Global Innovation Networks: State of the art and issues at stake for GVCs

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Biography

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She has led several qualitative studies on the internationalization of R&D processes, especially in the pharmaceutical industry. Paulina's research interests are in the areas of comparative national and regional innovation and business systems and the global political economy. This includes studying the relationship between the rise of global research and innovation networks and value chains, international knowledge flows, and innovation and business systems.

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Abstract

The objective of the study on "Literature review on Global Innovation Networks: State of the art and issues at stake for GVC" is to summarise the state of the art literature on Global Innovation Networks (GINs) in order to understand the patterns and evolution of these networks. Based on the review of the literature the study develops a conceptual framework on the relationship between GINs and global value chains (GVCs). The framework systematises the main commonalities and differences between GINs and GVCs and makes suggestions for further evidence collection to address the links between GINs and GVCs.

Table of contents

1 Introduction

Global innovation networks (GINs) is the more recent term used to refer to the complex webs of internationally dispersed research, development and innovation (RDI) networks that have developed since the 1990s and which have been studied by scholars interested in the internationalisation and globalisation of innovation. The term GIN has been used to refer to the internationally dispersed intra-firm RDI networks of MNCs (Barnard and Chaminade 2011; Chen 2004; Ernst 2006, OECD 2016) as well as to the increasingly diverse range of inter-firm RDI networks coordinated and governed by MNCs (more recently also known as 'lead firms') (Ernst 2009; Liu et al, 2013; OECD 2016). The term GIN has also been used more broadly in reference to the growing internationalisation of science through co-operative networks of universities, STI actors and firms (OECD 2014). These GINs differ from those that are organised, coordinated or governed by private firms and will not be discussed in this review of the literature.

The emergence and evolution of GINs is the result of a complex combination of forces associated with changes in the 'macro research and scientific environment' which has increased the importance of scientific knowledge and broadened the range of scientific fields and technological disciplines required for innovation (Howells 1995); institutional change which have resulted in new mechanisms for standardization and intellectual property rights (Alcácer et al 2015); changes in the world economy associated with the liberalisation of international trade and investment (Chesnais 1992, Lundvall and Borras 1997; Dunning 1997); as well as changes in the organisational forms and strategies of MNCs enabled by advances in information and communications technology (ICT) (Ernst and Kim 2002; Dunning and Lundan, 2008; Alcácer et al 2015; Cantwell 2013, 2017).

The study of GINs is particularly complex because of the multi-scalar and multidimensional nature of these networks which involve multiple actors and firms of different sizes resulting in a diversity of network architectures and strategies (Ernst 2009). Moreover, GINs have both an organisational as well as a locational dimension and their structure and evolution is influenced by the interaction of factors at micro, meso and macro level. The internationalisation of RDI activities and the emergence of GINs has therefore been studied by literatures from a variety of disciplines and theoretical approches which have used

different methodologies and focused on different aspects of their emergence, structure and evolution. These literatures have developed in parallel with little interaction with each other and have developed their own terminology for processes that often overlap adding an extra layer of complexity to the study of these networks.

The recent use of the term GIN to refer to phenomena that has been taking place since the late 1980s and early 1990s (see early literature on the internationalisation and globalisation of innovation) in part reflects significant changes in the organisation of MNCs as well as in the way the understanding of these organisations has evolved in recent academic literature (Ernst 2009; Cantwell 2013, 2017). The use of the term GIN follows the adoption of the terms global value chain (GVC) (Gereffi et al 2005) and global production network (GPN) (Ernst and Kim 2002; Ernst 2005; Henderson et al 2002) to refer to the new ways in which MNCs are organising their value-adding processes across organisational and international borders (Dunning and Lundan 2008; Saliola and Zanfei 2009; Cantwell 2017). Much of the difficulties in following studies on the patterns and evolution of GINs and their links with GVCs are therefore related to the ways the new organisational forms of MNCs have been theorised and conceptualised. The review of the literature will therefore centre on the different ways MNCs are being conceptualised and the implications of this for the study of GINs and GVCs. The review of the literature will also focus on the relationship between GINs and GVC and the co-location of RDI and productive activities.

Given the multi-scale and multidimensional character of GINs the study will review the most relevant literature that analyses these networks at three levels of analysis: micro, meso and macro.

- The micro level studies discussed will focus on the literature by scholars of inovation and modularisation.
- The meso-level studies discussed will focus on the literature on GVCs.
- The macro-level studies discussed will focus on aggregate-based studies by scholars of International Business (IB), geographers, as well as aggregate studies by international organisations such as OECD.

The interactions between these different sets of literatures have influenced how GINs and GVCs have been conceptualised, studied and discussed both theoretically and emprically. Together these literatures summarise the state of the art understanding of the patterns and evolution of these networks.

2. Global Innovation Networks: Key concepts

GINs are the product of the internationalisation and globalisation of RDI activities by MNCs where *internationalisation* refers to activities located outside the country of origin and the geographical spread of these activities and *globalisation* refers to the international division of labour and degree of integration of innovative activities (Cantwell 1995). The concept of GINs includes the intra-firm networks of internationally dispersed RDI facilities of MNCs (Barnard and Chaminade 2011; Chen 2004; Liu et al 2013) which has been the main focus of studies of the internationalisation and globalisation of RDI activities; we refer to these networks as *intra-firm GINs*. The notion of GINs also refers to an increasingly complex array of inter-firm RDI networks coordinated and governed by MNCs (Ernst 2006; 2009); we refer to these as *inter-firm GINs*. Inter-firm GINs include the international cooperative alliances established by MNCs as a means to access new knowledge and technology developed by public and private scientific research organisations as well as other innovative firms. Knowledge-intensive business service firms (KIBS) specialising in research and engineering services are included here. The central aim of these alliances from the point of view of the MNC is to access new knowledge being developed outside its organisational borders (Hagedoorn 1993; Howells et al 2008; OECD 2016). More recently, these inter-firm GINs have been associated with the increasing adoption of 'open innovation' strategies by firms (Chesbrough 2003). Following Cantwell (2017) we refer to these alliances as *knowledge-seeking inter-firm* GINs.

The term GINs is also being used to refer to newer types of international inter-firm RDI networks in industries such as electronics (Ernst 2006; 2009) and pharmaceuticals (Ramirez 2013) associated with processes of fragmentation and 'fine-splicing' of existing RDI activities which are then outsourced to internationally dispersed, independently-owned, contract research organisations (CROs) or manufacturing service firms (Ernst 2009; Cooke 2011: Contractor et al 2010; Howells 2008, Howells et al 2008; Ernst 2009; Mudambi and Tallman 2010; Massini and Miozzo 2010, 2012; Grimpe and Kaiser 2010; Hsuan and Mahnke 2011; Martinez-Noya et al 2012). The main motivation for the creation of these GINs is not principally to access new knowledge or technology (though this can also take place within these GINs) but to gain flexibility, spread risk, and reduce costs in RDI activities. We call these newer types of inter-firm GINs *contract-based inter-firm GINs*.

3 Micro-analysis of GINs

Central to the study of GINs are changes in the organisation and location of the RDI activities of firms, activities that are shaped and constrained by the character of knowledge and the nature of the innovation process. Similarly, in the case of GVCs, the configuration of value-added activities is shaped and constrained by the physical characteristics of products which have an impact on the flow of materials, components and knowledge (Rezk et al 2016). The two sets of literatures that focus on micro-level studies of innovation and knowledge and have influenced much of the discussion on the dynamics of GINs as well as GVCs are the works by scholars of innovation and technological change and that of scholars of the modularisation of industrial activity.

3.1 Literature on innovation and GINs

Studies by innovation scholars on the internationalisation of RDI activities and the emergence of intra-firm GINs have highlighted the importance of integration between the different stages of the RDI process (i.e research, design, development and testing) as well as between RDI and other corporate functions such as production (Rothwell 1977; Freeman 1982; Teece 1988; 2010; Dosi 1988; Kline and Rosenberg 1986; Patel and Pavitt 1991, 1998; Lundvall and Borras 1997; Ketoviki and Ali-Yrkkö 2009; Caraça *et al* 2009; Pisano and Shih 2012; Rezk *et al* 2016; Ivarsson *et al* 2017). The argument is that in most industries innovation requires firms to absorb advances in scientific knowledge through their internal research facilities and to link these to activities related to the development and testing of products, prototypes and production systems where advances are based on 'learning by doing' (Pavitt 1999; Cohen and Levinthal 1989; Ernst 2009; Dosi and Nelson 2010). Within the RDI function tight coordination is required because of the sequential and integrated nature of innovative activity in the sense that the performance of a task is often highly dependent on the problem-solving methods and solutions of related tasks and because much of the knowledge and know-how involved in these activities is of a tacit and unstructured nature involving negotiation, persuasion and common problem-solving activities which usually require face-to-face contact (Patel and Pavitt 1991, 1999; Howells *et al* 2008; Dosi and Nelson 2010). In this context the location of RDI activities in different cultural regions is seen to increase the difficulties and costs of knowledge and information exchanges and therefore of co-ordination and control (Granstrand *et al* 1992).

Similarly, the importance of tacit knowledge and timely information feedbacks between tasks requires the integration between RDI and early manufacturing activities, above all in engineering-based industries where changes in product design often directly affect production methods (Susman 1992; Pavitt 1999; Howells 2008; Pisano 2006; Pisano and Shih 2012; Rezk *et al* 2016; Ivarrson 2017). Integration between RDI and production is also important in many process industries where the properties of products are closely related to the manufacturing process and product development activities are carried out in the production environment (Pisano and Shih 2012; Storm *et al* 2013 in Ivarsson *et al* 2017;). In these industries the co-location and organisational integration between RDI and manufacturing is critical to the innovation process leading to the close integration between GINs and GVCs in the context of internationalisation. The integration between RDI and production also appears to have become more important as these activities have become more knowledge-intensive and the rate of technological change within an industry increases (Pisano 1996; Pisano and Shih 2012; Ernst 2005; Abele *et al* 2008; Ketoviki and Ali-Yrkkö 2009).

The need for co-location between RDI and manufacturing has been far less important in non-engineering or process based industries such as pharmaceuticals (Pisano 2006) (though the introduction of new manufacturing technologies into pharmaceutical production may change this). In science-based industries, such as pharmaceuticals, advances in scientific knowledge in the area of biotechnology since the mid-1980s have created a closer link between innovation and advances in scientific research. In this sector, over a period of several years, large pharmaceutical firms have re-structured and re-located their GINs close to international centres of scientific excellence (Ramirez 2006). The experience of pharmaceuticals shows that in industries where innovation is dependent on advances in scientific knowledge, GINs will be located close to centres of science. The innovation literature therefore points to the need to take account of differences in the dominant knowledge-base of industrial sectors (Pavitt 1984; Malerba 2002) which influence the organisation and location of the innovation process and the configuration of GINs. It indicates that care must be taken when generalising across industrial sectors. The experience of the pharmaceutical industry also shows that the boundaries of industrial sectors as well as the patterns of location of GINs can change over time (Ramirez 2006; Howells *et al* 2008) often in response to changes in technology. The

organisational and locational patterns of GINs have therefore to be seen as a dynamic phenomenon.

Though in the main innovation scholars emphasised the important of integration in the organisation of innovation, von Hipple (1990) has questioned whether integration is necessary for all RDI tasks suggesting that even within the innovation function activities can be separated where problem-solving interdependencies are weaker. Von Hippel (1990) argues therefore that integration is not a technological imperative for all tasks but that some managerial choice exists in the way RDI tasks are partitioned and efficiently distributed within and between firms. This argument is supported by recent trends towards the 'fine-splicing' of RDI activities and the growth of *contract-based inter-firm GINs* (Ernst 2009; Martinez-Noya *et al* 2012; Ramirez 2013). The argument is also supported by Ramirez (2006) and Ivarsson (2017) who found that the degree of integration between RDI activities also depended on how MNCs were established as well as their internationalisation strategies; for example, if the MNC expanded through Greenfield investment or the merger or acquisition of an existing firm with RDI facilities. These studies therefore suggest that the partitioning of RDI activities is possible and that further studies are needed to identify the conditions under which separation is possible and how this shapes organisational and locational configuration of GINs,

The innovation literature has also pointed to the importance of scale economies in RDI and the difficulties associated with reaching the 'critical mass' of activities needed for an efficient innovation organisation in a system of decentralised and internationally dispersed facilities (Pavitt 1991; Granstrand *et al* 1992; Dosi and Nelson 2010). There are several sources for these scale economies, for example, expensive equipment and the need to use specific types of scientific expertise which create indivisibilities and require a minimum volume of RDI in order to become economically viable. As MNCs have grown, however, their international RDIs efforts have frequently also expanded (often via mergers and acquisitions) to achieve the required minimum volume. In the case of some of the largest MNCs, their international RDI facilities have sometimes expanded to the point where they have been able to globalise their RDI efforts by establishing an intra-firm GIN where different locations specialise in specific products or technological areas (Ramirez 2006; D'Agostino and Santangelo,2012)

In terms of the location of RDI activities, the innovation literature has emphasised the importance of the country of origin of MNCs because of the importance of path-dependence in the innovation process (Pavitt 1999). The importance of the country of origin rests in the fact that when R&D facilities are first established they tend to be located close to the company's headquarters and central factories. The evolutionary character of firm-specific technological advantage also explains why the country of origin is so important, as firm-specific assets tend to evolve from, and mirror, the home country scientific, technological and market conditions (Granstrand *et al* 1992, Teece 2010; Cantwell 2017). This factor has been highlighted in more macro studies of GINs as an important explanation as to why the home country remains the most important location for the innovative activities of MNCs (Narula and Zanfei, 2005; Dunning and Lundan 2008; OECD 2016). In general, the innovation literature has not explored the process of internationalisation of RDI, the role of international RDI facilities or the emergence and development of GINs. The exploration of these subjects has been carried out by IB and geography scholars often drawing on the insights of the innovation literature (e.g. Iammarino and McCann 2013; Alcácer *et al* 2016; Cantwell 2017).

Inter-firm networks and GINs

The mid-1980s and 1990s witnessed significant changes in the organisation of the industrial RDI process with firms increasingly participating in technological alliances with other firms as well as with public and private research institutions (Chesnais 1988, 1996; Teece 1988, 2010; Mytelka 1990, 1991, 1999; Freeman 1991; OECD 1992; Hagedoorn and Schakenraad 1990; Narula and Zanfei 2005). Many of these alliances were international in character so that cross-border inter-firm GINs became an important mode for the globalisation of innovation (Hagedoorn 1993; Archibugi and Michie1997, Ramirez 2006). The innovation literature has explained the growth of technological alliances in the organisation of the RDI process by highlighting the increasing importance of advances in scientific knowledge for innovation as well as the increasing synergies, complementarities, and interdependencies between previously distinct scientific and technological fields (OECD 1992, Brusoni *et al* 2001; Granstrand 1997). In the context of major changes in the character of knowledge needed for innovation, inter-firm RDI collaborations became important mechanisms for firms to access new knowledge which was complementary rather than a substitute to the internal RDI effort (Teece, 2010). The growth of *knowledge-seeking* technological alliances represented a significant change in the strategy and management of innovation; the

broadening of this approach later became the basis for the strategy of 'Open innovation' (Chesbrough 2003) which is believed to reinforce the tendency for firms to established co-operative networks in RDI (Howells 2008). Whilst much attention has focused on knowledge-seeking technological alliances much less is known about the outsourcing of RDI tasks to contract research or manufacturing organisations as the basis for the development of contract-based GINs (Ramirez 2013, Ernst 2006; 2009, Howells 1999; 2008)

Howells (2008) identifies some of the major trends affecting the growth and development of global RDI activities. These include the growth of inter-firm RDI activities associated with the adoption of 'Open Innovation' strategies but also the rise of new actors in RDI such as the Institute of One World Health and other public-private partnerships. In this context it is important to monitor the emergence of new RDI actors and their patterns of interaction and internationalisation. The increasing importance of cost-led considerations in the choice of location is another factor likely to change the configuration of GINs intensifying the flow of RDI investment to developing countries with an educated and skilled workforce (see also UNCTAD 2005). A third trend identified by Howells (2008) is the increasing importance of RDI outsourcing. Howells claims that in the next 10 to 20 years the services sector linked to RDI activities is likely to become the *dominant form* of RDI activity in many developed countries (emphasis in Howells 2008) as both services and manufacturing firms contract-out RDI activities. Howells also notes the closer integration between the production and consumption of innovation and therefore RDI activities which is likely to embed GINs in large, dynamic, markets. This suggests that policy makers need to pay attention not only to the science and technology as well as industrial systems of regions but also dynamism of markets.

More significantly the organisational and locational configuration of GINs and GVCs are likely to be significantly transformed in the next period as a result of changes brought about by new manufacturing technologies and what is being termed as the new production revolution (Alcácer *et al* 2016; OECD 2016b). A new set of manufacturing technologies associated with digitalisation, automation, artificial intelligence, 'big data', the 'internet of things' and the 'industrial internet' (also known as Industry 4.0) and new materials (bio and nano-based) are expected to transform all parts of the industrial system (Rifkin 2014). Little is known at this stage about the impact of these new technologies on GVCs and GINs but the effect are likely to be radical and industry-specific.

The main contribution of the innovation literature to our understanding of GINs and the co-location of GINs and GVCs has been its focus on the following issues: The importance of integration between various RDI activities and between RDI and manufacturing; the role of the dominant knowledge base of different industries and how this influences the organisation and location of RDI; as well as the increasing trend towards technological alliances and collaborations in the context of the increasing scientific and technological complexity of goods.

3.2 The modularisation, fragmentation and vertical disaggregation of the value-adding process

One of the most influential ideas associated with the break-up of the value-adding process and the growth of international inter and intra-firm GINs as well as GVCs is the notion of modularity, a concept which has been adopted by all literatures analysing changes in the organisational form of the MNC (for examples see Sturgeon 2002; Gereffi *et al* 2005; Ernst 2005, 2009; Pisano and Shih 2012; Rezk *et al* 2016; Cantwell 2017). The following section will introduce the definition of modularity and discuss sectoral differences in the degree of modularity. The benefits and challenges of modularity for GINs and GVCs will also be discussed.

Unlike the innovation literature which tends to emphasise the importance of integration in the value-adding process, the modularity literature focuses on the partitioning and break-up of value chains. The concept of modularity refers to the ability to break-up products, tasks, operations or organisations into distinct parts (called modules) which are internally coherent and 'tightly coupled' but are less well integrated with other part of the products, tasks, operations and organisations operation/organisation (von Hippel 1990; Baldwing and Clark 2000; Baldwing 2007). Modularity is therefore characterised by strong integration and interdependencies within modules but greater independence between them (Baldwin and Clark 2000).

The benefit of modularisation for organisations is that it enables them to identify the points where the partitioning of products, production and business processes and tasks or organisational structures can best take place because close integration is less important and/or because codified information (e.g. industry standards and/or standard operating procedures (SOPs)) simplifies the process of coordination between modules (Sanchez and Mahoney 1996, von Hippel 1990; Baldwing 2007, Langlois and Robertson 1992; Sako 2006; Sturgeon 2002). It is acknowledged however that the degree of modularity varies according to industry, a factor determined by the specific technological characteristics of each sector (Pisano 2006; Mudambi and Venzin 2010).

In industries with modular product architectures such as electronics and automobiles it is easier to break-up and decentralise organisational structures because products can be broken-up into distinct components which can be supplied by separate sub-contractors. This differs from integral industries such as pharmaceuticals where the product is not made up of components or stand-alone attributes that can be 'bundled' or 'unbundled' (Pisano 2006). Even within modular industries, however, tasks and components can be decomposed and allocated in different ways both within and between organisations so that there is nothing deterministic about product modularity or industry structure (Sako 2006; Sturgeon and Gereffi 2009). For example, within the same industry GVCs and GINs can differ in terms of their degree of decentralisation and the extent to which they are organised around a 'lead' firm (Langlois and Robertson 1992). The figures below show two ways a GVC in the same industry can be organised. In the first figure, suppliers are tied to a 'lead' firm. While in the second figure, the components are broken-down and organised in a more complex manner.

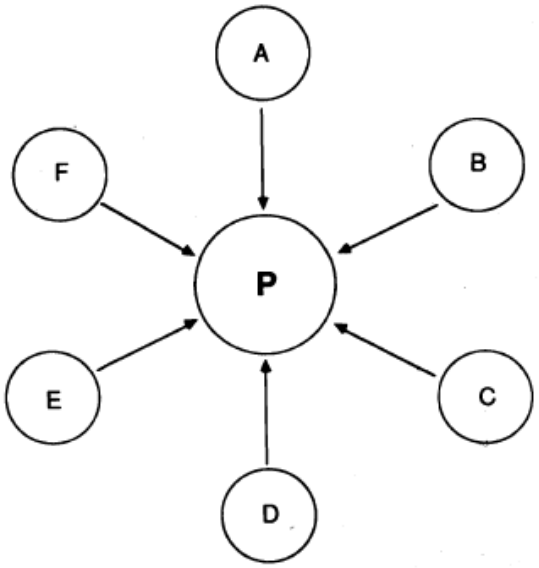

Fig. 4. A centralized network.

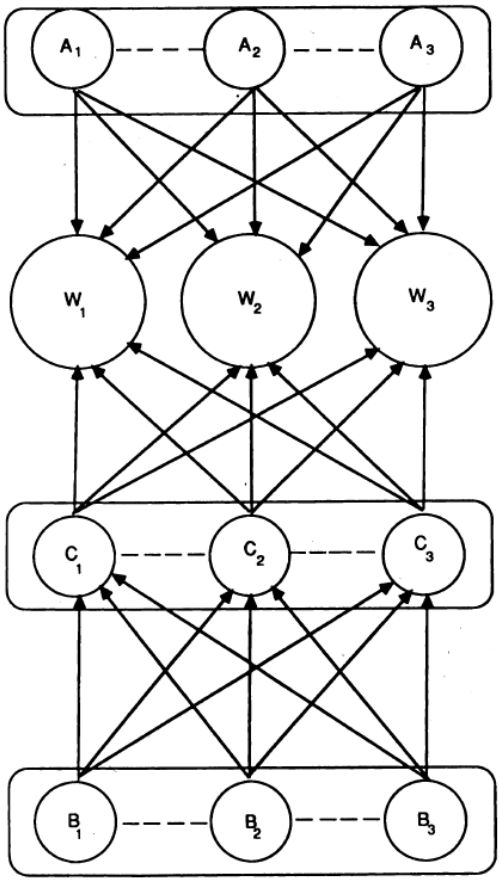

Fig. 5. A decentralized network.

The increasing importance of modularization in product design in industries such as electronics and automotive has resulted in increasing trends towards the outsourcing of manufacturing components and subsystems to independently-owned, internationally dispersed, suppliers (Ernst 2005; 2009). Similarly, service functions (e.g procurement, marketing, pay-roll) in both manufacturing and service industries have been 'unbundled' and outsourced to internationally dispersed service firms (Sako 2006, Gereffi and Fernandez-Stark 2010; Fernandez-Stark *et al* 2011). In both manufacturing and service industries these changes in industry structures have underpinned the growth of GVCs (Langlois and Robertson 1992; Sako 2006; Sturgeon 2002; Ernst 2005; 2009).

The literature on modularisation has highlighted the advantages for innovation associated with the vertical disaggregation of RDI activities and their externalisation (or outsourcing) to independent suppliers. This literature has therefore contributed to the theoretical foundations favouring the growth of *inter-firm GINs*. Mudambi and Venzin (2010) for example suggest that modularity in RDI enables firms to separate out the standard activities of this function and to relocate them in cost efficient emerging markets and argument supporting the growth of contract-based inter-firm GINs. On the other hand, Langlois and Robertson (1992; Robertson and Langlois 1995) have argued that the vertical disaggregation and specialisation of the RDI function can foster innovation by increasing the number of suppliers with RDI capabilities searching for solutions to technical problems and argue that this is particularly important when technology is changing rapidly and there is a high degree of both technological and market uncertainty. The authors also argue that one of the advantages of modularisation for RDI is that in industries where value added is organised in networks there are more points of entry for new firms, and therefore for ideas, than in vertically integrated industries. In this case providers of components and subcomponents would undertake responsibility for both the RDI and production of their parts. They conclude that modular systems may make innovation faster, above all in periods of uncertainty and change.

The advantages of modularisation for innovation have however been questioned by numerous scholars (Ernst 2005; Brusoni 2005). Based on his work of the electronics industry in Asia, the exemplar industry for the study of modularisation, Ernst (2005) argues that despite the increasing modularisation of RDI activities there are limits to modularisation as a result of fluid and rapidly evolving interoperability standards. Moreover, in industries which do not

have a modular structure or when subcomponents are closely integrated (e.g. pharmaceuticals or process-based industries) the integration of RDI activities is considered necessary (Pisano 2006); a point also acknowledge in Langlois and Robertson (1992). At the same time when innovation involves changes that span across stages of production or industries, information flows are likely to be more complex so that the break-up of the RDI value-chain could retard innovation (Langlois and Robertson, 1992). One interesting issue raised by Robertson and Langlois (1995) however is that in large organisation, ownership integration by itself does not guarantee the levels of coordination needed to solve problems of information fragmentation. The authors argue that sometimes these could be solved more effectively by closely linked networks that are not integrated by ownership.

Unlike the literature on innovation, studies of modularisation focus on the conditions required to separate RDI from production. In this context Pisano and Shih (2012) argue that when RDI and manufacturing are highly modular, the major characteristics of the product (e.g. features, functionality, aesthetics) are not determined by the production processes. In these cases RDI and manufacturing activities can be located far apart without negative consequences. Examples given by the authors include the writing of text, software, and music. On the other hand, when modularity is low (e.g. when product design can't be fully codified in written specifications and design choices influence manufacturing choices in difficult-to-predict ways) the co-location of RDI and manufacturing can be critical. In a number of industries where there is some degree of modularity, "design rules' have been established that ensure that designs will work given a specific manufacturing process as long as designers stay within those boundaries (Pisano and Shih 2012). Ernst (2005) however argues that when the technologies affecting the architectural design of products (their components as well as their manufacturing processes) keep changing in a fast and unpredictable way there is a greater need to integrate and coordinate activities. The point stressed by Ernst (2005) is that the importance of the co-location of design and manufacturing activities are contingent on the rate of technological change. Integration can be achieved however within a hierarchical firm or within a GVC where the 'lead' firm assumes the role of 'knowledge integrator' within the network. Therefore, even in industries prone to modularisation there are products and activities that require integration. Integration is also important when change is fast and unpredictable. However, the way that MNCs organise their activities to achieve integration can differ, a factor that increases the complexity of inter-firm GINs.

4 Approaches that focus on the meso scale (i.e. industry level)

4.2 Literature on global value chains (GVCs)

One of the most influential literatures analysing the new organisational forms of MNCs is the work on global value chains (GVCs) (Gereffi and Korzeniewicz, 1994; Gereffi 1994, 1999; Gereffi *et al* 2005; Humphrey and Schmitz 2002; Sturgeon 2002; Sturgeon *et al* 2008; Fernandez-Stark *et al* 2011). The following section will discuss the main elements of GVC theory, the importance of upgrading of supplier capabilities in GVCs, the GVC framework as a tool for the analysis of globalising industries and new trends in GVCs.

Studies of GVCs examine the global organisation of industries by examining the full range and sequence of value-adding activities within an industry from conception to production, end use and disposal. GVC analysis traces the international expansion and geographical fragmentation of production and has focused on issues of industry re-organisation, coordination, governance and power within GVCs (Gereffi and Lee 2012). It is important to note that in the GVC literature the notion of GVC includes activities such as R&D, design, production, marketing, distribution and customer support though in the main the GVC literature has tended to focus on production. The GVC literature therefore does not distinguish between GINs and GVCs because innovative activities are included in the general concept of value-added.

By focusing on the value chain rather than the integrated MNC as the unit of analysis, the GVC literature was one of the first to emphasise that although the activities that comprise a value-chain can all be undertaken within a single firm, they can also be distributed amongst different firms operating in geographically-dispersed inter-firm networks. Much of the GVC literature has therefore focused on the character and dynamics of the inter-firm networks which are formed around MNCs and the different types of governance arrangements adopted by MNCs (or 'lead firm' in GVC language) to give direction and coordinate their organisationally and geographically dispersed value-adding activities. The GVC literature has identified five modes of GVC governance: traditional markets and hierarchical firms but also three types of networks (modular, relational and captive). The way that lead firms break-up and govern their GVCs is determined by three sets of variables: (i) the complexity of the information exchange; (ii) the codifiability of knowledge and (iii) the capabilities of the

supply base (Gereffi *et al* 2005; Sturgeon *et al* 2008). The theory of GVC governance therefore deals with many of the challenges associated with the integration/modularisation of value-adding activities studied by scholars of innovation and modularisation discussed above (section 3).

The GVC literature has contributed to the analysis of the dynamics of the global structure of different industries and to our understanding of the role of different actors involved in the inter-firm networks created by MNCs. The GVC approach has been particularly influential in the study of the impact of globalisation on the upgrading strategies of firms from developing countries and the industrialisation of developing regions. The approach however has not been applied to the same extent to the analysis of MNCs from the point of view of the 'lead-firm' and how the organisational and geographical configuration of MNC activities has evolved (the work of Sturgeon being an exception to this).

In the main the GVC literature has focused on three dimensions of GVCs: (i) the way that tasks, activities, products and organisations are fragmented and geographically dispersed as well as the character of linkages between stages in the chain of value-added activities; (ii) the governance of GVCs and above all the way in which these global *inter-firm* networks are coordinated and governed. This dimension is linked to the distribution of power between firms and other actors in the chain; and (iii) the macro institutional context in which an industry's value-chain is embedded (Gerefi and Fernandez-Stark 2011; Sturgeon *et al* 2008; Gerefi 1995). These three dimensions have been use to analyse how industries evolve as well as the extent to which international linkages enhance the learning and upgrading efforts of firms, above all those from developing countries (Gereffi 1999; Ernst and Kim 2002; Giuliani *et al*, 2005; Schmitz 2006; Morrison *et al*, 2008; Pietrobelli & Rabellotti 2011; Humphreys & Schmitz 2002). The notion of 'upgrading' has been very influential, above all amongst scholars and policy makers interested in the patterns of industrialisation in developing countries. The upgrading of supplier capabilities is also critical for understanding the outsourcing of increasingly more complex activities- including some related to the RDI function- to independently-owned contractors located in developing countries.

The notion of upgrading refers to how firms learn and develop new capabilities within GVCs in order to undertake more complex activities. Following Humphrey & Schmitz (2002), the GVC literature has classified upgrading into *process upgrading*; *product upgrading*; *functional upgrading* which entails acquiring new functions (such as those related to RDI);

and *chain or inter-sectoral upgrading* where firms move into new chains or industries. The application of the GVC approach to the IT-driven service industry (what the GVC literature calls offshore services sector) has developed a different classification of upgrading for this sector including the shift from the provision of general IT services to 'knowledge process outsourcing' (KPO) activities and the development of RDI services for specific industries (Fernandez-Stark *et al* 2011). Qualitative studies of these service-based value-chains have picked up the increasing international outsourcing of some of the more repetitive and standardised IT-based RDI activities of US and European based MNCs (see the work of Fernandez-Stark and colleagues).

What makes GVCs particularly powerful from the point of view of the upgrading of supplier capabilities, above all but not exclusively in developing countries, is the purposeful transfer (rather than spillovers) of both codified and tacit knowledge within these global networks through both formal and informal mechanisms (Ernst and Kim 2002). Studies of GVCs show that in order to ensure that suppliers meet their standards for quality, speed and flexibility lead firms purposeful transfer both technical and managerial knowledge within GVCs. Much of the empirical research applying the GVC approach has found evidence that insertion in global networks does play a positive role in upgrading the capabilities of developing country firms, enhancing their technological and managerial knowledge and know-how (Ernst and Kim 2002; Gereffi 1999; Humphrey and Schmitz, 2002). However, empirical studies have found that the strength of these effects depend significantly on the already existing internal capabilities and absorptive capacity of firms (Cohen & Levinthal 1990; Ernst & Kim 2002; Schmitz 2006; Pietrobelli & Rabellotti 2011). Therefore, studies using the GVC approach indicate that the ability of firms to benefit from participation in GVCs also depend on the nature of national and regional innovation systems in which they are embedded (Ernst & Kim 2002; Humphrey & Schmitz 2002; Pietrobelli & Rabellotti 2010; Ramirez & Rainbird 2010).

Other scholars, whilst acknowledging the potential for knowledge transfer within GVCs, have also pointed to important limitations for capability upgrading within these networks (Schmitz 2006; Schmitz & Knorringa 2000; Bair & Gereffi 2001). For example, Humphrey & Schmitz (2002) argued that in industries where supplier capabilities are weak and product and process specifications are complex, suppliers may be confined to a narrow range of tasks

and be highly dependent on lead firms. So far, research evidence suggests that a multifaceted relationship exists between the capability of suppliers, the type and complexity of knowledge, the intellectual property appropriability strategy of lead firms, and the way GVCs are governed and that the interaction of these factors influence the dynamics of upgrading in GVCs (Schmitz 2006; Morrison *et al*, 2008; Pietrobelli & Rabellotti 2011; Ivarsson & Alvstam, 2005; Pavlínek and Ženka 2010).

The GVC literature does not make a clear separation between GVCs and GINs because RDI activities are seen as part of the value-adding activities off rims. This has meant that, in the main, the GVC literature has not focused on the organisational and locational links between production and RDI or between GVCs and GINs. A reading of specific industry case-studies carried out by scholars applying a GVC approach shows a complex picture. For example, Sturgeon (2002) argues that in the electronics industry product innovation was separated from process innovation and manufacturing and that this separation did not undermine the ability of MNCs (or lead firms) to innovate. He argues that as a result, a number of firms (e.g. Cisco systems) were able to win wide market share with little internal manufacturing capacity. These firms depended on a worldwide network of highly proficient contract manufacturers (who were not tied to specific MNCs) for nearly all their core manufacturing. The ability of firms to separate RDI and production is linked to the modular nature of this industry (see discussion in section 3.2) as the separation of product from process innovation and manufacturing in this industry was made possible because of the greater codification of knowledge and the use of standards. However, though modularisation enabled the organisational fragmentation of the industry the fact that within GVCs independently-owned and geographically dispersed firms share information (e.g. forecast and pricing data) in more intense and new ways is also associated with the adoption of new management practices (Ernst 2005).

4.2 GVC framework as a research tool

In the context of increasingly complex industry interactions as a result of the partitioning of activities which need to be integrated across a greater number of organisations and

geographically borders, GVC scholars argue that their approach and methodology can be used as a tool to trace shifting patterns of global production, link geographically dispersed activities and actors of a single industry, and determine the roles they play in both developed and developing countries (Gereffi and Fernandez-Stark 2011). Up to now, much of the work analysing changes in industrial organisation and the rise of GVCs has been carried out by a diverse and interdisciplinary network of scholars engaged in direct observational research of a set of global industries (Sturgeon *et al* 2008). This work has mainly been based on industry case-studies and has mainly focused on the dynamics of *inter-firm networks* which are part of GVCs. These studies have generated important insights relevant to innovation and the nature of knowledge flows within GVCs with potential implications for the location of RDI and productive activities (Gereffi, 1994, 1999; Sturgeon 2002, Sturgeon *et al* 2008, Sturgeon and van Biesebroeck 2011; Humphrey 2003, Humphrey and Memedovic 2003; 2011; Schmitt and van Biesebroeck 2013; Simona and Axèle 2012; Contreras *et al* 2012; Pavlinek 2012; Ernst 2005; 2009; Gereffi and Fernandez-Stark 2010; Fernandez-Stark *et al* 2011; Ramirez 2013). However in order to understand the impact of GVCs on the international division of labour in knowledge production and innovation and its implications for wealth creation and distribution, more aggregate-level studies based on quantitative data are required. One example of the attempt of GVC studies to develop quantitative indicators is Gereffi and Fernandez-Stark's (2010) research on the offshoring of services where the authors address the difficulties associated with measuring of the value of services by linking them to employee education levels and work experience. Sturgeon and Gereffi (2009) and Sturgeon *et al* (2013) discuss the limitations of existing trade statistics and quantitative studies for the analysis of GVCs which the authors argue do not tell all and often obscure key issues. For example, the authors reference studies that show how countries with the same industry exports can specialise in different types of products within the same industry with different implications for upgrading trajectories. They also argue that trade statistics contain very partial information about the location of value-added, and no information about the ownership of productive assets, the extent of meaningful linkages to the local economy or where profits are reaped (Sturgeon and Gereffi 2009). The authors call for the development of new methods and the collection of new information, such as internationally comparative data on business functions which would allow insights into how firms in different industries are bundling or unbundling, recombining and locating the different elements of their businesses. The work of Sturgeon and Gereffi therefore make the case for a mixed methods approach based on the

collection of qualitative and quantitative data for the study of GVCs but argue for the development of new indicators.

New Trends in GVCs

Gereffi (2014) argues that since the economic crisis of 2008-09 important changes have been taking place in the organisational and locational configuration of GVCs. One such change is the trend towards a streamlining of the number of suppliers in GVCs who are expected to be bigger, more capable and strategically located to access large markets (see also OECD 2012). Gereffi (2014) argues that this change has begun to undermine the great power asymmetries that characterised GVCs in the past with power shifting towards the top manufacturers located in large emerging economies. Gereffi (2014) argues that these countries have well-organized domestic supply-bases and they have upgraded their value-adding activities to include key input-suppliers as well as pre-production services such as R&D and design as well as post-production activities such as logistics, marketing and branding. Large developing countries have also become increasingly important as sources of demand and dynamic markets.

GVC scholars have tended to focus on the impact of GVCs for firms in developing countries and this literature has given important insights into how the upgrading of capabilities of developing country firms has changed the location and character of inter-firm networks. The literature however mainly focuses on production rather than innovation so it has not focused on the higher- value sections of GVCs or on GINs. Moreover, this literature has not dealt with how the new changes in manufacturing technologies are likely to affect the organisational and locational configuration of GVCs and GINs.

5 Macro-studies

5.1 IB and geography

Geographers and International Business (IB) scholars have in the main tended to focus on flows of foreign direct investment (FDI) in RDI but have not paid much attention to how technology is created or how innovation takes place and how this impacts on the

organisational or geographical architecture of GINs (Cantwell 2017). More recently however both of these literatures have started to created bridges to micro-level studies in order to understand how the process of innovation affects the configuration and dynamics of GINs as well as the manufacturing activities of MNCs (see for example Rezk *et al* 2016; Alcácer *et al* 2016; Iammarino and McCann 2013; Cantwell 2017). Both IB and the geography literatures have also acknowledged that significant changes are taking place in the organisation of MNCs (Cantwell 2017; Iammarino and McCann 2013).

This section discusses the literature by IB scholars and geographers focusing on the motives for the internationalisation of RDI activities, the co-location of RDI and manufacturing activities and the evolution of IB networks as a result of the emergence of new manufacturing technologies.

Studies of early internationalisation of RDI activities by MNCs showed that, in the majority of cases, this activity tended to be concentrated in developed capitalist economies (Patel and Pavitt 1998). Since the 2000s however there has been increasing evidence that MNCs are becoming more geographically dispersed and are locating some of their RDI effort in developing countries (UNCTAD 2005; Athreye and Cantwell 2007; Lewin *et al* 2009; Manning *et al* 2008; Bruche, 2009; Moncada-Paternó-Castello *et al* 2011; D'Agostino *et al* 2013; OECD 2016). Cantwell (2017) notes however that the pace of internationalisation differs between regions with European MNCs internationalizing earlier than their US counterparts whilst Japanese MNCs have been slower to internationalise. Moreover, the rise of MNCs from China and India has meant that MNCs from those two countries are also increasingly internationalising their RDI activities (Belderbos *et al* 2016).

In terms of the motivation for the internationalisation of RDI activities by MNCs, IB studies show that in the early period of RDI internationalisation the main drivers for locating RDI activities outside the home country was to support productive activities abroad as well as to adapt existing products and production processes to local markets and production conditions (Pavitt and Patel 1991; Pearce 1999; Dunning and Lundan 2008; Teece 2010). In recent IB literature this has been referred to as *asset-exploiting R&D* activities. In this early period of internationalisation therefore the international location of RDI facilities often tended to follow the internationalisation of production (Ivarsson *et al* 2017). From the early 1990s research began to highlight new motivations for RDI internationalisation associated with

efforts to acquire and gain access to international science and technology capabilities (OECD 1992; Chesnais 1992; Cantwell 1992, 1995, 2017; Pearce 1989, 1999; Dunning and Lundan 2008; Narula 2005; Castellani *et al* 2013). This has been referred to as *asset-augmenting or knowledge-seeking* (Cantwell 2017) RDI internationalisation. Above all the increasing importance of scientific knowledge for innovation associated advances in ICT and biotechnology from the mid-1980s drew attention to locations close to academic research centres and their clusters of spin-out firms as attractive locations for the RDI activities of MNCs from science-based industries. Since then, much attention has focused on the location of RDI activities close to centres of scientific excellence (and more recently areas of high connectivity) and on the linkages between RDI and territorially embedded systems of science and technology. Despite recognition of the importance of knowledge-seeking RDI internationalisation, IB scholars have continued to argue that the core of these firms' technology remains concentrated in the country of origin (Cantwell 2017 , OECD 2016). Therefore, when MNCs go abroad to seek new technologies it is to access technologies in 'other industries' (e.g. an electrical equipment MNC acquiring a chemical plant abroad). Due to the importance of shift in RDI investment to centres of scientific excellence less attention has been paid to the location of RDI activities that are more closely integrated with the production process despite the fact that as argued in (section 3.1) much of what constitutes industrial RDI activities is development and testing of products and production systems.

Studies of FDI in RDI activities to developing countries indicate that more recently access to lower-cost skilled workers has become an important motivation for the internationalisation of RDI activities (Lewin *et al* 2009). At the same time, recent research of international RDI facilities in both developed and developing countries which are co-located with manufacturing plants show that the main objective of this international research effort is not to adapt existing technology to local conditions but to develop new technologies for global markets (Ivarsson *et al* 2017; Ivarsson and Alvstam 2017). In these instances co-location has been driven by strong functional links and reciprocal information flows between RDI and manufacturing. The authors argue that co-location is becoming important in the context of a growth of business-to-business relationships and the co-development of products with key local customers. Moreover, the co-location of manufacturing and RDI facilities in developing countries is increasing in importance as MNCs design and develop industrial products specifically for emerging markets (Ivarsson and Alvstam 2017). The key point here therefore

is that in some industries RDI and production facilities are being co-located in foreign markets in order to develop new products for global markets.

Whilst much of the work of IB scholars and geographers has focused on intra-firm GINs there has been an increasing acknowledgement of significant changes in the organisation of these firms resulting in greater organisational decentralization and geographical dispersal of activities (Dunning 1994; Dunning and Lundan 2009; Alcácer *et al* 2015; Cantwell 2017; Iammarino and McCann 2013). Cantwell (2017) uses the term IB networks to refer to the present MNC and argues that IB scholarship is moving from a focus on the MNC towards the analysis of more open IB networks structures. In this context Cantwell (2017) refers to the increasing importance of *knowledge-seeking inter-firm* GINs (he uses the term *inter-organisational networks* to refer to the same phenomenon) which are organised in order to promote joint learning. The growth in the significance of inter-firm networks has led to more complex knowledge systems and has generated increasing interconnectedness between intra-firm and inter-firm networks blurring the boundaries of firms (Cantwell 2013). Cantwell (2017) also notes the importance of the empirical challenges associated with the shift from a conceptualisation of the MNC as an organisation defined by ownership to one where the network 'lead' controls and orchestrates value-added activities in networks based on collaboration.

New manufacturing technologies

Up to now IB scholars have emphasised how ICT has enabled the geographical dispersal of the intra-firm GINs. More recently, however scholars have begun to explore the impact of the new manufacturing technologies on the geographic span and density of GVCs as well as the balance between MNCs and SMEs in international business. Laplume *et al* (2016) for example argue that technologies such as 3D printing could partially reverse the trend towards fragmented, specialized and globally dispersed supply chains in upstream activities but increase the geographic dispersal of final stage production closer to end-users and markets. This suggests that the process of GVC restructuring would include both the geographic concentration of some activities and the greater dispersal of others. Similarly, Rezk *et al* (2016) find that the impact of the new generation of manufacturing technologies will have both centralisation and decentralisation effects on different RDI and manufacturing activities along the value-chain.

5.2 OECD

This section identifies how OECD has conceptualised GVCs and GINs and discusses the finding from patent and FDI data on the internationalisation of RDI activities RDI collaborations as well as the co-location of RDI and manufacturing activities. In their analysis of GVCs, OECD (2011) adopts the conceptualisation of GVCs developed by the GVC literature which includes both production and RDI activities. In OECD (2016) a distinction is made between GVCs which focus of production and GINs which are conceptualised as the inter and intra-firm R&D networks of MNCs and are distinct from production (a distinction not made in the GVC literature). The notion of GINs also includes universities and goverment research institutes and they are seen to link various science and technology actors across different countries (OECD 2016). The notion of GINs used by OECD (2016) therefore gives greater weight to the linkages MNCs establish with science and technology systems than the GVC literature which focuses on RDI activities in the context of production. In this sense OECD (2016) makes a sharper distinction between RDI and production whils the innovation and GVCs literature see these two sectors as interlinked and interdependent.

Separating GINs from GVCs enables OECD (2016, p3) to conceptualise GVCs as 'the international transfer of material goods' while GINs are associated with the 'transfer of intangibles and immaterial assets'. OECD (2016) uses patent data and in particular information on international co-invention to identify and analyse GINs, though it notes that there are important differences in the propensity to patent between industries so that this indicator does not allow for the identification of all types of GINs across countries and industries. The use of patent data to study GINs therefore limits the study of these networks to particular industries and to particular types of RDI activities. Above all it does not pick up many of the interactions and collaborationsin within inter-firm GINs linked to the diffusion of tacit knowledge or activities which involve service firms that undertake a RDI task under contract but do now own intellectual property as occurs in cintract-based inter-firm GINs.

The OECD (2016) study shows the importance of MNCs in both patenting in general as well as in international co-invention. It finds that more than 60% of all PCT patent applications were related to MNC activities (i.e. where an MNC- headquarter or affiliate- was the only one or one of the applicants of the patent (OECD 2016, p7). For co-invention the importance of MNCs was even greater with two-thirds of co-inventions linked directly to MNC activity. Fifty percent of these co-inventions were between inventors in different countries but within

the same MNC, that is within the *intra-firm GINs* of MNCs. In terms of international co-invention, intra-firm GINs from US, German and Swiss MNCs make the top-3 larges applicants.

The OECD (2016) study also shows that companies in North America and Europe still dominate international co-operation in invention as together they were responsible for more than 80% of all international co-inventions between 1995 and 2013. Patent data indicates strong intra-regional cooperation, above all in Europe, as well as between regions. Patent data also shows the growth in the importance of Asia as a location for innovation between 1995-2004 and 2005-2013 as Asian partners increasingly collaborate in innovation with North American and to a lesser extent European partners. Intra-regional co-inventions in Asia also increase over time but less strongly than the extra-regional links. Patent data show a change in the geography of co-invention over the past decades with GINs becoming denser and a broadening of the geographic scope of these networks. Above all, South East Asia has been incorporated into the GINs of MNCs from the US and Europe. However, aside from Brazil and Chile, countries in South America and the Africa region are not locations for the innovative activities of MNCs.

In a detailed analysis of close to 5000 cross-border Greenfield projects in RDI in global cities over the period (2003-2011), Belderbos *et al* (2016) show that the majority of these international projects concern development, design and testing. The authors argue that these are activities that often benefit from close proximity to major markets and it is implied that these intra-firm RDI activities are related to product adaptation. The study by Belderbos *et al* (2016) also shows that a substantial share of international Greenfield RDI investment has been going to Asian markets with internationally connected 'global cities', however in more recent years –above all after the financial crisis- the shift to the East has slowed down and OECD countries (e.g. USA, Germany and the UK) have attracted a growing number of international RDI investments. The study by Belderbos *et al* (2016) does show however that developing countries such as China and India have themselves increasingly invested in RDI activities abroad, a pattern supported by the IB literature.

The co-location of GVCs and GINs has also been explored by OECD (2016; Belderbos *et al* 2016). This question is particularly relevant given concerns that because of co-location

effects between production and innovative activies the offshoring of production today may result in the offshoring of RDI investment in the future (OECD 2013). Comparing GVCs and GINs, OECD (2016) found that trade networks appear more intensive with thicker links than GINs and although GINs have become more intensive in the period 2005-2013 they are not as intense as GVCs. Overal GINs show a more concentrated pattern with a small number of partners cooperating in innovation. GVCs are more dispersed and countries trade with more partners than they co-invent. There is however a significant geographic overlap between GINs and GVCs. There appears to be a strong concentration of international co-invention and trade across the large regions with important hubs in the US, Europe (around Germany and France) and East Asia (around Japan, China and Korea).

A more formal analysis was undertaken to asses the interdependencies between GVCs and GINs. OECD (2016) was interested in understanding whether countries that trade with each other in GVCs also have higher co-invention rates with each other in GINs, and if countries that start to trade more intensively subsequent exhibit higher co-invention rates. The research found strong and positive corelations between bilateral trade and co-invention suggesting the interdependence between GVCs and GINs at the country level. However, using data from the fDi Markets Database, the study by Belderbos *et al* (2016) found that the majority of RDI investments in a city (67%) did not follow any prior investment. Follow-on RDI investment into a city however tended to be higher when the firm already had invested in RDI in that city or when it had already invested in a core activity (manufacturing or services). The study also showed that co-location patterns tended to be higher in developing countries and this investment was more likely to take place when the firm already had invested in RDI in that city. Supporting the findings of micro studies which indicate that co-location patterns differ accross industries, Belderbos *et al* (2016) show that the co-location effects between RDI and manufacturing were stronger for engineering intensive industries than for what the authors call RDI-separable industries such as pharmaceuticals where important RDI activities tend to be located close to the science-base rather than production. The authors argue however that while co-location is important it is also dependent on firm-specific organisational factors as well as the maturity of technologies, the modularity of the industry and its production process and the complexity of the production processes.

6 General Conclusion

Despite differences in terminology and conceptualisation the literature identifies a shift in the organisation of international value-adding activities towards the creation of geographically dispersed intra and inter-firm networks created, coordinated and governed by powerful lead firms. Lead firms are often the traditional MNCs whose ability to integrate systems or networks is no longer solely based on ownership but now includes a broad range of cooperative relations.

Though the GVC literature includes RDI activities within their concept of GVC given the specific nature of the RDI process we think it is useful to make a distinction between GINs and GVCs, where GINs refer to activities related to learning, knowledge-creation and innovation and GVCs refer to activities associated with production. In this sense the concept of GINs focuses on the internal knowledge-systems of the MNC as well as the external knowledge-systems with which the MNC interacts. The internal knowledge-system includes all RDI activities within the MNC purposefully established to promote and support product and process innovation. External-knowledge systems include the global, regional, national and sub-national public and private science and technology organisations and institutions as well as private RDI service firms which are an important part of the KIBS sector of the economy. However, as discussed in the literatures on innovation and modularity there is often a significant overlap and integration between innovation and production (i.e. GINs and GVCs), above all in engineering-based and process-based industries. In these cases the internal knowledge-system of the MNC is tightly coupled with the system of production and the co-location of activities which are part of GINs and GVCs is necessary blurring the boundaries between the two systems. It is also important to note that important learning, knowledge-creation and innovation also takes place within the system of production as part of the routine activities of firms. Therefore, though the conceptual distinction between GINs and GVCs can be useful, it can also obscure important RDI activities taking place in GVCs.

At this stage we think it is useful to make a distinction between GINs and GVCs, where GINs refer to the knowledge-creation and innovation systems of MNCs and GVCs refer to their systems of production. In some industries, however, GINs and GVCs are tightly coupled so empirically they cannot be easily distinguished. We also identify three different types of GINs: (i) intra-firm GINs; (ii) knowledge-seeking inter-firm GINs; and (iii) contract-based inter-firm GINs. Though distinct, these three types of GINs are sometimes tightly linked leading, in some instances, to the co-location of these three types of organisational

arrangements. We therefore identify the following four types of networks that can be created by a MNC to undertake its RDI activities (see figure A in annex):

- Intra-firm GINs (A in diagram)
- Knowledge-seeking inter-firm GINs (B in diagram)
- Contract-based inter-firm GINs (C in diagram)
- GVCs (D in diagram)

From the review of the literature it is clear that one of the main challenges with the study of GINs is that their organisational and locational configuration varies according to industry, function and activity, as well as according to firm-specific strategies. Moreover, both GINs and GVC s are dynamic organisations and their configuration changes over time according to factors such as the maturity of the technologies. A further challenge is that in the next period GINs and GVCs are likely to change significantly due to the impact of new manufacturing technologies which are likely to centralise some activities and decentralise others.

Given our still poor understanding of the nature, configuration and linkages between GINs and GVCs and above all of the changes these organisations are likely to experience in the next period as a result of the diffusion of new manufacturing technologies, we suggest that qualitative industry-specific studies should complement the collection of more aggregate quantitative data. The qualitative studies should be conducted on a regular basis and be the foundation of a qualitative database of industrial GINs and GVCs. Given the expected turbulence in the organisation of GINs and GVCs as a result of the diffusion of new manufacturing technologies, qualitative studies should be exploratory in nature and include information about the organisational and geographical configuration and re-configuration of the GINs and GVCs of the industries critical for European development. These data should enable a greater understanding of the configuration of different GINs and GVCs both within different keys firms in an industry as well as between industries. The data should also identify patterns in the dynamics of GINs and GVCs above all in the context of manufacturing turbulence. Qualitative data should also identify new types of quantitative indicators that are generated and can be collected from both GINs and GVCs. Of special attention here is the development of indicators capable of tracing inter-firm GINs which have proved particularly difficult to measure. This data should also facilitate the interpretation of the findings of quantitative studies in the context of complex interactions and change. An example of this is how issues of intellectual property protection and patenting are organised within inter-firm GINs, above all contract-based-interfirm GINs, in the context of the increasing fragmentation and outsourcing of tasks.

References

Abele, E., Meyer, T., Näher, U., Strube, and Sykes, R., 2008, Global production: A handbook for strategy and implementation. Berlin: Springer.

Alcácer, J., Cantwell, J., Piscitello, L.,2016, Internationalization in the information age: A new era for places, firms and international business networks. Journal of International Business Studies, 47, pp 499-512.

Archibugi, D. and Michie, J, 1997, The Globalisation of Technology: a New Taxonomy', in Archibugi, D. and Michie, J., (eds) Technology, Globalisation and Economic Performance, Cambridge University Press.

Athreye, S., and Cantwell, J., 2007, 'Creating competition? Globalisation and the emergence of new technology producers', Research Policy, 36 (2), pp 209-226.

Bair, J., and Gereffi, G., 2001, Local clusters in global chains: the causes and consequences of export dynamism in Torreon's blue jeans industry, World Development, Vol 29 (11), pp 1885-1903.

Baldwin, C. Y., and Clark K.B, 2000, Design rules: The power of modularity, MIT Press, Cambridge.

Baldwing, C. Y., 2007, Where do transactions come from? Modularity, transactions, and the boundaries of firms, Industrial and Corporate Change, Vol 17 (1), pp 155-195.

Barnard, H., and Chaminade, C., 2011, Global Innovation Networks: what they are and where can we find them. feemdeveloper.net.

Belderbos, R., Sleuwaegen, L., Somers, D., and De Backer, K., 2016, Where to Locate Innovative Activities in Global Value Chains: Does OECD Science, Technology and Industry Policy Papers,Co-Location Matter?, No. 30, OECD, Paris.

Bruche, G., 2009, 'The Emergence of China and India as new competitors in MNCs' innovation networks', Competition and Change, Vol 13 (3), pp 267-288.

Brusoni, S, Prencipe, A., and Pavitt, K., 2001, Knowledge specialization, organizational coupling, and the boundaries of the firm: why do firms know more than they make?, Administrative Science, Vol 46, Issue 4.

Brusoni, S., 2005, The Limits to Specialization: Problem Solving and Coordination in 'Modular Networks', Organization Studies, 26 (12), pp 1885-1907.

Cantwell, J., 1992, The Internationalisation of Technological Activity and its Implication for Competitiveness', in Granstrand. O et a.l (eds), Technology Management and International Business, John Wiley and Sons.

Cantwell, J., 1995, 'The Globalisation of Technology: What Remains of the Product Cycle Model?', Cambridge Journal of Economics, 19, pp155-174.

Cantwell, J., 2017, Innovation and international business, Industry and Innovation, 24 (1), pp 41–60.

Cantwell, J., 2013, Blurred Boundaries between Firms, and New Boundaries within (Large Multinational) Firms: The Impact of Decentralized Networks for Innovation, Seoul Journal of Economics, Vol.26(1), pp 1-32.

Caraça, J., Lundvall, B.A., Mendonça, S., 2009, The changing role of science in the innovation process: From Queen to Cinderella? Technology Forecasting & Social Change, 76 (6), pp 861-867.

Castellani, D; Jimenez, A., Zanfei, A., 2013, How remote are R&D labs? Distance factors and international innovative activities, Journal of International Business Studies, Vol 44 (7), pp 649-675.

Chen, S-H., 2004, Taiwanese IT firms' offshore R&D in China and the connection with the global innovation network, Research Policy, Vol 33, pp 337-349.

Chesbrough, H. W.,2003, Open Innovation, Harvard Business School Press, Boston

Chesnais, F., 1992, National Systems of Innovation, Foreign Direct Investment and the Operations of Multinational Enterprise', in Lundval.BA, (ed), National Systems of Innovation, Pinter Publishers, London.

Chesnais, F., 1996, Technological Agreements, Networks and selected Issues in Economic Theory', in (Eds) Cooms., R, Richards., A, Saviotti., P. and Walsh. V., Technological Collaboration: The Dynamics of Cooperation in Industrial Innovation.

Cohen,W., and Levinthal,D., 1990, Absorptive Capacity: A New Perspective on Learning and Innovation, Administrative Science Quarterly, Vol 35 (1), pp128-152

Contractor, F.J., V. Kumar, S.K. Kundu, and T. Pedersen, 2010, Reconceptualising the Firm in a World of Outsourcing and Offshoring: The Organizational and Geographical Relocation of High-Value Company Functions', Journal of Management Studies 47:8.

Contreras, O.F., Carrillo, J., Alonso, J., 2012, Local Entrepreneurship within Global Value Chains: A Case Study in the Mexican Automotive Industry, World Development, Vol. 40 (5), pp 1013–1023.

Cooke, P., 2011, Global Innovation Networks, Territory and Services Innovation In (Ed) Cuadrado-Roura, J., Service Industries and Regions, Springer Publishers.

D'Agostino, L.M. and Santangelo, G.D., 2012, 'The Global Fragmentation of R&D Activities: The home region perspective', DRUID Working Paper No. 12-06.

D'Agostino., L. M., Laursen, K., and. Santangelo, G.D., 2013, 'The impact of R&D offshoring on the home knowledge production of OECD investing regions', Journal of Economic Geography, Vol 13, pp 145–175.

Dosi, G., 1988, 'The Nature of the Innovative Process', In Dosi, ,G., et al Technical Change and Economic Theory.

Dosi. G, Freeman. C, Nelson. R, Silverberg. G, Soete. L. (eds), 1988, Technical Change and Economic Theory, Pinter Publishers Ltd, UK.

Dosi, G., and Nelson, R., 2010, Technical Change and Industrial Dynamics as Evolutionary Processes, In Hall, .B., and Rosenberg, N., Economics of Innovation, North-Holland

Dunning, J., 1994, 'Multinational Enterprises and the Globalisation of Innovatory Capacity', Research Policy, 23, pp 67-88.

Dunning, J., 1997, "Alliance capitalism and Global Business, Routledge.

Dunning, J., and Lundan, S., 2008, Multinational Enterprises and the Global Economy, Edward Elgar (second Edition), UK.

Ernst, D. and Kim, L., 2002, 'Global production networks, knowledge diffusion, and local capability formation', Research Policy, Vol 31, pp 1414-1429.

Ernst, D., 2005, Limits to Modularity: Reflections on recent Developments in Chip Design, Industry and Innovation, Vol. 12 (3), pp 303-335.

Ernst, D., 2009, A New Geography of Knowledge in the Electronics Industry: Asia's Role in Global Innovation Networks, Policy Studies, Series 54.

Fernandez-Stark, K., Bamber, P., and Gereffi, G., 2011, The Offshore services Value Chain: upgrading trajectories in developing countries, International Journal of Technological Learning, Innovation and Development, Vol 4 (1,2,3)

Freeman, C., 1982, The Economics of Industrial Innovation, Second edition, Pinter Publishers.

Freeman, C., 1991, Networks of Innovators: A Synthesis of Research Issues', Research Policy 20, pp 499-514.

Gereffi, G. and Korzeniewicz, M., (Eds) 1994, Commodity Chains and global Capitalism. Westport: Praeger Publishers.

Gereffi, G.,1994, The organisation of Buyer-Driven Global Commodity Chains: How U.S retailers shape overseas production networks. In Gereffi, G. and Korzeniewicz, M., (eds) Commodity Chains and global Capitalism. Westport: Praeger Publishers.

Gereffi, G., 1999, International trade and Industrial Upgrading in the Apparel Commodity Chain, Journal of International economics, 48 (1): 37-70.

Gereffi, G., 2014, Global value chains in a post-Washington Consensus world. Review of International Political Economy, Vol. 21 (1), pp 9–37.

Gereffi, G., Humphrey, J. and Sturgeon, T., 2005 'The Governance of Global Value Chains', Review of International Political Economy, 12:1:78-104.

Gereffi, G., and and Lee, J., 2012, Why the World Suddenly Cares about Global Supply Chains, Journal of Supply Chain Management, Vol 48 (3), pp 24-32.

Gereffi, G., and Fernandez-Stark, K., 2010, The offshore Services Value Chain: Developing Countries and the Crisis, In: Cattaneo, O., Gereffi, G., and Staritz (eds): Global Value Chains in a Post-crisis World. World Bank, Washington D.C.

Giuliani, E., Pietrobelli, C., and Rabellotti, R., 2005 Upgrading in Global Value Chains: Lessons from Latin American Clusters', World Development, Vol 33 (4), 459-573.

Granstrand. O, Hakanson. L., Sjolander. S, 1992, Technology Management and International Business: Internationalisation of R&D and Technology, John Wiley and Sons.

Granstransd, O., Patel, P., and Pavitt, K., 1997, Multi-technology corporations: why they have "distributed" rather than "distinctive core" competencies, Californian Management Review, Vol 39, Issue 4.

Grimpe, C., and Kaiser, U., 2010, 'Balancing Internal and External Knowledge Acquisition: The Gains and Pains from R&D Outsourcing', Journal of Management Studies, 47 (8), 1483-1509.

Hagedoorn, J and Schakenraad. J., 1990, 'Inter-Firm Partnerships and Co-Operative Strategies in Core Technologies', in Freeman. C., and Soete. L., (Eds), New Explorations in the Economics of Technical Change.

Hagedoorn. J, 1993, 'Understanding the Rationale of Strategic Technology Partnering: Inter-organisational Nodes of Cooperation and Sectoral Differences', Strategic Management Journal Vol. 14, pp371-385.

Henderson, J, Dicken, P., Hess, M., and Coe N., 2002, Global production networks and the analysis of economic development, Vol 9 (3), 436-464.

Howells, J., 1995, Going Global: the use of ICT networks in research and development', Research Policy, Vol 24, pp 169-184.

Howells, J., 1999, 'Research and Technology Outsourcing', Technology Analysis & Strategic Management, Vol. 11, No 1, pp 17-29.

Howells, J., 2008, New directions in R&D: current and prospective challenges, R&D Management, Vol 38, Issue 3, pp 241–252.

Howells, J., Gagliardi, D., and Malik, K., 2008, The growth and management of R&D outsourcing: evidence from UK pharmaceuticals, R&D Management, Vol 38, 2, pp 205-219

Hsuan, J. and Mahnke, V., 2011, 'Outsourcing R&D: a review, model and research agenda', R&D Management, 41 (1), pp 1-7.

Humphrey, J., 2003, Globalization and supply chain networks: the auto industry in Brazil and India, Global Networks, Vol 3 (2), pp 121–141.

Humphrey, J., and Schmitz, H., 2002 , How Does Insertion in Global value Chains Affect Upgrading in Industrial Clusters? Regional Studies, Vol 36 (9), pp 1017-1027.

Humphrey. J., Memedovic, O., 2003, The Global Automotive Industry Value Chain: What Prospects for Upgrading by Developing Countries. Vienna, United Nations Industrial Development Organization (UNIDO). Vol 33 (8), pp 1325-1344.

Iammarino, S., and McCann, P.,2013, Multinationals and Economic Geography, Edward Elgar, U

Ivarsson, I., Alvstam, C.G., 2005, Technology Transfer from TNCs to Local Suppliers in Developing Countries: A Study of AB Volvo's Truck and Bus Plants in Brazil, China, India and Mexico. World Development, Vol 33 (8), pp 1325-1344.

Ivarsson, I., Alvstam, C.G. and Vahlne, J-E., 2017, Global technology development by co-locating R&D and manufacturing: the case of Swedish manufacturing MNEs , Industrial and Corporate Change, Vol. 26 (1), pp 149-168.

Ivarsson, I., and Alvstam C.G., 2017, New technology development by Swedish MNEs in emerging markets: the role of co-location of R&D and production Asian Business Management, Vol 16 (1-2), pp 92-116.

Ketokivi, M and Ali-Yrkkö, J.,2009, Unbundling R&D and Manufacturing: Post-industrial Myth or Economic Reality? Review of Policy Research, Vol 26 (1-2), pp 35-54.

Kline, S.J, and Rosenberg. N., 1986, An Overview of Innovation, in National Academic Engineering, the Positive Sum Strategy: Harnessing Technology for Economic Growth, The National Academic Press, Washington DC.

Langlois, R., and Robertson, P., 1992, Networks and Innovation in a modular system: Lessons from the microcomputer and stereo component industries, Research Policy, Vol 21, pp 297-313.

Laplume, A., Petersen, B., and Pearce, J.M., 2016, Global Value Chains froma 3D printing perspective, Journal of International Business Studies, Vol 47 (5), pp 595-609.

Liu, J., Chaminade, C., and Asheim, B., 2013, The geography and structure of global innovation networks: a knowledge base perspective,European Planning Studies, Vol 21 (9), pp 1456-1473.

Lundvall B.A., and Borras, S., 1997, 'The Globalising Learning Economy: Implications for Innovation Policy', Report from seven projects under TSER programme, Directorate-General Science, Research and Development of the European Union.

Malerba, F., 2002, Sectoral systems of innovation and production, Research Policy, Vol 31 (2), pp 247-264.

Manning, S., Massini, S., and Lewin, A.Y.,2008, A dynamic perspective on next-generation offshoring: The global sourcing of science and engineering talent. Academy of Management Perspective, Vol 22 (3), pp 35-54.

Martinez-Noya, A., Garcia-Canal, E., and Guillen, M., 2012, International R&D service outsourcing by technology-intensive firms: Whether and Where? Journal of International Management, 18, pp 18-37.

Massini, S., and Miozzo, M., 2010, 'Outsourcing and offshoring of knowledge-intensive business services: implications for innovation', In F. Gallouj and F. Djellal (eds), The Handbook of Innovation and Services, Edward Elgar, Cheltemham UK and Northampton, USA.

Massini, S., and Miozzo, M., 2012, 'Outsourcing and Offshoring of Business Services: Challenges to Theory, Management and Geography of Innovation' Regional Studies, 46 (9), 1219-1242.

Moncada-Paternó-Castello, P., M. Vivarelli and P. Voigt , 2011, 'Drivers and impacts in the globalization of corporate R&D: an introduction based on the European experience', Industrial and Corporate Change, Vol 20, (2), pp 585–603.

Morrison, A., Pietrobelli, C., Rabellotti, R., 2008, Global Value Chains and Technological Capabilities: A Framework to Study Learning and Innovation in Developing Countries, Oxford Development Studies 36 (1), pp 39-58.

Mudambi, R., and Venzin, M., 2010, The strategic nexus of offshoring and outsourcing decisions, Journal of Management Studies, Vol 47 (8), pp1510-1533.

Mudambi, S and Tallman. S., 2010, Make, Buy or Ally? Theoretical Perspectives on Knowledge Process Outsourcing through Alliances. Journal of Management Studies, 47(8), 1435-1456.

Mytelka, L.K., 1990, New Modes of International Competition: The Case of Strategic Partnering in R&D', Science and Public Policy, Vol 17, (5) pp 296-302.

Mytelka, L.K., 1991, (Ed) Strategic Partnerships and the World Economy, Pinter Publishers, London.

Mytelka, L.K., 1999, 'Mergers, Acquisitions and Inter-Firm Technology Agreements in the Global Learning Economy', Paper presented at the European Socio-Economic Research Conference, Brussels, 28-30 April.

Narula, R., and Zanfei, A.,2005, 'Globalization of Innovation: The Role of Multinational Enterprises', in J. Fagerberg, D. Mowery, and R. Nelson, R., The Oxford Handbook of Innovation, Oxford University Press.

OECD 1992 Technology and the Economy: The Key Relationships, OECD, Paris.

OECD, 2012, Mapping global value chains. OECD Trade Policy Papers NO: 159, Paris, The OECD Conference Centre, Paris.

OECD, 2014, Science, Technology and Industry Outlook 2014.

OECD, 2016, The links between global value chains and global innovation networks: An exploration, OECD, Paris.

Patel, P., and Pavitt, K., 1991, Large firms in the production of the world's technology: an important case of non-globalisation, Journal of International Business Studies, Vol, 22 (1)

Patel, P., and Pavitt, K., 1998, 'National Systems of Innovation under Strain; The Internationalisation of Corporate R&D', Paper presented at the Technologie et Connaissance dans la Mondialisation, Pointiers, 9-10-11 September 1998.

Pavitt, K., 1984, 'Sectoral Patterns of technical Change: Towards a Taxonomy and a Theory', Research Policy, Vol 13, pp 343-373.

Pavitt, K., 1999, The nature of technology, In, Pavitt., K., 1999, Technology management and systems of innovation, Edward Elgar.

Pavlinek, P., 2012, The Internationalization of Corporate R&D and the Automotive Industry R&D of Central Europe, Economic Geography, Vol 88 (3), pp 279-310.

Pavlínek, P., and Ženka, J.,2011, Upgrading in the automotive Industry: Firm-level evidence from Central Europe, Journal of Economic Geography, Vol 11, pp 559-586.

Pearce, R., 1989, "The Internationalisation of Research and Development by Multinational Enterprises, MacMillan, London.

Pearce, R., 1999, 'Decentralised R&D and Strategic Competitiveness: Globalised Approaches to Generation and Use of Technology in Multinational Enterprises (MNEs)', Research Policy, Vol 28, pp 157-178.

Pietrobelli, C., Rabellotti, R., 2011, Global Value Chains Meet Innovation Systems: Are There Learning Opportunities for Developing Countries? World Development, Vol3 (7), pp1261-1269.

Pisano, G., 1996, Learning-before-doing in the development of new process technology, Research Policy, Vol 25 (7), pp 1097-1119.

Pisano, G., 2006, Science Business, Harvard Business School Press, Boston

Pisano, G., and Shih, W.C.,2012, Does America Really Need Manufacturing, Harvard Business Review, Issue: March 2012.

Ramirez, P., 2006, 'The globalisation of research in the pharmaceutical industry: A case of uneven development', Technology Analysis and Strategic Management, Vol 18(2), 143-167.

Ramirez, P., 2013, The New Modes and Geography of Pharmaceutical R&D: Implications for policy Service Gap Discussion paper number 49.
http://www.servicegap.org/images/Publications/DP49_Pharma_Ramirez.pdf.

Ramirez, P., Rainbird, H., 2010, Making the connections: bringing skill formation into global value chain analysis, Work, Employment and Society, Vol 24 (4), pp 699–710.

Rezk, Rahsa; Srai, J. S., Williamson, P. J., 2016, The impact of product attributes and emerging technologies on firms' international configuration Journal of International Business Studies, 47, pp 610-618.

Rifkin, J.,2014, The Zero Marginal Cost Society. Palgrave Macmillan.

Robertson, P., and Langlois, R. N., 1995, Innovation, Networks, and Vertical Integration, Research Policy, Vol 24 (4), pp 543-562.

Rothwell, R., 1977, The Characteristics of Successful Innovators and Technologically Progressive Firms, R&D Management, Vol 7 (3), pp 191-206.

Sako, M., 2006, Outsourcing and offshoring of business services: Implications for Productivity', Oxford Review of Economic Policy, Vol 22 (4), pp499-512.

Saliola, F., and Zanfei, A., 2009, Multinational firms, global value chains and the organization of knowledge transfer, Research Policy, Vol 38 (2), pp 369-381.

Sanchez, R., and Mahoney, J.T., 1996, Modularity, Flexibility, and knowledge management in product and organisational design, Strategic Management Journal, Vol 17, pp 63-76

Schmitz, H., 2006, Learning and Earning in Global Garment and Footwear Chains, The European Journal of Development Research, 18 (4), pp 546-571.

Schmitz, H., Knorringa, P., 2000, Learning from Global Buyers, The Journal of Development Studies, 37 (2), pp 177-205.

Schmitt, A and Van Biesebroeck, J., 2013, Proximity strategies in outsourcing relations: The role of geographical, cultural and relational proximity in the European automotive industry, Journal of International Business Studies, Vol 44, pp 475–503.

Simona, G-L., Axèle, G., 2012, Knowledge Transfer from TNCs and Upgrading of Domestic Firms: The Polish Automotive Sector, World Development Vol 40 (4), pp 796–807.

Sturgeon, T., 2002, Modular production networks: a new American model of industrial organization, Industrial and Corporate Change, Vol 11 (3), pp 451-496.

Sturgeon, T., and Gereffi, G., 2009, Measuring success in the global economy: international trade, industrial upgrading, and business function outsourcing in global value chains Transnational Corporations, Vol. 18 (2), pp 1-36.

Sturgeon, T., and van Biesebroeck, J., 2011, Global Value Chains in the automotive industry: an enhanced role for developing countries, International Journal of Technological Learning, Innovation and Development, Vol. 4 (1,2,3), pp 181-205.

Sturgeon, T., and van Biesebroeck, J., and Gereffi, G., 2008, Value chains, networks and clusters: reframing the global automotive industry, Journal of Economic Geography, Vol 8, pp 297-321.

Sturgeon, T., Nielsen, P.B., Linden, G., Gereffi, G., and Brown, C., 2013, Direct Measurement of Global Value Chains: Collecting Product-and firm-level statistics on value added and business function outsourcing and offshoring, In (Eds) Aaditya Mattoo, Zhi Wang and Shang-Jin Wei, Trade in Value Added Developing New Measures of Cross-Border Trade.

Susman, G. I., 1992 Integrating Design and Manufacturing for Competitive Advantage, Oxford University Press, Oxford.

Teece, D.J., 1988, 'Technological Change and the Nature of the Firm', in Dosi et al., Technical Change and Economic Theory, Pinter Publishers Ltd, UK

Teece, D.J., 2010, Technological Innovation and the Theory of the Firm: The Role of Enterprise-Level Knowledge, Complementarities, and (Dynamic) Capabilities. In Hall B., and Rosenberg, N., Economics of Innovation, North-Holland.

UNCTAD, 2005, World Investment Report. TNCs and the Internationalization of R&D', United Nations, Geneva.

Von Hipple, E., 1990, Task partitioning: An innovation process variable, Research Policy Vol 19 (5), pp 407-418.

Annex

Figure A. Basic model of relationships between GINs and between GINs and GVCs

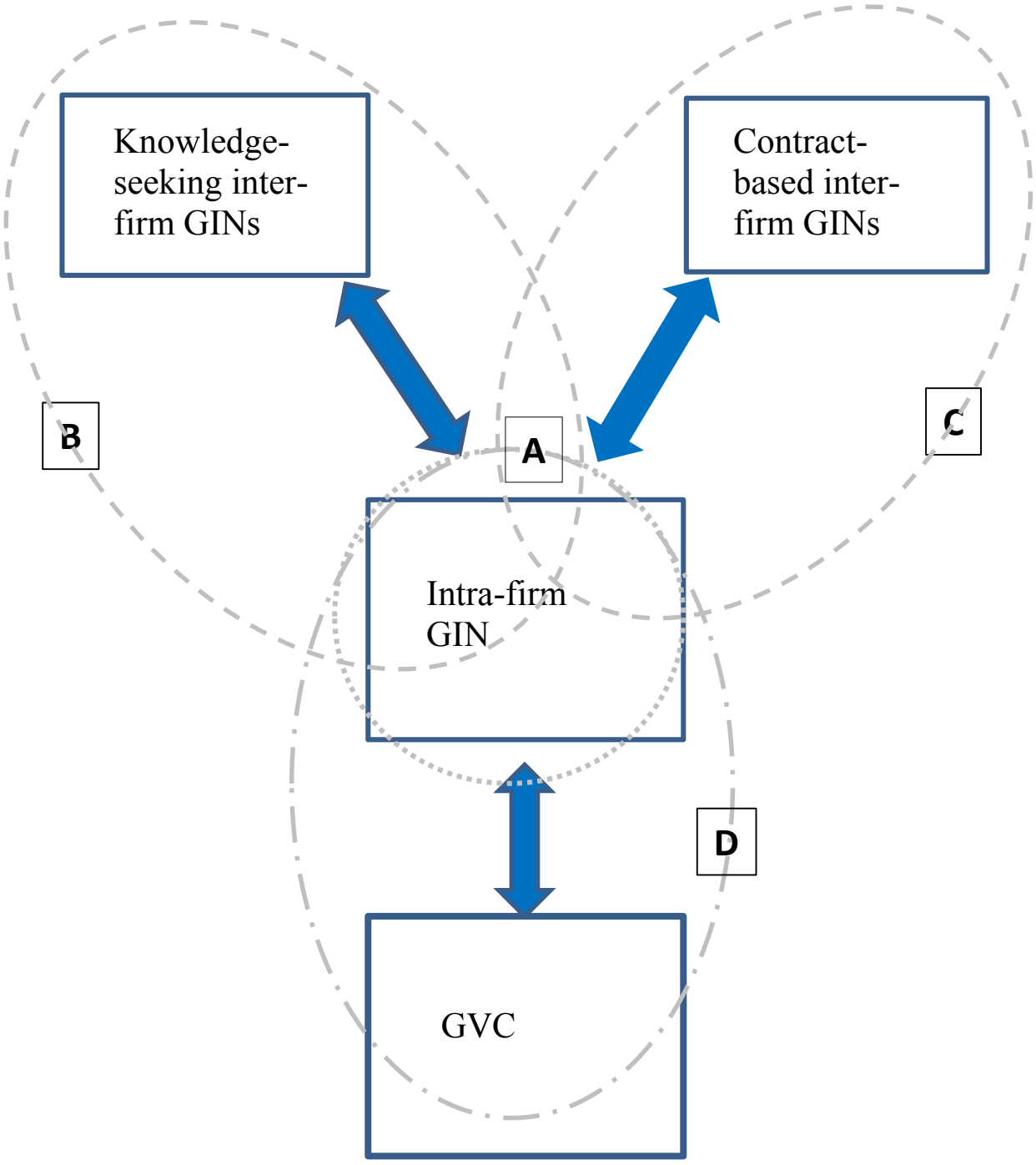

Table A. Types of firm GINs

Types of Global Innovation Networks	
Intra-firm GINs	The networks of internationally dispersed in-house RDI facilities of MNCs
Knowledge-seeking inter-firm GINs	Inter-firm RDI networks coordinated and governed by MNCs in order to access new knowledge and technology developed outside their organisational borders.
Contract-based inter-firm GINs	Inter-firm RDI networks coordinated and governed by MNCs to gain flexibility, spread risk and reduce costs of existing RDI activities. Associated with the fragmentation and 'fine-splicing' of existing RDI activities which are then outsourced to internationally dispersed, independently-owned, contract research organisations or manufacturing services organisations.

Table B. Conceptual backgrounds for GINs: a summary

Main lines of conceptual contribution to GIN study: Examples of works		
MICRO STUDIES		
Innovation	Concerns with how the character of knowledge and the innovation process influences the organisation and location of innovation. Focuses on the importance of tacit and unstructured knowledge in RDI activities. Emphasis on the integrated nature of the RDI process rather than how these activities can be partitioned. Highlights importance of links between R&D and production in engineering and process-based industries (i.e. between GINs and GVCs). Highlights importance of close links between RDI and national and regional science-base in the case of science-based industries. Has tended to focus on intra-firm networks but increasingly recognises the distributed nature of RDI activities as a result of the increasing scientific and technological complexity of products	Rothwell 1977; Freeman 1982; Teece 1988; Dosi 1988; Patel and Pavitt 1991, 1998; Howells *et al* 2008; Ernst 2009; Dosi and Nelson 2010. Ketoviki and Ali-Yrkkö 2009; Pisano 1996; Pisano and Shih 2012; Ivarsson *et al* 2017 Malerba 2002; Pisano 2006; Ramirez 2006 Chenais 1988, 1996; Hagerdoorn and Schakenraad 1990; Hagerdoorn 1993; Howells 2008; Teece 2010; Chesbrough 2003

Modularity	Concerned with how products, tasks, and organisations can be partitioned. Focus is on the codification of knowledge and the development of industry standards that enables communication between dispersed suppliers. Highlights the advantages associated with the vertical disaggregation and outsourcing of value-adding activities. Focuses on the study of 'modular industries' such as electronics and decentralised inter-firm networks.	Von Hippel 1990; Sanchez and Mahoney 1996; Langlois and Robertson 1992, Robertson and Langlois 1995; Baldwin and Clark 2000; Baldwin 2007 Sako 2006; Pisano 2006; Ernst 2005; 2009; Mudambi and Venzon 2010; Pisano and Shih 2012.
MESO STUDIES		
GVC	Concerned with the organisational fragmentation and geographical dispersal of the value chain and the resulting global organisation of industries. Focus is on the governance, coordination and power within inter-firm networks. Mainly focuses on manufacturing. Focuses on industry case-studies Mainly focuses on developing countries above all on the possibilities for the grading of capabilities of developing country firms as a result of participation in GVCs.	Gereffi and Korzeniewicz 1994; Gereffi 1994, 1999, 2014; Gereffi *et al* 2005; Sturgeon 2002; Sturgeon *et al* 2008; Fernandez-Stark *et al* 2011. Sturgeon and van Biesebroeck 2011; Humphrey 2003, Humphrey and Memedovic 2003; 2011; Schmitt and van Biesebroeck 2013; Simona and Axèle 2012; Contreras *et al* 2012; Pavlinek 2012; Ernst 2005; 2009; Gereffi and Fernandez-Stark 2010; Fernandez-Stark *et al* 2011; Ramirez 2013). Gereffi 1999; Bair and Gereffi 2001; Humphrey and Schmitz 2002; Ernst and Kim 2002; Giuliani *et al*, 2005; Schmitz 2006; Morrison *et al*., 2008; Pietrobelli & Rabellotti 2011; Humphreys & Schmitz 2002; Morrison *et al* 2008; Ivarsson and Alvstam 2005; Pavlínek and Ženka 2010
MACRO STUDIES		

IB	Focuses on integrated MNCs and the geographical configuration of intra-firm RDI networks	Cantwell 1992, 1995, 2017; Pearce 1989, 1999; Dunning and Lundan 2008; Narula 2005; Castellani *et al* 2013; Rezk *et al* 2016; Alcácer et al 2016; Iammarino and McCann 2013.
	More recently also interested in inter-firm networks	Dunning 1994; Dunning and Lundan 2009; Alcácer *et al* 2015; Cantwell 2013
	Recent interest in RDI investment in developing countries	Athreye and Cantwell 2007; Lewin *et al* 2009; Manning *et al* 2008; Bruche, 2009; Moncada-Paternó-Castello et al 2011; D'Agostino *et al* 2013; Belderbos et al 2016; Ivarsson *et al* 2017; Ivarsson and Alvstam 2017.
OECD	Interested in the geographical patterns of FDI flows in RDI activities	OECD 2011; Belderbos *et al* 2016
	Focuses on linkages between MNCs and national science systems	OECD 2016
	Frequent use of patent data	
	Interest in co-location of RDI and productive activities	OECD 2013