Paper no. 2014/07

Exploring the interplay, differences, and commonalities between global production networks and global innovation networks of two multinational companies

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This is a pre-print version of a paper that has been submitted for publication to a journal.

This version: May 2014

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WP 2014/07

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JEL codes: O32, F610, M160

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1. INTRODUCTION

One of the most distinctive characteristics of the recent wave of globalisation has been the increased number of cross-border production networks (Kogut and Kulatilaka 1994; Gereffi and Korzeniewicz 1994; Bonacich et al. 1994; Sturgeon 1997; Borrus and Zysman 1997; Henderson, Dicken et al. 2002; Coe, Dicken et al. 2008) as well as the increasing formation of international joint ventures and strategic alliances for R&D (George 1995; Bowonder and Miyake 1995; Zander 1999; Hagedoorn 2002; Oxley and Sampson 2004) and cross-border R&D investment (Castelli and Castellani 2013).

Theoretically, the distinction between global production network (GPN) and global innovation network (GIN) is quite blurry and the discussion of the interplay between GPNs and GINs is often based on theoretical assumptions rather than on sound evidence. The possible causes of this conceptual neglect are twofold. First, the globalisation of production started much earlier than the globalisation of innovation; thus, with few exceptions (Audrescht and Feldman 1996; Mariani 2002), most research implicitly assumes that GINs evolved from GPNs. Second, the tendency to add innovation as another function developed within the framework of GPNs (Ernst 2002), instead of clearly distinguishing between GPNs and GINs, blurs the distinction between the two kinds of networks. The perspective of innovation as an add-on function of GPN assumes that innovation happens in the same structure of the GPN. This assumption may be flawed for different reasons. First, production and innovation are two different processes of value creation (Vermeulen and KoK 2013). Production involves producing and distributing products based on existing designs and technologies to create current value. Innovation involves researching and developing new knowledge or technologies for future production to create future value. Second, the globalisation of production has different motivations compared with the globalisation of innovation. The globalisation of production is mainly driven by efficiency-seeking (Ghoshal 1987) or market-seeking strategies (Ferdows 1997), while the globalisation of innovation is mainly driven by knowledge-seeking strategies (Brusoni, Prencipe et al. 2001; Dunning and Lundan 2009). The different tasks and motivations of GPNs and GINs imply that the actors in GPNs and GINs can be different and the network structure of GPNs and GINs can also differ. Third, production and innovation are interrelated. On the one hand, the production infrastructure and process have to be created or adjusted in order to fit the need to produce new products or implement a new process. On the other hand, innovation should plan for future production, so the condition of the current production infrastructure and process is usually taken into account. Thus, actors in production

networks can be involved in the process of innovation and actors in innovation networks can also engage in the production process. It is important to empirically study the interplay, differences, and commonalities of GINs and GPNs in order to reach conceptual clarity and to generate precise implications for both practitioners and policymakers.

Methodologically, the studies on GPN and GIN are often based on secondary data. In GPN research, the most commonly used data sets are trade data (e.g. Cassi, Morrison et al. 2012; Brooks 2013) and foreign affiliation data (e.g. Ghoshal and Bartlett 1990; Hanson, Mataloni et al. 2005). In this strand of research, global trade networks (including producers and customers but taking the focal firms as black boxes and excluding suppliers and other stakeholders) and MNCs' global internal production networks (including subsidiaries and headquarters but excluding outside partners) become a proxy for GPNs because these two types of data cannot provide enough information to show the real map of GPNs. In GIN research, the most commonly used empirical source is patent data (Cantwell and Santangelo 1999; Sorenson, Rivkin et al. 2006; Shih and Chang 2009; Nam and Barnett 2011; Guan and Shi 2012; Huang, Dong et al. 2012), which also has limited capability to show the real GINs since not all patents are commercialised, not all innovations are patented and patenting activities are industry sensitive (Ter Wal and Boschma 2009). Furthermore, most of the existing literature does not attempt to simultaneously capture the GPNs and GINs of a particular company thanks to the limitations of the secondary data. Existing secondary data such as trade or patent data are only related to either GPN or GIN and hardly reflects the relations in both networks. A clear understanding of the interplay, differences, and commonalities between GPNs and GINs calls for primary data.

This paper aims to address these research gaps by distinguishing GPNs and GINs as two different but interwoven layers of MNCs' global value creation networks and exploring the interplay, differences, and commonalities between them based on the primary data of two multinational companies headquartered in Sweden. The GPNs and GINs include both internal players (headquarters and subsidiaries) and external collaborators (customers, suppliers, universities, government agencies etc.) in different geographical scopes, namely local, national and international. Taking a network perspective and using social network analysis, this exploratory case study addresses the following questions:

1. Do the GPNs and GINs interplay? If so, how?
2. What are the differences between the GPNs and the GINs?
3. What are the commonalities between the GPNs and the GINs?
4. What are the implications of the interplay, differences, and commonalities?

The rest of the paper is presented in five sections. The first contains the conceptual framework in which the concept of GPN and GIN are defined, the relevant literature is reviewed, and the main hypotheses are generated. The second contains the analytical framework for mapping the firms' GPNs and GINs and studying the interplay, differences, and commonalities of them. The third contains methodology, including the design of the case study, the selection of the case firms, the identification of the networks and the network actors, and the selection of the indicators used to analyse the structural attributes of the GPNs and GINs. The fourth contains the main findings. The fifth contains conclusions.

2. CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

The term global production network (GPN) emerged in the international business literature to capture a major organisational innovation in global operations at the end of the nineties (Dicken, Kelly et al. 2001; Ernst and Kim 2002; Henderson, Dicken et al. 2002). The concept of GPN was explicitly suggested as an alternative to global value chain (GVC), which is a linear model, to highlight the networked character of production and its global geographical scope. GPNs are complex structures embracing horizontal and vertical linkages and containing all activities supporting the production of a good or service (Dickens 2007).

In this paper GPN is defined, following Coe and Yeung et al. (2004), as "the globally organized nexus of interconnected functions and operations by firms and non-firm institutions through which goods and services are produced and distributed". One of the main characteristics of a GPN is that it involves both a high degree of geographical dispersion worldwide and a high degree of concentration in few specialised local clusters, thus pointing to the strong relationship between the local and the global (Giuliani 2004; Bathelt 2005; Giuliani, Pietrobelli et al. 2005; Giuliani 2007).

The research on global innovation networks (GINs) started with techno-globalism (Ostry and Nelson 1995), the global research village (OECD 1998), and the internationalisation of R&D (Patel and Pavitt 1998; Von Zedtwitz and Gassmann 2002; Criscuolo, Narula et al. 2005; Gammeltoft 2006; Gassler and Nones 2008; Van Beers, Berghäll et al. 2008; Dunning and Lundan 2009). The concept of GIN is distinguished from other similar concepts such as international R&D organisation/alliance (Gassmann and Von Zedtwitz 1999; Oxley and Sampson 2004) and transnational innovation network (Frenken 2000; Coe and Bunnell 2003; Oxley and Sampson 2004). First, in terms of geography, GIN refers to firms' balanced

geographical distribution of innovation activities across the conventional triad (US–Europe–Japan) and the developing countries, particularly the emerging economies, (Chen 2004; Sachwald 2008; Ernst 2009; Dias, Pereira et al. 2012) rather than within the same region or among the neighbouring regions/countries. Second, relations among actors in a GIN include all the connections that are related to creation of innovation, not just R&D. For example, it includes the connection between firms and government agencies for standardisation or co-funding of research, the connection between firms and universities for recruiting and hiring talent to develop new products and processes, etc.

In this paper, GIN is defined, following Chaminade (2009) and Barnard and Chaminade (2011), as "a globally organised network of interconnected and integrated functions and operations by firms and non-firm organizations engaged in the development or diffusion of innovations". This definition captures the truly global characteristics of a GIN, that is, its reach beyond the traditional triad of US–Europe–Japan, the variety of actors engaged in innovation (both firms and non-firm organisations), the integration of internal and external networks, and the high degree of functional integration.

We consider a firm's GPN and GIN to be two different but interwoven layers of the firm's global value creation network. It has been argued recently that a firm's production network and innovation network could be considered two layers of the firm's value creation network in which the production network creates current value while the innovation network works on future value (Vermeulen and Kok 2013). Since production activities and innovation activities of a firm are repeatedly, simultaneously, and mutually antecedently processes with shared and different actors (Vermeulen and Kok 2013), it is theoretically more proper and clearer to consider a firm's production network and innovation network to be two different but interwoven layers of the firm's network for value creation rather than to treat them as two separate networks or one single network with two embedded functions. In a firm's value creation network, the actors involved in production activities form the production network, while those involved in innovation activities form the innovation network. When an actor or a group of actors in the value creation network is involved in both production and innovation activities, the production network and innovation network interplays.

We expect that our case firms' GPNs and GINs interplay. Research in international business and innovation systems (Ernst 2002; Malerba 2002; Lundvall 2009) implies

that actors in a firm's collaborative network can engage in both production and innovation activities. It is found that the production–R&D interface is a key component of the innovation process (Ginn and Rubenstein 1986; Nihtilä 1999). Empirical evidence also shows that there is always some innovation occurring in the production process, and as a consequence, there is a certain interplay between GINs and GPNs in terms of geographical dispersion (Mariani 2002) or co-location of production and innovation (Ekholm and Hakkala 2007; Ketokivi and Ali- Yrkkö 2009). In this line of research, Mariani (2002), using data on Japanese subsidiaries in Europe, suggests that innovation tends to follow production and the more R&D intensive the firm is, the more likely they will establish R&D units independent from production. Firms or industries with higher technology intensity will be more likely to have innovation independent of production. We therefore expect that the interplay between GPNs and GINs will be higher in low- and medium-tech industries (like automotive) than in high-tech industries (like ICT).

We expect a firm's GPN and GIN have some differences since production and innovation are two different activities in the value creation process in a firm. To begin with, innovation is more related to creating new knowledge or new combinations of existing knowledge and relies more on the interaction between heterogeneous knowledge sources (Laursen and Salter 2006), while production is more related to exploiting existing knowledge and is to a larger extent based on existing design, in which a relatively smaller scope of actors is involved. We expect that variety in the organisational composition of the network might be characteristic of GINs in contrast to GPNs. Furthermore, innovation entails more complex-problem-solving, which bears high uncertainty, ambiguity and complexity, while production involves more simple-problem-solving, which is more routinised and consequently more certain. Observing the relation between the centralisation of the innovation network and the outcome of innovation projects, some researchers found that centralised networks limit the provision of innovation (Hennessey and Amabile 1988; Fleming and Koppelman 1996; Leenders, van Engelen et al. 2003). Experimental research on innovation networks also shows that high network centralisation is more conducive to simple-problem-solving than to complex-problem-solving (Leavitt 1951). Thus, we expect that GPNs are more concentrated than GINs.

However we also expect that a firm's GPN and GIN share certain common characteristics. In terms of network relational pattern, it is widely argued in network literature that the formation of network is to access different resources and the relational pattern of a network provide opportunities and constrains to actors in the

network to access resources (Wellman 1983). No doubt that the formation of GPNs and GINs is to access different resources. The formation of GPN is for efficiency (Ghoshal 1987) or market access (Ferdows 1997) while that of GIN is for knowledge and competences (Brusoni, Prencipe et al. 2001; Dunning and Lundan 2009). But such difference does not necessarily lead to different relational pattern of the two networks. On the contrary, the relational pattern of GPN and GIN may converge under certain conditions. First, when the market resources for production and knowledge resources for innovation agglomerate together, the relational pattern of the GPN and GIN aiming at these two types of resources may converge. Second, production and innovation are also interrelated processes mainly initiated and coordinated by the focal firm. Many of the activities actually are coordinated by the same actor and conducted at the same site. Thus, we have reason to expect that GPN and GIN share similar relational pattern.

The interplay, differences, and commonalities between the GPN and GIN will be explored by looking at the structure of both networks in the same case firm. Using social network analysis we are able to investigate the composition of both networks in terms of actors as well as the structural characteristics of the networks. The method used for the analysis is described next.

3. METHODS

Selection of case companies

This research uses primary data to map the GPNs and GINs of two multinational companies. Firm selection is based on four criteria, namely the firm's global presence, its production and innovation capabilities, its size, and the market structure in which it operates. These four criteria were chosen from the perspective of geography, firm character, and market character, which have a fundamental influence on a firm's production and innovation processes. Based on these four criteria, we selected a company in the telecommunication industry and one in the automobile safety industry. Due to the request for anonymity from both companies, we use TELE to refer to the former and AUTO to refer to the latter.

Both companies are headquartered in the same region of Sweden and have a strong global presence in most of the countries and regions in Europe, Asia and the Pacific, and North and South America, as well as some countries in Africa. The case firms' strong global presence gives us a great opportunity to observe and collect data on their broad global distribution of production and innovation activities. Both firms have

strong production and innovation capabilities, are large companies, and operate in oligopoly markets in which a small number of sellers dominate.

Collection of data

Data sources of this paper include interviews, questionnaires, archives, websites, internal reports, internal documents and press news. Multiple data sources provide more accurate information and improve the robustness of the results (Jick 1979). One questionnaire was developed and administered to elicit responses from the middle managers and top management team members in the two case companies. Four interviews were conducted. Each interview lasted from one to three hours. All interviews were recorded. The interviews were conducted in 2010 and 2011 in both the companies' headquarters and their branches in other locations in Sweden.

The interview started by asking the informants some background questions about their company and the industry, such as the history of the company, the organisational structure of the company, their strategy of innovation, the technology nature and competition in the industry etc. Then the questions moved to the relationship among the functional departments or groups in the headquarters, the relationships among the headquarters' functional departments/groups, the company's subsidiaries, the outside organisations such as customers, suppliers, universities, government agencies etc. The informants were reminded constantly that all relationships should be relevant to either the companies' production or technological innovation activities. At the end of the interview, open-ended questions were asked to identify the purpose of the companies' strategy of going global for both production and innovation.

Potential informant bias is addressed in three ways. First, we selected highly knowledgeable informants. At AUTO we interviewed the vice president (VP) of research twice. He was also previously the manager of engineering of AUTO for five years and the VP of engineering of AUTO for eleven years. At TELE we interviewed the VP of research twice. After the first interview he was assigned as the head of corporate strategy of TELE. He was also previously the head of the largest business unit of TELE for many years. Both of our informants not only have rich knowledge about innovation activities in the company but also are familiar with the production activities of the firm. Second, we used a "courtroom questioning" technique to focus on factual accounts (Lipton 1977; Huber and Power 1985). We asked the informants to specify what kinds of activities are carried out in each specific relationship so as to ensure that the informant did not mix up the relationships for innovation or production

or any other activities. It was also helpful for informants to avoid confusion between what really happened and what should happen. Third, we granted anonymity to the informants.

Despite the efforts to triangulate the information collected during the interview with archives, websites, internal reports, internal documents and press news, the limited number of interviews conducted in each of the case firms seriously limits the extent to which the observed patterns can be generalised to other companies, and thus this study can only be considered explorative.

The case companies' GPNs and GINs are weighted and undirected networks. GPN in this paper refers to the set of relationships of the case company aimed at manufacturing products. GIN in this paper refers to the set of relationships of the case company aimed at technological innovation, including both product and process innovation. Provision of services and service innovations are excluded from this research to facilitate the comparison between networks and between firms.

We identified two groups of actors in GPNs and GINs. One is the group of internal actors, including the functional departments or groups in the company's headquarters and the company's subsidiaries. The functional departments/groups include the department/groups for production, R&D, marketing, finances, human resources, and purchasing/sourcing, the taxonomy of which follows Porter's (1985) value chain analysis. The subsidiaries include the company's sub-organisations for R&D, production and marketing. These three groups of subsidiaries are the main types of subsidiaries for the case companies' global operation. The other group is the external actors, which includes the outside organisations, namely customers, suppliers, universities, research institutes, competitors and government agencies, who are the main actors in the production and innovation system (Lundvall, Johnson et al. 2002). The differentiation between internal and external networks was done to better observe whether the core of the networks for production and innovation lay within the firm or outside of it.

We identified three different geographic levels of GPN and GIN: local, national and international. Local level refers to the Swedish region where the case companies are headquartered. National level refers to the rest of Sweden excluding the headquarters region. International level refers to the rest of the world excluding Sweden.

The names and abbreviations of the actors in both the GPNs and GINs are shown in

Table 1. We used one initial letter to distinguish the different geographic locations of external actors: L, N, and I representing Local, National, and International respectively. For example, LCST refers to Local CuSTomers in the headquarters region. NGOV refers to National GOVernment agencies in the rest of Sweden excluding the headquarters region. ISRD refers to International Subsidiaries for R&D located in other countries.

Table 1. Names and abbreviations of internal and external actors of production/innovation networks

Internal Actors		External Actors	
R&D	R&D Department	CST	Customers
PRD	Production coordinator[3]	SPL	Suppliers
HR	Human Resource	CPT	Competitors
MKT	Marketing Department	U&R	Universities and research institutes
FIN	Financial Department		
PCH/SOC	Purchasing Department/ Sourcing Department	GOV	Government agencies
SPD	Subsidiaries for production		
SRD	Subsidiaries for R&D		
SMK	Subsidiaries for marketing		

The relational data on the ties between actors was collected through a roster recall method (Wasserman and Faust 1994). Each case company was presented with a complete list (roster) of the actors in the network and was asked the following questions:

Q1: Do the following actors contact each other for your company's production or innovation activities?

Q2: If so, what are the types of these connections: for production, for innovation, or for both?

Q3: What is the strength of these connections in terms of the intensity with which they contact each other, the frequency with which they contact each other, and the level of mutual trust? Please give a score to represent the strength of the connections:

Strength	Very strong	Strong	Normal	Weak	Very weak	No connection
Score	5	4	3	2	1	0

[3] In both case companies' headquarters, there is not a production department but a person/group who acts as the production coordinator. We still consider it a function of the headquarters even though just one or several persons are in charge.

We mapped the GPNs and GINs of the two case companies using UCINET social network analysis software.

Analysing GPN and GIN

The analysis of the networks presented in this paper was done using social network analysis (SNA). SNA facilitates the comparison of different layers of a network – for example, to understand how the same actors can configure different networks to convey different types of knowledge (Giuliani and Pietrobelli 2011) . Using SNA we can clearly see the GPNs and GINs as two different but interwoven layers of the global value creation networks of the case firms.

Based on the literature review, we explore the interplay between GPNs and GINs of the case firms by analysing the overlap of cliques and key actors in the two networks. We investigate the differences between GPNs and GINs of the case firms by examine the composition and connectedness of the two networks. We study the commonalities between the GPNs and GINs of the case firms by understanding the relational pattern of the two networks.

To understand the overlap of cliques, we produce a census of all cliques in both GPNs and GINs and see which cliques work for both networks. A clique is a sub-group in a network. In this paper, a clique is a maximal complete sub-network in which everybody is connected to everybody, with as many actors as possible. Divisions of actors into cliques can be a very important aspect of social structure (Hanneman and Riddle 2005), especially for understanding how the network as a whole is likely to behave. First, a clique is a form of network that guarantees a cooperative environment where social monitoring and trust are bound to be high and resource distributing is expected to be equal (Giuliani and Pietrobelli 2011). Moreover, the overlap of cliques between two networks indicates smooth information sharing and knowledge transfer between these two networks. A clique overlap between GPN and GIN refers to the situation where a clique's actors work closely for both networks. In such circumstances, one may expect conflict and obstacles to information sharing and knowledge transfer within the overlapped clique to be lower, and trust and understanding higher, than that between two different cliques. Where the GPN's and GIN's cliques overlap, diffusion of knowledge and information may occur rapidly and consensus and common awareness may build up quickly across these two networks. In contrast, where the cliques do not overlap, knowledge and information may more likely stay in one group and not diffuse to the other. Thus, clique overlap is an

indicator of smooth interplay between two networks.

To understand the overlap of key actors, we identify the key actors in both the GPNs and GINs and see if there are any actors who act as the key actors for both networks. We calculate the Freeman degree of each actor. The Freeman degree is a measure of the connectedness of a specific actor in a local environment. It measures the centrality of the node in the network and shows the potential of the node's positional power. It is used to identify the most connected actors in the networks. The most connected actor has the highest possibility of reaching heterogeneous resources in the network and has the most opportunities to choose the proper partner in the network. If two networks share the same key actors, the two networks interplay through them.

To understand the composition and connectedness of the GPNs and GINs, we analyse the type of actors in the GPNs and GINs to see how diverse the actors are and we calculate the network centralisation to see how centralised the GPNs and GINs are.

To understand the relational pattern of the two networks we do structural equivalence analysis. Structurally equivalent actors have exactly the same ties with exactly the same other individual actors. Structurally equivalent actors in a social network have the same pattern of relations (Lorrain and White 1971) and are expected to yield the same behavioural outcome (Burt 1987). If we understand the pattern of relations of the actors in the GPNs and GINs, we know how the networks are organised as social networks. To visually distinguish structurally equivalent sets, we use NetDraw with a principal components layout (Borgatti, Everett et al. 2002), which assigns locations to actors according to their similarity in terms of pattern of ties. Actors having similar patterns of ties are located close to each other in the map of the network. Actors with exactly the same pattern of ties are located in the same position (one on the top of the other) in the graph. In order to see all the overlapped nodes, we slightly separate them so as to make them visible in the maps.

4. MAIN FINDINGS

GIN interplays with GPN in both cases but such interplay shows firm/industrial difference.

There are two pieces of evidence showing the interplay between GIN and GPN of both case firms.

First, for both case firms, the R&D-focused actors – namely headquarters' R&D

department (R&D), local R&D subsidiaries (LSRD), national R&D subsidiaries (NSRD) and international R&D subsidiaries (ISRD) – play key roles not only in the GIN but also in the GPN, while production-focused actors – that is, headquarters production coordinator (PRD), national production subsidiaries (NSPD) and international production subsidiaries (ISPD) – have important positions not only in the GPN but also in the GIN. Figure 1 and Figure 2 show how the R&D-focused and production-focused actors are the most connected actors in both the GPNs and GINs of both case companies.

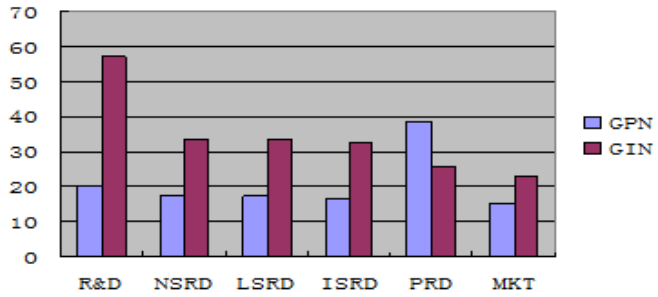


Figure 1. TELE's most connected actors' Freeman degrees

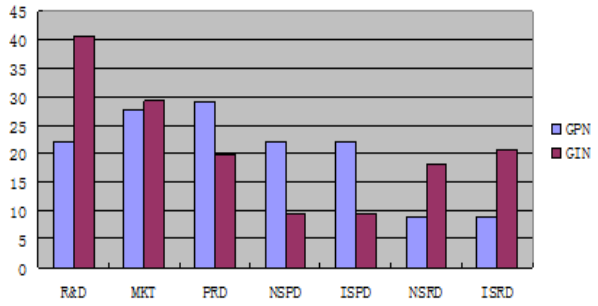


Figure 2. AUTO's most connected actors' Freeman degrees

Second, in both cases, there are clique overlaps between the GPN and GIN. A clique is a fully connected sub-group with a maximum number of actors. For example, there is an overlapping clique between GPN and GIN consisting of the headquarters' R&D department (R&D), the headquarters' production coordinator (PRD), the international customers (ICST), and the international R&D subsidiaries (ISRD). This means all these actors work closely together for both production and innovation. Thus, the knowledge and skills possessed by these actors are naturally shared between GPN and GIN. Furthermore, thanks to the cooperative environment and mutual trust created within the cliques, information and knowledge are able to smoothly travel between GPN and GIN via this sub-group.

Nevertheless, the GPN–GIN interplay is different between the two case companies.

TELE's GPN and GIN have more interplay with each other than do AUTO's. This contradicts our expectation from the literature review. As illustrated in Figure 3, in TELE, 44.4% of GPN cliques overlap 21.6% of GIN cliques, while in AUTO, only 7.6% of GPN cliques in overlap 6.7% of GIN cliques. TELE has more clique overlap than AUTO, which means more sub-groups in TELE work for both GPN and GIN than in AUTO. Clique overlap is an important social structure between two networks indicating smoother sharing of actors' knowledge and skills and smoother information exchange and knowledge transfer between the two networks in question. The more cliques overlap between GPN and GIN, the less conflict, the more consensus and common awareness, and the faster knowledge and information diffusion may occur between these two networks. TELE's overlapped cliques involve local and international customers beside R&D and production-focused actors. AUTO's overlapped clique involves local university beside R&D and production-focused actors. We assume such differences may result from the different knowledge bases of industries or from the different strategies of the firms. Whether the difference is firm- or industry-specific needs further research.

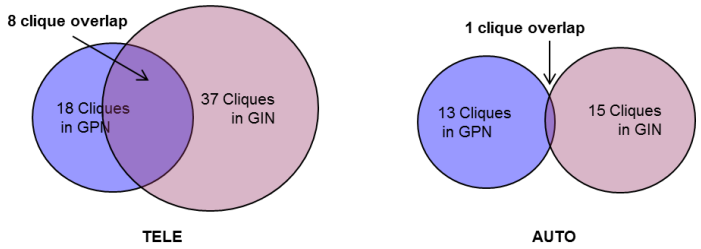


Figure 3. Illustration of clique overlap between the GPNs and GINs of the two cases

The interplay between GPNs and GINs of the case firms support our argument to conceptually consider GPN and GIN to be two different but interwoven layers of a firm's global value creation network.

GINs have more diverse actors than GPNs in both cases.

Both case companies' GINs have more diverse actors than their GPNs (see Figure 1 and Figure 2), which confirms the existing literature about the importance of standard settings for innovation in certain industries and the role of universities and research institutes as heterogeneous knowledge sources for innovation. In the case of TELE, its GIN involves local competitors, international competitors and international

government, while its GPN does not. The connections with these actors are all for the purpose of negotiating new standards. This finding shows that the composition of an ICT firm's GIN reflects the importance of industrial standards for innovation in the industry (Ehrhardt 2004; Dittrich and Duysters 2007; Soh 2010), as well as the important role of government and competitors in the standard-setting alliance (Fontana 2008; Funk 2009). In the case of AUTO, its GIN involves international universities and research institutes that its GPN does not. This finding echoes the empirical evidence, which stresses the important role of universities and research institutes in innovation networks (Spencer 2003; Hemmert 2004; Chen and Kenney 2007).

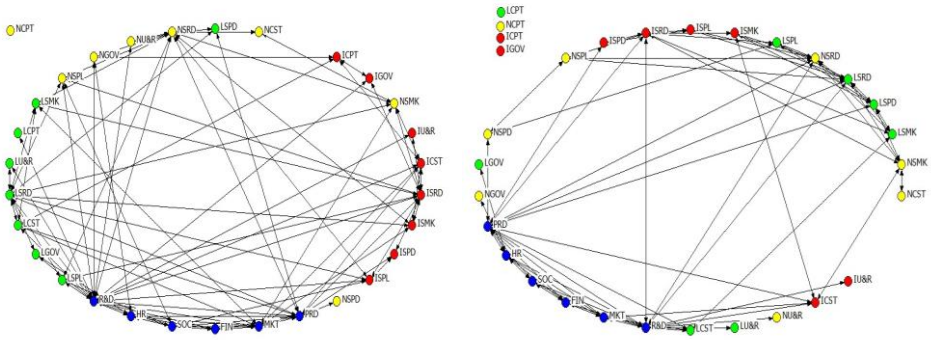
GINs are more centralised than GPNs in both cases.

Both case companies' GINs have higher network centralisation than their GPNs (see Table 2), which does not confirm the literature about the negative influence of centralised network structure on innovation performance. This can also be visually seen in Figure 4 and Figure 5. It is more obvious in the GINs than in the GPNs that a certain group of actors is more intensively connected than the others, which also points to the skew of knowledge distribution in the network. Network centralisation indicates the extent to which network positional power is concentrated in a small group of actors. Centralisation facilitates coordination and integration (Provan and Milward 1995), though it limits the accessibility of information to peripheral actors in the network. The higher network centralisation of the GINs compare to the GPNs implies that globalisation of innovation needs more integration and coordination among its actors than does globalisation of production, which may result from the greater complexity, uncertainty and ambiguity of innovation.

Table 2. Network centralisation of GPNs and GINs (%)

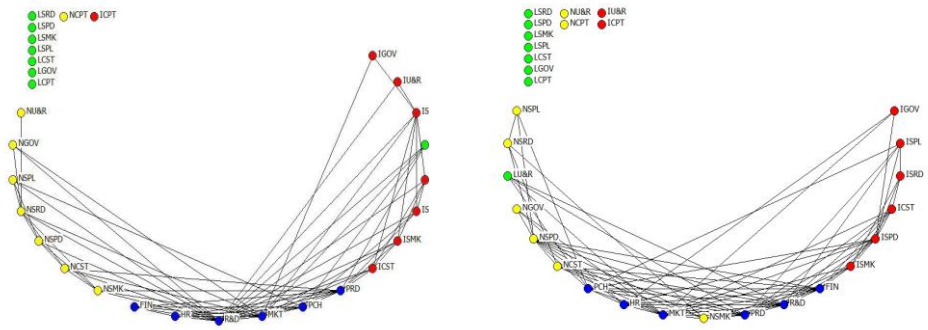
	GPN	GIN
TELE	30.44	44.09
AUTO	21.23	33.62

Our finding shows that heterogeneity plays a bigger role in GINs than in GPNs as variety increases innovation (Lundvall 2002; Malerba 2002). But higher heterogeneity of actors is accompanied by higher inequality of connectedness of actors in a GIN. This suggests that increasing the heterogeneity of the network may increase the innovativeness of the network but at the same time require more coordination, which can be facilitated by centralisation.



TELE GIN **TELE GPN**

Figure 4. TELE's GIN and GPN



AUTO GIN **AUTO GPN**

Figure 5. AUTO's GIN and GPN

In terms of the central control of R&D, the VP of AUTO commented:

> (We centralise R&D so that) we can manage it; otherwise we risk having R&D centres that go in different directions and this can create confusion among our customers about what our strategies are. So we can have control of the strategy that is in line with the whole group. . . . The generic innovation is owned by (our headquarters in) Sweden because it is financed by us and it is controlled by us. The patents are also managed at a central level; we have a global patent centre and the manager reports to me. He is positioned here in

> Sweden and he has patent people spread throughout other countries.

In TELE, the VP also explained the centralised strategy of innovation:

> When ideas become products we globalise product development, so we have representatives of other subsidiaries that take part in making decisions. We have some special sections where people from the whole group participate (to discuss how to develop) the research idea into whatever product; this is called pre-development activities, which try to prove whether the idea works. Moreover, if somebody comes up with the idea and if the idea is core, then we centralise the process. We founded pre-development globally.

The clear evidence of the differences between the GPNs and GINs of the case firms suggests that it is improper to treat innovation as an add-on function of GPN assuming that innovation happens in the same structure of GPN. It is more proper to consider the GPN and GIN as two different layers of the firm's global value creation network.

GINs and GPNs have same pattern of ties but there are firm/industrial differences.

Both case companies' GPNs and GINs have same pattern of ties. We mapped the two case firms' GPNs and GINs using NetDraw with the principal components layout (see Figure 6 and Figure 7. In these maps, actors who are close have similar geodesic distances to all other actors, while actors who overlap have exactly the same ties to the same actors. We slightly separated the overlapping nodes in the map so as to make them visible. As shown in the map, there are several aggregations in the GPNs and GINs. Actors in the same aggregation have the same or similar pattern of ties. It can be clearly seen that the aggregations in each of the case companies' GPNs and GINs are organised in the same way. In both the GPN and GIN of TELE (see Figure 3), the actors aggregated together are for the same function, such as R&D, marketing, suppliers, customers, government agencies, competitors etc. However, for AUTO (see Figure 4), the actors aggregated together in both the GPN and GIN are in the same geographic scope, such as headquarters, local, national and international. The colour of the nodes represents the number of connected members.

The fact that the GPN and GIN in the same company have the same pattern of ties is in line with the fact that production and innovation are highly integrated value creation processes coordinated by the focal firm, according to the interviews in the

two firms. The integration of production and innovation becomes more important when innovation is strongly related to customer or market-specific knowledge as mentioned by the interviewees. Under such condition, market resources that attract GPN and knowledge resources attract GIN agglomerate together to the same location which leads to the convergence of relational pattern of GPNs and GINs.

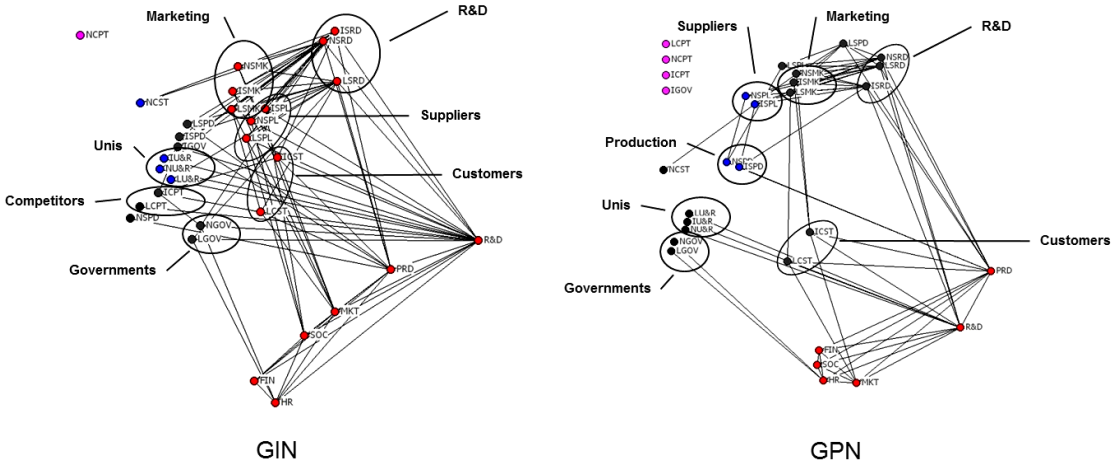


Figure 6. TELE's GPN and GIN

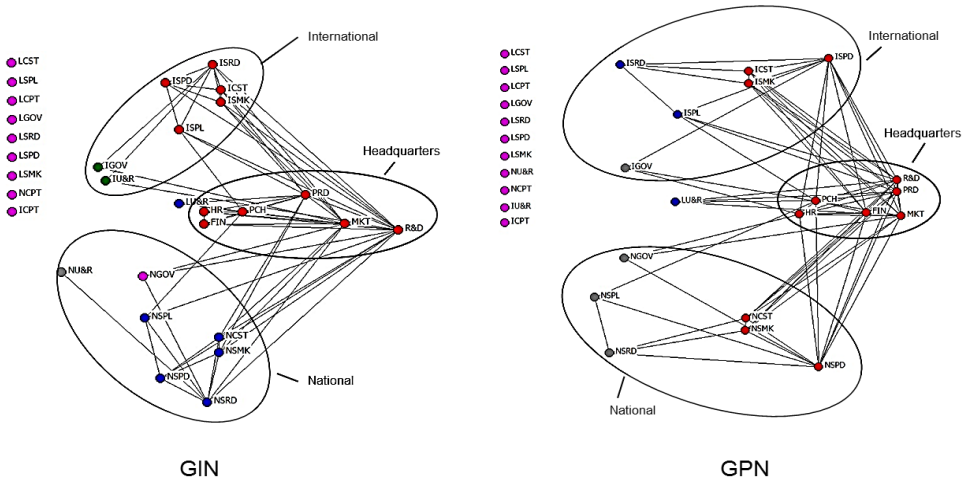


Figure 7. AUTO's GPN and GIN

The VP of TELE commented on the close relationship between production and innovation:

> The relation between R&D and production is very tight and intimate. There are no secrets between these two parts and they engage in

> continued cooperation. . . . Lots of production challenges are generated within R&D. . . . They discuss how we should produce and where we should produce to make it as easy as possible for the hundreds of thousands of products to be delivered. The design of the products is therefore (an) important (task) in the triangle of production and R&D together with customers.

The close relation between production and innovation is reflected by the importance of the engineering process, which links innovation to production, as the AUTO VP of research (former VP of engineering) told us:

> In AUTO, R&D is always followed by E, which stands for application engineering. It is an application work. It is the final work to get an innovation into production. There is less innovation. It is to create the final design that can meet customer demand on the final product. . . . If we have a production factory in a country, we always have our application engineer there to do the engineering work to put innovation into production.

In both case firms, its GPN and GIN have a similar pattern of ties; however, such pattern is different between two different companies in different industries. We found that the GPN and GIN of TELE are more globally organised, while those of AUTO are more locally organised. The global vs. local organisation model reflects the effect of the different feasibility and necessity of long-distance knowledge transfer on the organisation of the networks of the case firms (Liu, Chaminade et al. 2013).

The globally organised model of TELE is explained by the VP:

> (For innovation), taking the relationship between R&D and the suppliers as an example, our suppliers are global. So everyone talks to everyone. An R&D branch at headquarters will talk to all levels of suppliers within their product line. If they are responsible for that machine, then they need to form their own network. . . . It is the same thing for any R&D site regardless of whether it is in the European headquarters or in Beijing. If they are responsible for product development, they need to talk to, for example, all the marketing units at all levels who can provide relevant information. That's why it becomes a global "mess". . . . (For production), there is

> a dialogue from Stockholm, Sweden and the rest of the world about production. That's for cost reduction. This connection is much formalised based on the company's database. So there is no problem of trust. . . . You can find that if there is interaction between two actors, most of the time they interact in the same way for both production and innovation. It is very global.

The locally organised model of AUTO is explained by the VP:

> For innovation, Sweden is not the only centre, particularly for development and engineering of new products and processes. If we have a production facility, we have application engineers there. For example, we have a technical centre in China to better understand this fastest growing car market and to build up competence in this experience-based industry. . . . (For production) we have an internal supply chain. These connections (between the internal suppliers and customers) are mainly in the same regions. We have more consolidated production for the key components. There are subsidiaries for production, which are also in a vertical line organised as tier one, tier two and tier three. Tier one suppliers are our main suppliers and they are the closest to the customers.

Existing literature has heavily discussed the different motivations for globalisation of production and innovation, arguing the former is mainly to seek low cost or market advantage while the latter is mainly for knowledge competences. The argument is also confirmed by our interviews in both case firms. However, despite the difference in motivation and tasks undertaken in GPNs and GINs, we still see a convergence in the relational patterns of the two networks. The way that the GPN and GIN are organised, or the way that the actors in the two networks are interconnected, is found to be the same in both cases. The shared relational pattern of the GPN and GIN indicates the strong inherent connection between the production and innovation processes. It reflects the simultaneity and interdependence of production and innovation activities particularly when market resources for production and market-specific knowledge for innovation agglomerate to the same location. Thus, we argue that it is important to conceptually consider the GPN and GIN as two different but interwoven layers of the same global value creation network of a firm rather than two separate ones.

Table 3. Summary of the main results

Interplay		
Literature	Results	Explanations
GPNs and GINs interplay	Confirmed, for both AUTO and TELE. 1) The GPN and GIN share the same key R&D-focused and production-focused actors. 2) There is clique overlap between GPN and GIN in both case firms.	The interplay between GPN and GIN reflects the interconnection between innovation and production processes in the value creation process.
The interplay between GPN and GIN is to greater extent in AUTO than in TELE	Not confirmed with our cases. On the contrary, the interplay is higher in TELE than in AUTO.	Probably because of 1) the different dominant knowledge bases of the industry or 2) the different firm strategies. Needs further research.
Differences		
Literature	Results	Explanations
GINs have a larger number of diverse actors than have GPNs	Confirmed. GINs are more heterogeneous than GPNs. 1) For AUTO, international universities and research institutes are involved in GIN rather than in GPN. 2) For TELE, government agencies and competitors of all geographical levels are involved in GIN rather than in GPN.	1) The greater importance of universities and research institutions for innovation than for production in automotive industry. 2) The important role of government agencies and competitors in standards-setting in the ICT industry.
GINs are more concentrated than GPNs	Confirmed, for both AUTO and TELE.	GIN needs more integration and coordination, which is facilitated by network centralisation, than does GPN thanks to the greater complexity, uncertainty and ambiguity of innovation.
Commonality		
Literature	Results	Explanations
GINs and GPNs have a similar relational pattern	Confirmed, for both AUTO and TELE. AUTO's GPN and GIN are both locally organised while TELE's are both globally organised.	Innovation and production processes are inherently interconnected, which is reflected in their similar relational pattern. The relational pattern of GPN/GIN is influenced by the feasibility and necessity of long-distance knowledge transfer within the GPN/GIN.

5. CONCLUSIONS

This paper is an explorative case study about the interplay, differences, and commonalities between the GPNs and GINs of two MNCs headquartered in Sweden.

Based on the primary data collected through interviews and other information sources, after comparing the GPNs and GINs of the two case firms, we find that 1) the interplay between GPNs and GINs of the case firms can be observed not only in the shared key actors in the networks, but also in the shared closely connected sub-groups in the networks. The interplay between GPN and GIN reflects the interconnection between production and innovation as two different but intertwined processes of value creation in the case companies. 2) The differences between the GPNs and GINs of the

case firms lie in the degree of diversity in actors and the centralisation of the networks. The two case firms' GINs are formed by a larger number of diverse actors than are the GPNs. This reflects the situation in the automobile industry in which innovation needs to tap into diversified sources of knowledge through collaborating with universities and research institutes more than does production. The greater diversity of the GIN than GPN in the ICT case is because of the important role of competitors and government agencies in standards-setting for innovation in the industry. The greater network centralisation of case firms' GINs than of their GPNs reflects the reality that globalisation of innovation needs more integration and coordination than does production thanks to the uncertainty, ambiguity and complexity of innovation. 3) The commonality between both firms' GPNs and GINs is that they share the same pattern of ties. This reflects the strong inherent interconnection between production and innovation processes as two different parts of the same value creation process that is coordinated by the focal firm and the agglomeration of market resources for GPN and knowledge resources for GIN to the same location.

The interplay, differences, and commonality between GPNs and GINs that we find in this case study bring forth theoretical implications. GPNs and GINs have distinctive characteristics in terms of network composition and network structure. At the same time they also share common attributes and they interplay. Thus, it is improper to consider GPN and GIN as two separate networks or to consider GIN as an extension of GPN. Instead, regarding GPN and GIN as two different but interwoven layers of the global value creation network of a firm may provide better conceptual clarity and lead to more precise implications for both policymakers and industrial practitioners

Furthermore, we also find firm/industrial differences when comparing the two case companies' GPNs and GINs. 1) TELE's GPN and GIN are globally organised while AUTO's are locally organised; 2) TELE's GPN and GIN's centrality is higher than AUTO's; 3) TELE's GPN–GIN overlap is greater than AUTO's. Whether these differences are explained by their belonging to different industries or by different firm strategies remains to be studied.

As with any exploratory analysis using novel, dedicated survey data, the paper has inevitable limitations. The first limitation is the limited number of interviews. To reduce possible informant bias, the interviewees were carefully selected (top managers – vice president of research with extensive previous experience serving as vice president of engineering or as the head of the largest business unit), concepts

were clearly defined, one interview questionnaire were used, four interviews were conducted, all interviews were recorded, and data was triangulated with published information when available. The second limitation is the cross-sectional nature of the data, which does not allow us to investigate whether GINs evolve from GPNs, as the extant literature argues, or how GINs and GPNs co-evolve, which can be of great theoretical importance.

The value of our study is in the exploratory purpose that it serves, providing some evidence for the interplay, differences, and commonalities of GINs and GPNs in two multinational companies based on primary data for further theoretical development.

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