneously consists of supplier and customer integration (e.g. Ellinger et al., 2000; Frohlich and Westbrook, 2001). Therefore, external integration in this study was measured using supplier and customer integration. Furthermore, to reflect the definitions of supplier and customer integration introduced in section 2.2, supplier and customer integration were each operationalised through four items indicating the current levels of adoption related to: 1) sharing information with key suppliers/customers, 2) developing collaborating approaches with key suppliers/customers, 3) joint decision making with key suppliers/customers, and 4) system coupling with key suppliers/customers.

Operational performance was measured as current performance relative to the main competitors across the dimensions of quality, flexibility, delivery and service in this research. In the existing literature these dimensions are among the key determinants of operational performance (Rosenzweig and Roth, 2004; Wiengarten et al., 2014), together with cost. However, in this research, cost was not included because of its low standardised factor loading on operational performance according to confirmatory factor analysis (CFA), which is much less than 0.50. More specifically, this research operationalised quality in terms of a two-item scale: 1) conformance quality and 2) product quality and reliability. Similarly, flexibility was operationalised as: 1) volume flexibility and 2) mix flexibility and delivery was operationalised as: 1) delivery speed and 2) delivery reliability. For service, we considered: 1) product assistance and 2) customer service quality. We relied on the survey respondents to identify their main competitors and report whether the operational performances of their plants were equal to or lower/higher than their main competitors.

Finally, in order to ensure the contextual validity of our results, we employed two control variables, namely organisation size and demand-supply fluctuation. For organisation size, we measured the logarithm of the total number of employees of the business unit that the plant belongs to, which has been widely applied in the existing studies, such as Zhu and Sarkis (2004) and Peng et al. (2013). Demand-supply fluctuation was operationalised as a four-item agreement-disagreement five-point scale: 1) demand fluctuates drastically, 2) stability of production process fluctuates drastically, 3) production mix and sequence changes considerably, and 4) supply requirements (volume and mix) vary drastically.

The descriptive statistics and correlations are shown in Table 2, in which the second and third columns indicate the mean and the standard deviation of the variables respectively, and the remaining values below the diagonal show the Pearson correlation coefficients between them.

Table 2: Descriptive statistics

Variable	**Mean**	**SD**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1. Size	6.43	1.78	1									
2. Quality	3.56	0.70	0.05	1								
3. Flexibility	3.44	0.72	0.05	0.36**	1							
4. Service	3.35	0.70	0.03	0.44**	0.30**	1						
5. Delivery	3.53	0.78	0.10*	0.48**	0.45**	0.42**	1					
6. Demand-supply fluctuation	2.70	0.96	-0.07	-0.06	0.07	-0.04	0.02	1				

7. Internal integration	3.56	0.86	0.09*	0.23**	0.16**	0.26**	0.18**	-0.03	1			
8. Supplier integration	3.21	0.86	0.16**	0.25**	0.22*	0.25**	0.24**	0.10*	0.58**	1		
9. Customer Integration	3.09	1.00	0.17**	0.21**	0.13**	0.22**	0.24**	0.08*	0.45**	0.65**	1	
10. Inter plant coordination	3.21	0.87	0.15**	0.23**	0.14**	0.20**	0.28**	0.04	0.48**	0.52**	0.57*	1

* p<0.10 (two-tailed); ** p<0.05 (two-tailed); *** p<0.01 (two-tailed)

3.4 Reliability and validity

A rigorous process was used to develop and validate the survey instrument, modelled on previous empirical studies (Flynn et al., 2010; Zhao et al., 2011; and Schoenherr and Swink, 2012). Prior to data collection, content validity was established by the close collaboration between academics and industry professionals in the development of the measurement items and supported by previous literature, executive interviews, and pilot tests. After the data collection, a series of analyses were performed in order to ensure the reliability and validity of the constructs.

First, the reliability of each construct was tested. Reliability is an assessment of the degree of consistency between multiple measurements of a variable (Hair et al., 1998). Although Cronbach's alpha was widely used in the existing studies, e.g. Flynn et al. (2010) and Zhao et al. (2011), to assess construct reliability, we were aware that this coefficient alpha is based on the essentially tau-equivalent measurement model. It is the violation of the assumptions required by this measurement model that are often responsible for coefficient alpha's underestimation of reliability (Graham, 2006). Therefore, instead of simply relying on "rule of thumb", i.e. Cronbach's alpha > 0.70 (Nunnally, 1994), we decided to follow two-step approach proposed by Graham (2006) to assess construct reliability. The first step is to select appropriate measurement model among the parallel model, the tau-equivalent model, the essentially tau-equivalent model, and the congeneric model based on the model fit and the chi-square test on difference in fit between different models. The second step is to estimate reliability based on the best possible model chosen from the first step, by squaring the implied correlation between the composite latent true variable and the composite observed variable. It should also be noted that if in the first step, the tau-equivalent model is chosen, the reliability we calculated in the second step is actually coefficient alpha. The results are shown in Table 3, which allow us to conclude that the reliability of constructs is established.

Table 3: Reliability analysis

Measurement Items	Standardised factor loadings	Reliability based on Graham (2006)	AVE	Composite reliability
Inter-plant coordination		0.872	0.580	0.874
Information sharing with other plants	0.809			
Joint decision making with other plants	0.768			
Innovation sharing/joint innovation with other plants	0.744			
Use of technology to support inter-plant communication with other plants	0.742			
Developing comprehensive network performance management system	0.744			
Internal integration		0.879	0.642	0.877
Sharing information between manufacturing and purchasing	0.727			
Joint decision making between manufacturing and purchasing	0.761			
Sharing information between manufacturing and sales	0.849			
Joint decision making between manufacturing and sales	0.861			
Supplier integration		0.839	0.579	0.846
Sharing information with key suppliers	0.757			
Developing collaborative approaches with key suppliers	0.815			
Joint decision making with key suppliers	0.793			
System coupling with key suppliers	0.672			
Customer integration		0.889	0.670	0.890
Sharing information with key customers	0.853			
Developing collaborative approaches with key customers	0.845			
Joint decision making with key customers	0.767			

System coupling with key customers	0.805			
Quality		0.771	0.627	0.771
Conformance quality	0.803			
Product quality and reliability	0.781			
Flexibility		0.709	0.555	0.713
Volume flexibility	0.794			
Mix flexibility	0.692			
Delivery		0.801	0.684	0.812
Delivery speed	0.793			
Delivery reliability	0.860			
Service		0.702	0.547	0.706
Product assistance	0.789			
Customer service quality	0.686			
Demand-supply fluctuation		0.845	0.651	0.882
Demand fluctuates drastically	0.795			
The stability of production process fluctuates drastically	0.818			
Production mix and sequence changes considerably	0.764			
Supply requirements (volume and mix) vary drastically	0.847			
External integration (2nd order construct)			0.734	0.847
Supplier integration	0.895			
Customer integration	0.817			
Performance (2nd order construct)			0.548	0.828
Quality	0.784			
Flexibility	0.650			
Delivery	0.798			
Service	0.720			

Second, we used CFA to further test unidimensionality and reliability. Each measurement items was linked to its corresponding construct, and the covariance among the constructs was freely estimated. The model fit indices were $\chi^2(361)=1013.71$, GFI=0.894, AGFI=0.872, RMR=0.044, 90% confidence interval for RMSEA=(0.051, 0.059), NFI=0.896, RFI=0.884, IFI=0.931, NNFI=0.922, CFI=0.930. Thus, the model was acceptable (Hu and Bentler, 1999) and CFA factor loadings are listed in Table 3. All items had strong loadings on the construct they were supposed to measure, which further demonstrate construct unidimensionality. Furthermore, based on these loadings, average variance extracted (AVE) values and composite reliability values for all the constructs were calculated. It is shown in Table 3 that the AVE values for all the constructs are higher than 0.50 and the composite reliability values for all the constructs are higher than 0.70 (Hair et al., 2010). In this case, unidimensionality and reliability were further confirmed (Fornell and Larcker, 1981).

Finally, convergent validity and discriminant validity were tested. CFA was again used to assess convergent and discriminant validity. As shown in Table 3, all the factor loadings are greater than 0.50. Furthermore, in our CFA model, all the t-values are greater than 2.0, and each item's coefficient is greater than twice its standard error (Anderson and Gerbing, 1988; Flynn et al., 2010). Therefore, convergent validity is achieved. We conceptualised external integration as a higher order construct consisting of supplier and customer integration as the two first order factors. Similarly, performance is conceptualised as a higher order factor consisting of quality, flexibility, delivery and service. All the second order factor loadings are high as shown in table 3 and are significant at ($p<0.001$). Thus, external integration and performance can indeed be considered as higher order constructs. Besides, additional analyses were conducted to confirm the choice of second-order constructs, which will be introduced below in Section 4.3. In order to assess discriminant validity, a constrained CFA model was built for each possible pair of latent constructs, in which the correlations between the paired constructs were fixed to 1.0. This model was then compared with the original unconstrained model, in which the correlations were freely estimated. As shown in Table 4, a significant difference of the χ^2 statistics between the constrained and unconstrained models indicates high discriminant validity (Fornell and Larcker, 1981). Furthermore, for each pair, all the differences of the χ^2 between two models were significant at the 0.01 level, providing further evidence of discriminant validity. In addition, following the suggestion of Voorhees et al. (2015), we also applied the approach proposed by Henseler et al. (2015) to further test discriminant validity.

The heterotrait-monotrait ratios (HTMT) of the correlations between the constructs were calculated two by two. As all the HTMT values were less than 0.85, discriminant validity was further confirmed.

Table 4: Pairwise chi-square difference tests for discriminant validity

	Unconstrained model		**Constrained model**		
Internal integration	χ^2	df	χ^2	df	$\Delta\chi^2$
Interplant coordination	247.09	26	382.06	27	134.97***
External integration	326.9	51	463.6	52	136.7***
Demand-supply fluctuation	227.05	19	569.5	20	342.45***
Performance	215.45	49	538.63	50	323.18***
Interplant coordination					
External integration	225.87	62	327.28	63	101.41***
Demand-supply fluctuation	170.49	26	405.33	27	234.84***
Performance	165.77	60	412.08	61	246.31***
External integration					
Demand-supply fluctuation	224.55	51	472.85	52	248.30***
Performance	238.78	97	518.34	98	279.56***
Demand-supply fluctuation					
Performance	166.07	49	547.42	50	381.34***

*** $p<0.01$

4. Analyses and results

4.1 Structural model

Structural Equation Modeling (SEM) was used to estimate the relationships among different constructs and test the research hypotheses. The SEM estimates were generated by using AMOS 22 with the maximum likelihood estimation method. The goodness of fit indices for our model are $\chi^2(392)=1083.02$, GFI=0.891, AGFI=0.870, RMR=0.068, 90% confidence interval for RMSEA=(0.050, 0.058), NFI=0.890, RFI=0.878, IFI=0.927, NNFI=0.919, CFI=0.927. These indices are better than the commonly accepted threshold values (Hu and Bentler, 1999; Shah and Goldstein, 2006) and therefore indicate that the model can be accepted for future discussions.

The results of SEM path analysis are shown in Table 5, which provide mixed supports for the hypotheses H1, H2, H3, H5, and H7. Hypotheses 1 (inter-plant coordination is related to operational performance) and 2 (internal integration is related to operational performance) are not supported. In contrast, external integration was found to have a positive influence on operational performance of networked plant (H3). Furthermore, it was found that internal integration has a positive impact on inter-plant coordination (H5), whereas inter-plant coordination positively influences external integration (H7). Nevertheless, size and demand-supply fluctuation, as two control variables, have no significant impact on operational performance of networked plant.

Table 5: Results of hypotheses H1, H2, H3, H5, and H7 using SEM

	Unstandardised coefficient	Standardised coefficient	T-value
H1: Inter-plant coordination → Operational performance	0.051	0.091	1.122
H2: Internal integration → Operational performance	0.032	0.045	0.587
H3: External integration → Operational performance	0.247	0.337**	3.034
H5: Internal integration → Inter-plant coordination	0.693	0.545*	10.911
H7: Inter-plant coordination → External integration	0.378	0.488*	9.466

($p<0.001$, ** $p<0.01$)*

4.2 Mediation analysis

To further test the three mediation relationships, i.e. H4, H6, and H8, we needed to decide which procedure to follow. Following the suggestion of Rungtusanatham et al. (2014), we chose to adopt the explicit procedure, i.e. bootstrapping for testing mediation effects. Bootstrapping can correct for the non-normality of the sampling distribution of a specific indirect effect and accommodate models with multiple mediation processes in parallel or in a series. In fact, it has been demonstrated to have the greatest statistical power to detect significant mediation processes while maintaining acceptable Type I error rates, especially with large samples (Taylor et al., 2008; Rungtusanatham et al., 2014).

Consequently, we used bias-corrected bootstrapping method implemented in AMOS 22 (Preacher and Hayes, 2008), based on the model illustrated in Figure 1. Five thousand resamples with replacement were used to empirically represent the sampling distribution of the indirect effects (Hayes, 2009). Using this method, we were able to determine the significance of the constituent mediation paths by estimating the indirect effect in the population sampled and thereby generate a 95% confidence interval. According to the decision tree proposed by Zhao et al. (2010), whether the direct and indirect effects between two variables are significant is the key to understand their relationship through a mediation factor. Therefore, we report these effects with respect to hypotheses H4, H6, and H8 in Table 6.

Table 6: Bootstrapping results for mediation relationship tests

	Inter-plant coordination	External integration			Performance		
		Direct effect	Indirect effect	Total effect	Direct effect	Indirect effect	Total effect
Internal integration	0.545**	0.430**	0.266*	0.696*	0.045	0.284*	0.329*
Inter-plant coordination		0.488*	0.000	0.488*	0.091	0.165**	0.255*
External integration					0.337**	0.000	0.337**
Size					0.021	0.000	0.021
Demand-supply fluctuation					-0.033	0.000	-0.033

Note: standardised effects; model fit indices: χ2(392)=1083.02, GFI=0.891, AGFI=0.870, RMR=0.068, 90% confidence interval for RMSEA=(0.050, 0.058), NFI=0.890, RFI=0.878, IFI=0.927, NNFI=0.919, CFI=0.927
* p<0.001, ** p<0.01 (two tailed significance)

For H8, the indirect effect from inter-plant coordination to performance through external integration is significant, while the direct effect is not significant, indicating the presence of indirect-only mediation and the absence of any additional mediators (Zhao et al., 2010). Thus, the relationship between inter-plant coordination and performance is fully mediated by external integration and H8 is supported. Similarly, the indirect effect from internal integration to performance is significant, whereas the direct effect is insignificant. Thus, the relationship from internal integration to performance is also fully mediated. As shown in Figure 1, external integration and inter-plant coordination can be viewed as the parallel and series mediators for this relationship simultaneously. Accordingly, the indirect effect from internal integration to performance actually represents the total indirect effect from internal integration to performance through three different paths (Taylor et al., 2008), i.e. (1) internal integration → external integration → performance (H4); (2) internal integration → inter-plant coordination → performance (H6); and (3) internal integration → inter-plant coordination → external integration → performance. For such a model with multiple parallel mediators, erroneous conclusions about each individual mediation process may be reached through evaluation of the total indirect effect (Preacher and Hayes, 2008; Rungtusanatham et al., 2014). Therefore, in order to test H4 and H6, it is important to individually examine the specific indirect effects of each constituent path (Macho and Ledermann, 2011). In general, the SEM literature provides two main approaches for addressing the estimation, testing, and comparison of specific effects: one employing matrix methods (Bollen, 1989) and the other relying on so-called phantom variable (Cheung, 2007). In this study we decided to follow the phantom model approach proposed by Macho and Ledermann (2011), which is well suited with complex models and for users employing SEM software with a graphical interface enabling the representation of a model by means of a causal diagram. The estimated specific effects and 95% confidence intervals (CIs) based bootstrapping are summarised in Table 7. Again, the bootstrapping results are based on 5,000 bootstrap samples (Hayes, 2009).

Table 7: The estimated specific effects and 95% confidence intervals for testing H4 and H6

Path	Value[a]	Standardised indirect effect[b]	Bootstrapped standard errors	95% CI based on Bootstrapping	
				Lower bounds	Upper bounds
Path 1: Internal integration → external integration → performance (H4)	0.105	0.145	0.038	0.037	0.189
Path 2: Internal integration → inter-plant coordination → performance (H6)	0.036	0.050	0.034	-0.032	0.099
Path 3: Internal integration → inter-plant coordination → external integration → performance	0.065	0.090	0.024	0.023	0.121
Contrast between Paths 1 and 3	-0.040		0.023	-0.096	-0.004

a: Point of estimate of the specific effect or the difference of two effects being compared
b: Calculated based on standardised direct effects shown in Table 6 (Taylor et at., 2008)

The results indicate significant specific effect for path 1 and insignificant specific effect for path 2, as zero is not included in path 1's CI but is included in the path 2 (Preacher and Hayes, 2008; Macho and Ledermann, 2011). This further suggests that H4 is supported and H6 is not. However, it should also be noticed that inter-plant coordination might mediate the relationship from internal integration to performance through external integration as shown by Path 3. In fact, as zero is not included in the CI of this path, the specific effect for path 3 is also significant. Therefore, we can conclude that H6 is partially supported. The mediation of inter-plant coordination on the relationship from internal integration to performance has to be through external integration. Furthermore, we contrast two significant effects of paths 1 and 3. Because zero is not contained in the CI (Preacher and Hayes, 2008; Macho and Ledermann, 2011), these two effects can actually be distinguished, in terms of magnitude. In other words, the mediation effect of path 1 is significantly higher than that of path 3.

4.3 Additional analysis

Given our conceptualisation of external integration and operational performance as second-order factors, we further tested whether these second-order factors account for the relationships among the first-order dimensions (Tanriverdi, 2006). First, we compared the model illustrated in Figure 1 against the other one in which we removed two second-order latent constructs (i.e. external integration and operational performance of networked plant) from Figure 1 and then added paths from internal integration and inter-plant coordination to supplier integration and customer integration, as well as from internal integration, inter-plant coordination, supplier/customer integration, and control variables to all four performance measures. The remaining paths were similar to those in Figure 1. As proposed by Bollen (1989) and Vanpoucke et al. (2014), we compared the models according to their overall fit statistics, and then used component fit statistics to judge the adequacy of individual aspects. The overall fit statistics for the first-order model, i.e. $\chi^2(377)=1501.69$, GFI=0.848, AGFI=0.813, RMR=0.083, 90% confidence interval for RMSEA=(0.067, 0.074), NFI=0.848, RFI=0.824, IFI=0.881, NNFI=0.862, CFI=0.881, were inferior to those of the second-order model (Tippins and Sohi, 2003; Grover et al., 2007). Second, all of the second-order factor loadings shown in Table 3 are significant at $p<0.001$, which also indicates the appropriateness of adopting second-order factors (Tippins and Sohi, 2003; Grover et al., 2007). Third, the T-coefficient is 0.93 (χ^2 of 947.14 for the first-order CFA model divided by χ^2 of 1013.71 for the second-order model), which is >0.80, the generally accepted cut-off, thus providing further evidence of the existence of second-order constructs (Marsh and Hocevar, 1985; Dobrzykowski et al., 2015). Last, we followed the parsimony rules proposed by Hull et al. (1995) to select final model. The second-order model was also more parsimonious than the first-order model, in that it demanded the estimation of much fewer paths. All the results above individually and collectively led us to prefer the second-order model as illustrated in Figure 1.

The respondents were from multiple countries, so we next controlled for cultural effects by splitting the data into three geographically determined groups: Europe, Asian, and America. We further investigated whether the coefficients connecting the latent constructs to the observed indicators, i.e. the measurement weights of the hypothesized model, are the same across groups (Koufteros and Marcoulides, 2006; Vanpoucke et al., 2014). In a multi-group analysis, the indices for the baseline model (i.e. the factor loadings varied freely across the three continent groups) are IFI=0.894, CFI=0.892, RMSEA=0.039, 90% confidence interval (0.036, 0.041), whereas those for the constrained model (i.e. the factor loadings constrained to be equal across the three groups) are and IFI=0.892, CFI=0.891, RMSEA=0.038, 90% confidence interval (0.036, 0.041). In other words, the data fit the different continents reasonably well. Besides, we did not find significant differences in the $\chi 2$ statistics ($p>0.05$) between these two models. Therefore, we concluded measurement equivalence is confirmed across continents.

5. Discussions

We found that most of our hypotheses were supported or partially supported. All the results are summarised in Table 8. Combining these results, it is implied that the direct paths from internal integration and inter-plant coordination to performance can actually be removed from the model shown in Figure 1 and the model fit indices will not be changed after doing so (Hayes, 2009). We run the SEM path analysis under the new setting and obtained the new model fit indices, which are identical to the previous ones. This further confirms our results regarding all the hypotheses.

Table 8: Summary of all the hypothesis tests

Tests	Outcome
H1: Inter-plant coordination → Performance	Not supported
H2: Internal integration → Performance	Not supported
H3: External integration → Performance	Supported
H4: Internal integration → External integration → Performance	Supported (fully mediated)
H5: Internal integration → Inter-plant coordination	Supported
H6: Internal integration → Inter-plant coordination → Performance	Partially supported (has to be through external integration)
H7: Inter-plant coordination → External integration	Supported
H8: Inter-plant coordination → External integration → Performance	Supported (fully mediated)
Path 3: Internal integration → inter-plant coordination → external integration → performance	Supported
Contrast between H4 and Path 3	Significantly different

5.1 Supply chain integration and operational performance of networked plant

Different from the previous research, our paper mainly focuses on networked plant and investigates the relationship between SCI and operational performance of plant in a manufacturing network. In this case, our findings are in some ways consistent and in some ways in contrast with prior research. Our finding that external integration is significantly related to operational performance of networked plant (*H3*) is consistent with prior studies that take firm as the unit of analysis (Frohlich and Westbrook, 2001;Wong et al., 2011; Schoenherr and Swink, 2012). Although the value of external integration has been proven by prior studies, our results further reinforce the importance of external integration in improving operational performance and justify its value in a context of networked plant.

The result that internal integration is not significantly related to operational performance of networked plant is in contrast with several studies that take firm as the unit of analysis (Droge et al., 2004, Flynn et al., 2010, Wong et al., 2011). Nevertheless, our study clearly shows that internal integration is an enabler for external integration, as in Table 6 the path from internal integration to external integration is significant at the $p<0.001$ level. This finding is consistent with Koufteros et al. (2005, 2010) and Zhao et al. (2011), which in turn suggests that for a firm or for a plant in a manufacturing network, an effective approach to enhance external integration is to pursue internal integration. Following this path, it is further shown in our study (*H4*) that internal integration, even without direct impact, can still influence the operational performance of networked plant through external integration. In other words, the efforts on internal integration can lead to the improvement of operational performance of networked plant, only if external integration is in effect. Without good cooperation with external partners, the networked plant even with superior internal integration capability might not achieve high quality, better delivery, flexibility and service, as the superiority on internal integration can be offset by bad cooperation with suppliers and/or customers.

5.2 Inter-plant coordination, supply chain integration, and operational performance of networked plant

Although the relationships between inter-plant coordination and internal/external integration have not been discussed explicitly, the prior literature indeed implied the existence of these relationships as indicated previously in section 2.3. Our results of *H5* and *H7* further add evidence to the purported positive impact of internal integration on inter-plant coordination, as well as the positive impact of inter-plant coordination on external integration. In other words, our study clearly suggests, from both conceptual arguments and empirical evidence, that internal integration can also be viewed as the foundation for inter-plant coordination, whereas inter-plant coordination is further an enabler for external integration.

Furthermore, the previous literature also demonstrated a positive link between inter-plant coordination and operational performance of networked plant based on case studies. However, this theoretical proposition is not supported by our study, as the result of *H1* indicates that there is no significant direct relationship between inter-plant coordination and operational performance of networked plant. Nevertheless, our result of *H8* further shows that inter-plant coordination could still influence the operational performance of networked plant through external integration. Similar to the relationship between internal integration and performance, the influence of inter-plant coordination on operational performance is also fully mediated by external integration. It means that the efforts on inter-plant coordination can be converted into the improvement of operational performance of networked plant, only when external integration is in effect. For example, as introduced in section 2.1, one important aspect of inter-plant coordination is related to the allocation of production and the distribution of products among plants (Rudberg and Olhager, 2003), which require close co-operations with both suppliers and customers. On the one hand, relocating production from one plant to the other in the same manufacturing network demands close collaborations with suppliers, as discussed by Camuffo et al. (2007). Sometimes, optimising the allocation and the distribution can further lead to the development of new local supplier networks around the production plants delocalised offshore (Danese and Vinelli, 2009). On the other hand, the transfer of new products and processes from one plant to the other in the same network is usually accompanied with the adaptions of products and processes to better meet local regulations, language and consumer preferences (Cheng et al., 2015b). Thus, customer integration seems to be necessary due to the lucrative prospects of local potential markets. All these imply that the effort of inter-plant coordination can be offset by the absence of external integration.

We also addressed the mediation effect of inter-plant coordination on the relationship between internal integration and operational performance of networked plant. Although this mediation effect can be derived from the extant literature as shown in section 2.3, it is not supported by our result of *H6*. Nevertheless, our result supports the hypothesis that inter-plant coordination can mediate the relationship from internal integration to performance through external integration. In other words, inter-plant coordination and external integration can be viewed as the two mediators intervening in a series (Taylor et al., 2008) between internal integration and operational performance of networked plant. Such a mediation effect of inter-plant coordination and external integration has not been reported in the prior study. Thus, this is an interesting finding that deserves future research. Besides, this finding is consistent with our results of *H4* and *H8*, which reinforces the importance of external integration on the relationships from internal integration/inter-plant coordination to performance.

6. Conclusions

6.1 Theoretical contributions

This paper mainly focuses on networked plant, i.e. plant in a manufacturing network, and specifically investigates the relationships between inter-plant coordination, SCI, and operational performance. In this paper, inter-plant coordination is distinguished from internal integration, as it goes beyond internal integration and extends internal integration's elimination of functional silos to span across plants in the same manufacturing network. It is also different from external integration, as it merely focuses on single firms and does not address inter-firm collaboration with external partners (Cheng et al., 2015a). This paper seeks to fill the voids in both areas of SCI and inter-plant coordination. Accordingly, its theoretical contributions are twofold.

This study extends the existing research on SCI in several important ways. First, it adds to the literature by empirically testing the relationship between SCI and operational performance of networked plant. By providing evidence for the impacts of external integration on operational performance of networked plant, this study adds richness to the SCI literature and further extends our understanding of the impact of external integration on performance. Second, this research indicates that for a networked plant, internal integration forms the foundation upon which external integration is developed. The importance of internal integration in developing external integration is thereby strengthened and further extended to the new context of a plant in a manufacturing network. Lastly, this research provides preliminary evidence on the full mediation effect of external integration on the relationship between internal integration and operational performance of networked plant. It further lays the foundations for developing complete understandings on the relationship between SCI and performance.

This study also enriches our understandings on inter-plant coordination and its relationships with SCI and operational performance in several aspects. The first contribution is the development and testing of the relationships between inter-plant coordination and SCI, which have seldom been addressed in the existing literature. This paper adds evidence to the purported positive impact of internal integration on inter-plant coordination, as well as the positive impact of inter-plant coordination on external integration. Second, this study tests a novel theoretical model on the mediation effect of external integration on inter-plant coordination-performance relationship. This paper complements the previous studies by revealing the essence about how inter-plant coordination influences the operational performance of networked plant. Third, this paper demonstrates a new causal path among SCI, inter-plant coordination and operational performance by indicating that inter-plant coordination and external integration can be viewed as the two mediators intervening in a series between internal integration and operational performance. This finding enriches the literature by suggesting that in addition to the path from internal integration, via external integration to operational performance, there is one more path to improve operational performance for networked plant. Such a path is through inter-plant coordination and external integration working in series, but more credence should be given to the first path. Finally, by exploring the relationship between inter-plant coordination, SCI, and operational performance of networked plant, this paper implies the importance of integrating the knowledge of (intra-firm) manufacturing network and (inter-firm) supply chain/network in a holistic way (Cheng and Johansen, 2014).

6.2 Managerial implications

In terms of implications for managerial practice, this paper advances the understandings of operations and supply chain managers. First, managers should recognise the importance of internal integration efforts when pursuing collaboration with other plants and supply chain partners. They need to keep in their mind that internal integration is the foundation for building up both inter-plant coordination and external integration. Next, managers should understand external integration is paramount in providing input to the operational tasks required to improve operational performance. Without proper external integration setup, plants are unable to reap the full benefits of their efforts on internal integration and inter-plant coordination, i.e. they might not achieve high operational performance, even if they are superior on internal integration and inter-plant coordination. In this case, managers need to progress from good internal practices and processes to effective management of external processes. They should focus on investment in external integration to make sure their efforts on internal integration and inter-plant coordination can be converted into high operational performance of their plants in the manufacturing networks. This is consistent with the trend that plants are forced to cooperate closely with their suppliers and customers in today's competitive environment. Last, managers should also pay attention to inter-plant coordination, which can be viewed as the additional enabler for enhancing external integration. It also positively influences customer or supplier integration and further improves operational performance of networked plants.

6.3 Limitations and future research directions

This research has certain limitations, which present opportunities for future research. First, this paper only considers internal integration between manufacturing and purchasing/sales, since the existing literature only revealed the influence of close cooperation between manufacturing and purchasing/sales functions on inter-plant coordination (Rudberg and Olhager, 2003; Olhager et al., 2015). Nevertheless, there indeed exist other kinds of internal integration, such as between manufacturing and R&D, which have been often mentioned in the literature (Droge et al., 2004; Koufteros et al., 2005). Therefore, it can be interesting in the future research to explore the impact of internal integration on inter-plant coordination in a wider framework. Second, this paper mainly addressed the relationships between inter-plant coordination/SCI and operational performance. Business performance that has not been included in this paper should be taken into consideration in the future research work. Third, this paper suggests the full mediation effects of external integration on the relationships from both internal integration and inter-plant coordination to operational performance. Although this paper has proposed some explanations to the two full mediation effects, more research is needed to fully understand the mechanisms behind them for plants in a manufacturing network and also to understand why and how inter-plant coordination mediates the relationship from internal integration to performance through external integration. Fourth, this paper relies on cross-sectional data. As inter-plant coordination and SCI are actually developed over time, it will be fruitful for future research to examine the evolution of inter-plant coordination and SCI as well as their impacts on performance over a longitudinal period. Finally, the data used in this study was only collected from plants. Future studies can broaden their scope by collecting data from all other stakeholders in a manufacturing network, such as suppliers and customers.

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8. Appendix: Questionnaire

Interplant coordination	**Current level of implementation**				
	None				**High**
Improve information sharing for the coordination of the flow of goods between your plant and other plants of the network (e.g. through exchange information on inventories, deliveries, production plants, etc.)	1	2	3	4	5
Improve joint decision making to define production plans and allocate production in collaboration with other plants in the network (e.g. through shared procedures, shared forecasts)	1	2	3	4	5
Improve innovation sharing / joint innovation with other plants (through knowledge dissemination and exchange of employees inside the network)	1	2	3	4	5
Improve the use of technology to support communication with other plants of the network (e.g. ERP integration, shared databases, social networks)	1	2	3	4	5
Developing a comprehensive network performance management system (e.g. based on cost, quality, speed, flexibility, innovation, service level)	1	2	3	4	5

Internal integration	**Current level of implementation**				
	None				**High**
Sharing information with purchasing department (about sales forecast, production plans, production progress and stock level)	1	2	3	4	5
Joint decision making with purchasing department (about sales forecast, production plans and stock level)	1	2	3	4	5
Sharing information with sales department (about sales forecast, production plans, production progress and stock level)	1	2	3	4	5
Joint decision making with sales department (about sales forecast, production plans and stock level)	1	2	3	4	5

External integration		**Current level of implementation**				
		None				**High**
Supplier integration	Sharing information with key suppliers (about sales forecast, production plans, order tracking and tracing, delivery status, stock level)	1	2	3	4	5
	Developing collaborative approaches with key suppliers (e.g. supplier development, risk/revenue sharing, long-term agreements)	1	2	3	4	5
	Joint decision making with key suppliers (about product design/modifications, process design/modifications, quality improvement and cost control)	1	2	3	4	5
	System coupling with key suppliers (e.g. vendor managed inventory, just-in-time, Kanban, continuous replenishment)	1	2	3	4	5
Customer integration	Sharing information with key customers (about sales forecast, production plans, order tracking and tracing, delivery status, stock level)	1	2	3	4	5
	Developing collaborative approaches with key customers (e.g. risk/revenue sharing, long-term agreements)	1	2	3	4	5
	Joint decision making with key customers (about product design/modifications, process design/modifications, quality improvement and cost control)	1	2	3	4	5
	System coupling with key customers (e.g. vendor managed inventory, just-in-time, Kanban, continuous replenishment)	1	2	3	4	5

Operational performance		**Relative to our main competitors, our performance is**				
		much lower		equal		much higher
Quality	Conformance quality	1	2	3	4	5
	Product quality and reliability	1	2	3	4	5
Flexibility	Volume flexibility	1	2	3	4	5
	Mix flexibility	1	2	3	4	5

Service	Product assistance/support	1	2	3	4	5
	Customer service quality (e.g. training, information, help-desk)	1	2	3	4	5
Delivery	Delivery speed	1	2	3	4	5
	Delivery reliability	1	2	3	4	5