Beyond Value Capture - Exploring Innovation Gains from Global Networks[1]

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Abstract
Increasingly complex and diverse global corporate networks of production (GPNs) and global innovation networks (GINs) are transforming international trade, production and innovation, creating new, yet little understood, challenges for national policies that seek to foster economic growth and prosperity through productivity-enhancing innovation. As countries are integrated into these global networks, they are forced to rethink a broad array of policies. A fundamental tension needs to be addressed between global knowledge sourcing, which requires trade liberalization, and domestic capability development, which requires supporting industry and innovation policies.

To reap innovation gains from global networks, countries need to address simultaneously two challenges. From the "outside", national policies have to deal with a multitude of bilateral and regional trade agreements (RTAs) and attempts to establish a new architecture of mega-regional trade agreements, like the Transpacific Partnership (TPP), that seek to create and harmonize new international benchmark standards for national policies, rules and regulations, e.g., for intellectual property, technical standardization, government procurement, taxation, and competition policy. National policies need to take into account these changes in the governance of the international economy[2].

This chapter focuses on a second set of challenges that originate from the "inside": countries differ in their capabilities to learn and innovate, and hence they differ in their capacity to capture potential gains from integration into GPNs and GINs. I outline a conceptual framework and describe research needed to trace the dissemination (or lack thereof) of innovation resources and capabilities through knowledge-sharing within those networks that span developed and developing worlds. The analysis focuses on the experience of China and other leading Asian

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[2] Impacts on national policies and possible responses are addressed in chapters by Plummer, Lippoldt, Helper, Braga, Maskus, ….in this book.

electronics manufacturing exporting countries. All of these countries are deeply integrated into international trade and FDI through GPNs, and in some cases, through GINs.

I argue that research on global networks needs to move beyond value capture. Instead more effort should be invested in exploring whether and how integration into these networks might foster or erode a country's absorptive capacity and firm-level innovation capabilities. The chapter reviews what is known about driving forces and characteristics of GPNs and GINs, and highlights the increasing diversity and complexity of these networks in the electronics industry. To establish whether global network integration might foster or erode the host country's absorptive capacity and firm-level innovation capabilities, three scenarios are considered: i) the "Gains from Trade" effect; ii) the "Domestic Disintegration" effect; iii) the "Innovation Trap" effect; and iv) the "Limits to Modularity" effect.

Key words: Global production network, global innovation networks, global value chains, value capture, innovation, trade and innovation, innovation policies, trade policies, mega-regional trade agreements.
JEL: F13,F23,F63, L24, L63,N6,O19,O24,O25,O31,O32,O53

Trade and Innovation within Global Networks

Increasingly complex and diverse global corporate networks of production (GPNs) and global innovation networks (GINs) transform international trade, production and innovation, creating new, yet little understood, challenges for national policies that seek to foster economic growth and prosperity through productivity-enhancing innovation. These networks integrate dispersed production, engineering, product development and research across geographic borders.

The spread of global networks has outgrown the capacity of multilateral World Trade Organisation (WTO) agreements. Mega-regional trade agreements signal the beginning of big changes in international commercial governance, moving beyond tariff reduction to the harmonization of rules, regulations and policies. This trend has far-reaching implications for national trade policies and for the link between trade and innovation. For instance, deep regional trade agreements (RTAs) and the provisions of the Transpacific Partnership Agreement (TPP), released on November 5, 2015 and signed on February 4, 2016[3], allow enforcement of contracts and intellectual property rights across borders. These Mega-regionals exceed commitments covered by WTO (WTO "plus") in areas such as free movement of foreign direct investment (FDI); technical barriers to trade; liberalization of services; dispute settlement; customs cooperation; and government procurement.

As countries are integrated into these global networks (some more than others), they are forced to rethink a broad array of policies, well beyond the realm of international trade. In order to foster innovation within global networks, new ideas are required on how to adjust policies on education; research and innovation, especially climate change, environment and green technology; widespread but neglected diseases; the development, use and protection of intellectual property; technical standards and certification needed to enhance technology transfer and knowledge diffusion; the treatment of workers and investors; and cybersecurity. Equally important are policies to reduce harmful side effects of 'wild innovations' in the financial sector that have completely lost sight of fundamental rules that are necessary to balance profits with due process and risk analysis.[4]

Some basic definitions are in order to study the gains from innovation that countries and companies might capture via participation in global networks. *Innovations* convert ideas, inventions, and discoveries into new products, services, processes, and business models. Radical breakthrough discoveries and inventions through scientific research are only the tip of the iceberg[5]. It is important to emphasize that innovation is more than research and product development; that users must perceive an advantage to pay for the innovation; and that entrepreneurs are not just founders of Internet start-ups, but vary in terms of size, business

[3] For the full text of the TPP agreement, see https://ustr.gov/trade-agreements/free-trade-agreements/trans-pacific-partnership/tpp-full-text. For initial responses in the US, see the USTR Releases of Advisory Committee Reports on TPP, at https://ustr.gov/trade-agreements/free-trade-agreements/trans-pacific-partnership/advisory-group-reports-TPP.

[4] See Bill Lazonick's Think Piece for the MCTI workshop ("How Stock Buybacks Make Americans Vulnerable to Globalization").

[5] Ernst, D. 2009. "A New Geography of Knowledge in the Electronics Industry? Asia's Role in Global Innovation Networks." Policy Studies, No. 54, East-West Center, Honolulu, Chapter 2.

model, and organization.[6] Critical are innovations in generic industrial technologies that allow for new ways of manufacturing existing products (e.g., with new materials or by using 3D printing) as well as for manufacturing new products derived from new ideas, discoveries, and inventions (e.g., implanted sensors). Without large-scale advanced manufacturing facilities, which can draw on an integrated domestic industrial value chain, even the most sophisticated research and development (R&D) capabilities are of little use to generate innovations[7].

To reap innovation gains from global networks, countries need to address simultaneously two challenges. From the "outside", national policies have to deal with a multitude of RTAs and attempts to establish a new architecture of mega-regional trade agreements, like the TPP, that seek to create and harmonize new international benchmark standards for national policies, rules and regulations, for instance for intellectual property, technical standardization, government procurement, taxation, and competition policy.

This chapter however focuses on a second set of challenges that originate from the "inside": countries differ in their capabilities to learn and innovate, and hence they differ in their capacity to capture potential gains from integration into GPNs and GINs. A huge gap in innovation capacity continues to separate emerging and developing countries from the US, the main European countries and Japan[8]. For the technology followers, this raises important challenges.

In this chapter, I outline a conceptual framework and describe research needed to trace the dissemination (or lack thereof) of innovation resources and capabilities through knowledge-sharing within those networks that span developed and developing worlds. The analysis focuses on the experience of China and other leading Asian electronics manufacturing exporting countries. All of these countries are deeply integrated into international trade and FDI through GPNs, and in some cases, through GINs[9].

Part One of the chapter argues that research on global networks needs to move beyond value capture and explore whether and how integration into these networks might foster or erode a country's absorptive capacity and firm-level innovation capabilities. Part Two reviews what is known about driving forces and characteristics of GPNs and GINs, and highlights the increasing diversity and complexity of these networks in the electronics industry.

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[6] This broad definition is in line with Peter Drucker's classic statement, "The test of an innovation, after all, lies not in its novelty, its scientific content, or its cleverness. It lies in its success in the marketplace" (Drucker 1985: viii).
[7] As demonstrated in Helper, S., T. Krueger, H. Wial, 2012, *Why Does Manufacturing Matter? Which Manufacturing Matters?* Brookings Institution, Washington, D.C.
[8] See Cornell University, INSEAD and WIPO, eds., 2015, *Global Innovation Index 2015*, Geneva, Ithaca and Fontainebleau.
[9] For these Asian economies, international trade now approaches 100 percent of GDP on average, ranging from 42% in quasi-continental China to 78% in Korea, 136% in Malaysia and 140% in Taiwan. (Merchandise trade as a share of GDP is the sum of merchandise exports and imports divided by the value of GDP, all in current U.S. dollars, http://data.worldbank.org/indicator/TG.VAL.TOTL.GD.ZS). Developing Asia has captured the largest share of global FDI inflows, growing from $401billion in 2012 to $465billion in 2014, with China ($129bn), Hong Kong ($103bn) ahead of the US ($92bn) and the UK ($72bn). At the same time, Asia's share in FDI outflows has increased from $299bn in 2012 to $432bn in 2014, accounting for almost one third of global FDI outflows, with Kong Kong ($143bn) and China ($116bn)now being the second and third largest home economies, after the US (with $337bn). (UNCTAD, 2015, *World Investment Report*, Chapter I Global Investment Trends, figures 11.2 and 1.3, and chapter II Regional Investments Trends, United Nations, New York and Geneva)

To establish whether global network integration might foster or erode the host country's absorptive capacity and firm-level innovation capabilities, Part Three considers the following scenarios: i) the "Gains from Trade" effect; ii) the "Domestic Disintegration" effect; iii) the "Innovation Trap" effect; and iv) the "Limits to Modularity" effect.

The chapter concludes with implications for policy and research**.**

Part One - Moving Beyond Value Capture

Research on global networks has mostly concentrated on *trade in value-added* and the *capture of value* across different locations. The joint *OECD-WTO Trade in Value-Added (TiVA) database* for instance measures the foreign content share of exports as a proxy for global network integration, while using an increasing domestic content share of exports as an indirect signal of "an increasing ability to upgrade within the value chain".[10] In a similar vein, work at the World Bank explores policies that might help to capture value from global network integration for developing countries[11]. A recent report by the ILO seeks to identify ways to capture value for employment[12], while UNCTAD attempts to assign "labor and profit components of the value-added …[to] … the locations where participating firms are headquartered (for profit accounting) and have located their factories (for labour accounting)."[13]

At the center of much of the research on value capture is the assumption that the proliferation of global networks will continue unabated, as more and more countries participate in international trade and investment. Implicit in this assumption is that the current slow-down of international trade (discussed below) is cyclical rather than structural, and that global networks will soon return to their role as the engine of international trade.

A second assumption is that, as global networks proliferate, "[i]t is necessary to value imports as well as exports, to reduce time delays as well as tariffs, and to look 'behind the border' at regulatory measures as well as 'at the border' measures."[14] This has important implications for policy. "In a world characterized by geographical fragmentation of production, policies aimed at supporting production of specific industries by protecting them from foreign competition seem even less likely than in the past to reach the intended target of sustaining activity in the protected industries." (ibid.: p.33)

The first assumption is contentious. 2016 marks the eighth consecutive year in which annual trade growth has fallen below 3 per cent and the fifth year in which world trade will have grown

[10] http://www.oecd.org/sti/ind/measuringtradeinvalue-addedanoecd-wtojointinitiative.htm; and http://www.oecd.org/sti/ind/tiva/CN_2015_China.pdf .

[11] Taglioni, D. and D. Winkler, 2014, *Making Global Value Chains Work for Development*, The World Bank, Washington, D.C.

[12] ILO, 2015, *Value Chain Development for Decent Work*, Geneva.

[13] UNCTAD, 2015, *Tracing the Value Added in GVCs: Product-Level Case Studies in China*, New York and Geneva: p.25. However, this report concedes "challenging" data problems as tear-down reports which physically disassemble and examine component parts of a product are available for the IT industry, but not for most other sectors.

[14] OECD,WTO, World Bank, 2014, *Global Value Chains: Challenges, Opportunities, and Implications for Policy, Report submitted to G20 Trade Ministers Meeting, Sydney Australia, 19 July*: p.7.

at roughly the same rate as world GDP (at market exchange rates), rather than twice as fast, as was previously the case[15]. Such a long, uninterrupted spell of slow trade growth is unprecedented. There is evidence "that the slower pace of expansion of global supply chains is an important determinant of the trade slowdown."[16] And the most recent *World Bank June 2016 Global Economic Prospects* concludes that the persistent trade slow-down is structural: "Declining commodity prices; China's shift towards a slower, more sustainable, growth path; and soft activity in advanced economies appear to have been mutually reinforcing drivers for weaker merchandise trade growth."[17] Further support for a slow-down of global production networks comes from research by the Canadian Trade Commissioner Service which highlights a disproportionally large fall in exports of intermediate goods as a main contributing factor[18].

The second assumption brings back into the analysis insights from *endogenous growth* theory that "trade restrictions prevent new types of goods and new types of productive activities being introduced from abroad"[19], and thus may stifle productivity and technology diffusion. Paul Romer's important proposition however needs to be balanced with the "infant industry" argument, formalized by Greenwald and Stiglitz[20]. At the same time, innovation theory tells us that strengthening national innovation capabilities improves a country's ability to engage in and benefit from the international trading system."[21] This gives rise to a central proposition of this essay: *there is a fundamental tension between global knowledge sourcing, which requires trade liberalization, and domestic capability development, which requires supporting industry and innovation policies.*

It is important to highlight a third assumption underlying the 'value capture' research agenda which may no longer hold today. For Paul Romer, for instance, "the most important policy questions about growth …[are] …: In a developing country…, what are the best institutional arrangements for gaining access to knowledge that already exists in the rest of the world? In a country like the United States, what are the best institutional arrangements for encouraging the

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[15] https://www.wto.org/english/news_e/pres16_e/pr768_e.htm

[16] Constantinescu, C., A. Mattoo, M. Ruta, 2015, "The Global Trade Slowdown: Cyclical or Structural?", *IMF Working Paper* WP/15/6, International Monetary Fund, Washington, D.C.: page 26. See also World Bank, 2015, *Global Economic Prospects*, chapter 4 "What lies Behind the Global Trade Slowdown?", January, which finds that the trade slow-down may be explained by "shifts in the structure of value chains, in particular between China and the United States, with a higher proportion of the value of final goods being added domestically – that is, with less border crossing for intermediate goods." (p.173)

[17] http://pubdocs.worldbank.org/en/842861463605615468/Global-Economic-Prospects-June-2016-Divergences-and-risks.pdf : p.16.

[18] The Canadian Trade Commissioner Service, (2015, "Is vale chain-driven trade on the wane?", October 20) finds that, "while total exports rose US$47.5billion in 2012, intermediate exports fell US$ 116.8billion … [T]his decline could … indicate firms' withdrawal from participating in GVCs." (p.2)

[19] Romer, P., 1994, "New goods and the welfare costs of trade restrictions", *The Journal of Development Economics*, 43: page 6.

[20] Greenwald, B. C. and J.E. Stiglitz, 2006, "Helping Infant Economies Grow: Foundations of Trade Policies for Developing Countries", *AEA Papers and Proceedings*, May: pages 141-146. Philippe Aghion summarizes the argument as follows: For developing countries with a nascent industrial sector, "full trade liberalization will make it very costly for domestic industrial sectors to invest in learning by doing … since domestic costs are initially higher than foreign costs … [and] … the social benefits from learning by doing are not fully internalized." (Aghion, P., 2014, "Afterword: Rethinking Industrial Policy", in: Stiglitz,J.E. and B.C. Greenwald, *Creating A Learning Society. A New Approach to Growth, Development, and Social Progress*, Columbia University Press, New York

[21] See Carlos Primo Braga's MCTI Think Piece: p.3.

production and use of new technology?"[22] This statement seems to assume that the division of innovation capacity between the US and developing countries remains unchanged, and that the gains from trade for innovation will largely remain uneven.

Whether or not this clear-cut division of innovation capacity still holds requires empirical research. Innovation however has not been at the center of trade in value-added research. It is time to move beyond value capture and to conduct empirical research on the gains for innovation from global network integration and on the domestic capabilities that might help to capture these gains[23].

Part Two - Driving Forces and the Increasing Diversity and Complexity of Global Networks

Global production networks began to proliferate during the 1970s, signaling a shift from *partial* to *systemic globalization*[24]. With a "partial globalization" strategy, MNCs invest in a loose patchwork of stand-alone affiliates, joint ventures, and suppliers, that are scattered across the globe and which co-exist without much interaction and coordination across functions and locations. "Partial globalization" implies that the MNC cannot reap the full benefits of international specialization. With "systemic globalization", a lead firm (a "network flagship") proceeds to integrate its dispersed operations ("intra-firm") and inter-firm relationships worldwide, both across functions and locations. Integration enables the flagship to internalize and combine resources and capabilities without running into the constraints of excessive centralization.

A more recent development is the emergence of GINs, driven by the relentless vertical disintegration of engineering, product development, and research. A gradual opening of corporate innovations systems disperses R&D across firm boundaries and national borders. Take Intel, whose R&D activities are expanding most rapidly in India and China. A closer look at Intel Bangalore shows substantial progress in the portfolio of innovative capabilities, but it also reveals a persistently hierarchical division of labor[25]. Bangalore's strength continues to lie primarily in the so-called back-end design tasks, which includes re-verifying the design, chip layout, running manufacturability tests, and performing product engineering.

Overall, GINs have dispersed innovative capabilities to new players, but this dispersion remains highly concentrated. For instance, with respect to chip design, instead of the established global centers of excellence (such as Silicon Valley), there are now a handful of rapidly expanding new

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[22] Romer, P., 1994, "The Origins of Endogenous Growth", *Journal of Economic Perspectives*, Vol.8,#1, Winter: page 21.

[23] For related ideas, see the chapters by Susan Helper and Tim Krueger; Keith Maskus; and Chen TainJy. A case study on the tension between global knowledge sourcing and innovation policy can be found in Ernst, D., 2015, Ernst, D., 2015, *From Catching Up to Forging Ahead: China's Policies for Semiconductors*, East-West Center Special Study, September: 74 pages.

[24] Ernst, D., 1997, *From Partial to Systemic Globalization: International Production Networks in the Electronics Industry*, Berkeley Roundtable on the International Economy (BRIE) Working Paper 98, April: 113 pages.

[25] Ernst, D., 2009, *A New Geography of Knowledge in the Electronics Industry? Asia's Role in Global Innovation Networks*, *Policy Studies* #54, August 2009, East-WestCenter, Honolulu, USA, chapter III (What do we know about Global Innovation Networks)

clusters emerging in Asia in places like Hsinchu, Taipei, and Tainan (in Taiwan); Shanghai, Suzhou, Hangzhou, Beijing, Shenzhen, and Xián (in China); Seoul, Incheon, and Daedok Science Town (in Korea); Bangalore, Noida, Chennai, Hyderabad, Mumbai, Pune, and Ahmedabad (in India); Penang and Kuala Lumpur (in Malaysia); and Singapore.

The electronics industry has been in the vanguard of this transformation. Today, however, GPNs and GINs are driving production, R&D and trade in myriad goods and services sectors, from clothing, food processing, motor vehicles, and pharmaceuticals, to accounting, finance and legal services.

Global production networks

Trade economists have explored the importance of changes in the organisation of international production as a determinant of trade patterns[26]. Their work demonstrates that (i) production is increasingly 'fragmented', with parts of the production process being scattered across a number of countries, hence increasing the share of trade in parts and components; and (ii) countries and regions which have been able to become a part of GPNs are the ones that have industrialised the fastest.

Building on this work, I have developed a broader concept that emphasises three essential characteristics[27]: i) *asymmetry*: lead firms ('flagships') dominate control over network resources and decision-making; ii) *knowledge diffusion*: the sharing of knowledge is the necessary glue that enables these networks to grow; and iii) *scope*: GPNs encompass all stages of the value chain, not just production. Over time, the focus of outsourcing is shifting from assembly-type manufacturing to knowledge-intensive support services, like supply chain management, engineering services, and new product introduction. Outsourcing may also include design and product development. This indicates that GPNs also differ from traditional forms of subcontracting – much denser interaction between design and production and other stages of the value chain require substantially more intense exchange of information and knowledge. Network flagships increasingly rely on the skills and knowledge of specialised suppliers to enhance their core competencies.

In short, GPNs are a major organizational innovation that enables "network flagships" to reap the combined advantages of outsourcing ("vertical disintegration") and integration. Outsourcing

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[26] For instance, Feenstra, R. (1998) 'Integration of trade and disintegration of production in the global economy', *Journal of Economic Perspectives*, 12/4: 31–50; and Jones, R. and H. Kierzskowski (2000) 'A framework for fragmentation', in: S. Arndt and H. Kierzkowski (eds), *Fragmentation and International Trade*, Oxford: Oxford University Press.

[27] Ernst, D. (1997) 'From partial to systemic globalisation. International production networks in the electronics industry'. Report to Sloan Foundation, published as *The Data Storage Industry Globalisation Project Report 97-02*, Graduate School of International Relations and Pacific Studies, University of California at San Diego. See also Ernst, D. (2002), 'Global Production Networks and the Changing Geography of Innovation Systems. Implications for Developing Countries', *Economics of Innovation and New Technologies* XI(6): 497–523; Ernst, D. (2005) 'The New mobility of knowledge: digital information systems and global flagship networks', in: R. Latham and S. Sassen (eds), *Digital Formations. IT and New Architectures in the Global Realm*, Princeton and Oxford: Princeton University Press for the US Social Science Research Council.

allows for the separation of labor-intensive processes (that move to low-cost locations) from capital- and knowledge-intensive processes and their dispersion across firm boundaries and national borders. Integration of the dispersed production, supplier and customer, and knowledge bases is necessary to reduce the high costs and risks of coordinating cross-border exchanges of products, people, information and knowledge.

Asymmetry is a fundamental characteristic of this process. Network flagships dominate and define network organization and strategy. Control over and coordination of network resources and decision-making enables the flagship to directly affect the growth, the strategic direction and network position of lower-end participants (e.g., specialized suppliers and subcontractors)[28].

GPNs cover both intra-firm and inter-firm transactions and forms of coordination: a GPN links together the flagship's own subsidiaries, affiliates and joint ventures with its subcontractors, suppliers, service providers, as well as partners in strategic alliances. A network flagship like Apple or Intel breaks down the value chain into a variety of discrete functions (by product or by production process) and locates them wherever they can be carried out most effectively, where they can improve the flagship's access to resources and capabilities, and where they are needed to penetrate important growth markets[29].

A great variety of governance structures is possible. GPNs range from loose linkages that are formed to implement a particular project and that are dissolved after the project is finished (so-called 'virtual enterprises') to highly formalized networks ('extended enterprises') with clearly defined rules, common business processes and shared information infrastructures. Formalized networks do not require common ownership - these arrangements may, or may not involve control of equity stakes. What really matters for innovations regards whether relations between the parties in the GPN are collaborative or arm's-length[30].

Arbitrage of differences in factor costs across locations has been a fundamental motivation behind the construction of those networks. In the garments industry, for instance, local suppliers are under constant pressure to reduce costs and to speed-up delivery. In collaborative networks, however, local suppliers are expected to constantly upgrade their capabilities. If they fail to upgrade, these suppliers will perish[31]. Flagships seek to gain quick access to skills and capabilities at lower-cost overseas locations that complement the flagships' core competencies. As a result, two-way knowledge-sharing among network participants has gained in importance. As Ernst and Kim (2002) demonstrates, network flagships transfer both explicit and tacit

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[28] The complexity of these global networks is mind-boggling. According to Peter Marsh, the *Financial Times'* manufacturing editor, "…[e]very day 30m tones of materials valued at roughly $80 billion are shifted around the world in the process of creating some 1 billion types of finished products." P. Marsh, "Marvel of the World Brings Both Benefit and Risk," *Financial Times*, June 11, 2010, 7. For a detailed case study of the multi-layered global production networks in Asia, see Ernst, D., 2004, "Global Production Networks in East Asia's Electronics Industry and Upgrading Perspectives in Malaysia", in Shahid Yusuf, M. Anjum Altaf and Kaoru Nabeshima (eds.), *Global Production Networking and Technological Change in East Asia*, The World Bank and Oxford University Press.
[29] Apple for instance relies heavily on Foxconn's gigantic production complexes in Shenzhen, Chengdu and other major Chinese cities.
[30] Helper, S., 1991, "Strategy and Irreversibility in Supplier Relations: The Case of the U.S. Automobile Industry", *Business History Review*, Volume 65 / Special Issue 04 / Winter 1991, pp 781-824.
[31] Ernst, D. and Linsu Kim, 2002, Global Production Networks, Knowledge Diffusion and Local Capability Formation, *Research Policy*, 31, no.8/9, special issue in honor of Richard Nelson and Sidney Winter.

knowledge to local suppliers through formal and informal mechanisms. This is necessary to upgrade the local suppliers' technical and managerial skills so that they can meet the flagships' specifications. Once a network supplier successfully upgrades local capabilities, this creates an incentive for flagships to transfer more sophisticated knowledge, including engineering, product and process development". This process however is not automatic: for upgrading to run its course, supportive industrial and innovation policies are required to foster the absorptive capacity of local suppliers.

What distinguishes global innovation networks?

Since the turn of the century, outsourcing has included product development, design and research, giving rise to GINs. There is an important element of continuity: GINs emerge as a natural extension of GPNs and hence share most of their characteristics. As explained below, GINs are prone to systemic pressures to internationalize innovation that distinguishes them from GPNs[32].

Good data on the international dimension of innovation remain scarce, in particular on the importance of GINs and the motivations for establishing these networks. One such attempt is a database, developed at the East-West Center, which draws on findings of questionnaire-based case studies of GINs in the integrated circuit design industry[33]. The questionnaire surveys and case studies provide basic information (some quantitative, but mostly qualitative) on the location and type of activity of offshore R&D labs, date of establishment, the size and composition of the workforce, and the educational background and work experience of senior managers[34]. In addition, the database contains information on the rationale for establishing a GIN rather than following a traditional integrated R&D model; the scope and stability of these networks and their governance; management practices to implement network coordination; approaches to learning and knowledge sharing; and the types of innovation and innovative capabilities at different network locations and their interaction[35].

Conducting such in-depth and standardized case studies requires deep industry knowledge. Collecting these data is a time-consuming and costly affair – an important drawback from the perspective of funding agencies. Nevertheless, this type of industry-specific micro-level "detective work" is necessary to move research on innovation gains from global networks

[32] See analysis below of enablers and driving forces. For another attempt to capture such differences, see Cooke, P., 2013, "Global Production Networks and Global Innovation Networks: Stability versus Growth", *European Planning Studies*, Vol.21, No.7: 1081-1094.

[33] As described in Ernst, D., 2009, *A New Geography of Knowledge in the Electronics Industry? Asia's Role in Global Innovation Networks*, *Policy Studies* #54, August 2009, East-WestCenter, Honolulu, USA, chapter 2.

[34] To address this research agenda, data were collected for a sample of almost 150 companies in the electronics industry. Companies differ in terms of size, ownership, business model, and nationality, ranging from large global brand leaders from the United States, Asia, and Europe to specialized suppliers of technology, core components, and product development services. Also collected are profiles of mini-GINs for small transpacific start-up companies of foreign-born engineers from Taiwan, China, and India that are headquartered in Silicon Valley. These start-ups had to commit to conducting product development and research work in Asia in order to receive venture capital funding. The database is representative, capturing important protagonists that shape the dynamics of GINs in the electronics industry and providing important qualitative insights into the nature of these global transformations.

[35] Questionnaires were distributed to engineers involved in research and product development, and were customized for China-based chip design companies (both international and domestic) and for buyers of those chips (the so-called Original Equipment Manufacturers/OEMs, both international and domestic).

beyond the fairly general statements typical of much of the value capture research mentioned at the beginning of this essay.

Since space is limited, two examples must suffice to illustrate the depth of findings of such case study research on GINs in China's chip design industry. As for enabling factors, the interviews emphasize (in this order): modular design which enables vertical specialization (i.e. the slicing and dicing of the innovation value chain); the role of information and communications technology in enhancing cross-border coordination of diverse tasks; as well as trade and investment liberalization through multilateral trade agreements within GATT and WTO, and, more recently, RTAs including mega-regional trade agreements.

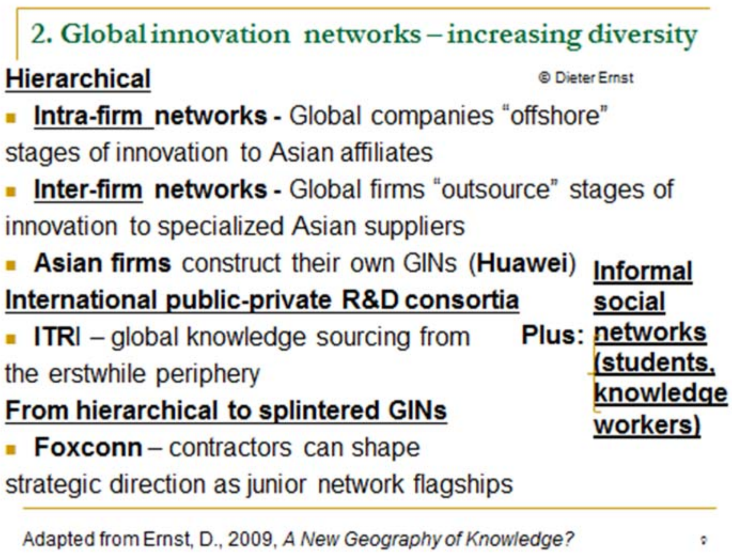
With respect to driving forces, the interviews highlight their systemic nature – labor cost differentials matter, but they are only one among a package of competitive pressures. Global companies expect China's integration into their GINs (either through local affiliates in China or through outsourcing to independent local suppliers) to:

- enable them to increase the return-on-investment on R&D, despite the rising cost, complexity, and uncertainty of R&D;
- facilitate the penetration of high-growth emerging markets in compensation for the slow demand growth in core OECD countries;
- accelerate speed to market in line with shorter product life cycles;
- gain access to lower-cost pools of knowledge workers;
- tap into the resources and innovative capabilities of new competitors and emerging new innovation hubs;
- provide them with opportunities for so-called "regulatory arbitrage", i.e. the exploitation of differences in IPR regimes; incentives; tax laws (especially for transfer pricing); and in regulations on finance, the environment, and health.

Increasing diversity and complexity of global innovation networks

An important recent development is the *increasing diversity and complexity* of these knowledge-sharing network arrangements. Global innovation networks (GINs) now involve multiple firms and organizations that differ substantially in size, business model, market power, and nationality of ownership, giving rise to a variety of networking strategies and network architectures (**Table 1**).

Table 1



The flagship companies that control key resources and core technologies, and hence shape the hierarchical intra-firm and inter-firm networks, are still overwhelmingly from the US, the EU, and Japan. However, there are also now network flagships from emerging economies, especially from Asia, which construct their own GINs. Huawei, China's leading telecommunications equipment vendor, and the second largest vendor worldwide, provides an example of a Chinese GIN that illustrates the considerable organizational complexity of such networks. Huawei's own GIN now includes, in addition to at least eight R&D centers in China, five major overseas R&D centers in the United States, and at least ten R&D centers in Europe[36].

In addition, international public-private R&D consortia are no longer exclusively originating from the US, the EU and Japan. Asian countries are also quite active now in global sourcing through such cross-border public-private partnerships. Taiwan's ITRI provides a telling example of such global knowledge sourcing from the erstwhile periphery[37].

An important recent transformation are splintered GINs with diverse network flagships which increasingly complement the erstwhile dominant hierarchical networks. This indicates that vertical specialization within GINs continues unabated. Different types of splintered GINs are emerging, and network flagships now might include: core component suppliers (Intel, Microsoft; ARM; Qualcomm) which control technology platforms; Mega-contractors (like Taiwan's Foxconn) which can co-shape strategic direction and provide integrated solutions; global mega-

[36] For details, see Ernst, D., 2009, *A New Geography of Knowledge in the Electronics Industry? Asia's Role in Global Innovation Networks*, *Policy Studies* #54, August 2009, East-WestCenter, Honolulu, USA: pages 27 ff.

[37] Within Europe, ITRI's global knowledge network concentrates on Germany, the Netherlands, France, where it covers a broad array of science disciplines and technologies. By contrast, ITRI's presence in Russia is heavily focused on the country's leading research institutes for advanced mathematics and physical sciences. It is also noteworthy that ITRI has a much larger and widely diversified presence in the US, both with leading universities and with global industry leaders. Finally, ITRI's knowledge network closely interacts with private GINs established by leading Taiwanese companies. For instance, Taiwan's TSMC (the world's largest provider of chip manufacturing services) has a strong presence in UC Berkeley and at Stanford University, with a heavy focus on leading-edge IC development for advanced computing.

distributors of semiconductors (e.g., Arrow Electronics; Avnet) which can provide integrated solutions; and suppliers of new generic technology platforms like IBM which seeks to capture industry-specific data and knowledge from major users like leading US health care providers to enable its Artificial Intelligence "Watson" platform to solve real-world business problems[38].

Arguably, the most important manifestation of rising network complexity is the convergence of ICT infrastructure for the Internet, wireless and mobile communications, and cloud computing that culminates in "The Internet of Everything". While the vision of an "Internet-of-Everything" certainly exaggerates what will be possible over the next decade , concepts like "Connected Manufacturing" highlight how global manufacturers are implementing "… bidirectional information-sharing through the global manufacturing value chain—from research and development (R&D) to the customer and back; from suppliers to plants to sales-channel partners, and conversely."[39]

Part Three – Capturing Innovation Gains from Global Networks – Alternative Scenarios

Economic theory still has a long way to go to catch up with the new world of increasingly complex GINs. As indicated, research has mostly concentrated on *trade in value-added* and the *capture of value* across different locations. This is important, but it tells us little about the distribution of innovation gains from global network integration, and about ways to improve a country's innovation capacity.

To establish whether global network integration might foster or erode the host country's absorptive capacity and firm-level innovation capabilities, the remainder of the essay considers the following scenarios of contingent impacts: a) *the "gains from trade" effect*[40]*; b) the "domestic disintegration" effect*[41]*; c) the "innovation trap" effect*[42]*; and d) the "limits to modularity" effect*[43]*.*

The "Gains from Trade" effect

The first scenario considers how global network integration might unlock new sources of industrial innovation through technology diffusion and global technology sourcing. Research on gains from trade for innovation typically focuses on trade liberalization through the reduction of tariffs and non-tariff barriers to trade, such as quotas, rules of origin, embargoes, sanctions, levies and other restrictions, as well as "trade facilitation" such as improved customs procedures. By lowering import prices, improving market access for exporters, and enhancing competition, trade liberalization is expected to strengthen a country's innovation capacity through three

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[38] Waters, R., 2016, "FT Big Read. Artifical Intelligence", *Financial Times*, January 6: p.5.

[39] Hartman, C., R. Kuppens, D. Schlesinger, *Connected Manufacturing*, 2006, http://www.cisco.com/web/CA/pdf/Cisco_Connected_Manufacturing.pdf

[40] As formalized in Romer, P., 1994, "New goods and the welfare costs of trade restrictions", *The Journal of Development Economics*, 43: pages 5-38.

[41] Rodrik, D., 2015, *Past, Present, and Likely Future of Structural Transformation*, Presentation at ODI, 23 June, http://www.odi.org/events/4213-economic-transformation-growth-dani-rodrik

[42] See Chen Tai-Jy's MCTI Think Piece.

[43] Drawing on Ernst, D., 2005, "Limits to Modularity - Reflections on Recent Developments in Chip Design", *Industry and Innovation*, Vol. 12, No., September: pages 303-335; and Chesbrough, H. W. (2003) Towards a dynamics of modularity. A cyclical model of technical advance, in: A. Prencipe et al. (Eds) *The Business of Systems Integration*, Oxford: Oxford University Press.

specific channels: i) imports, FDI and technology licensing; ii) learning-by-exporting would both expose the region to foreign technology and intangible knowledge as a source of product and process innovation; and iii) competition may reduce monopoly rents from innovation and create pressure to increase productivity[44].

Important theoretical contributions are Paul Romer's analysis of the welfare costs of trade restrictions and their constraining effects on innovation, described earlier in this essay; Robert Feenstra's analysis of Integration of Trade and Disintegration of Production in the Global Economy[45], and Lee Branstetter's work on the role of FDI as a channel of knowledge spillovers[46]. These arguments have been popularized into widely disseminated policy prescriptions by Richard Baldwin's proposition that global network integration provides "the 21st century's fast lane to industrial development"[47]. Baldwin however also proposes restrictions on trade (such as enhanced TRIPS-Plus IP protection and constraints on national technical standardization in line with the WTO Agreement on Technical Barriers to Trade[48]) so as to incentivize multinational participation.

Research on Asia's global innovation network hubs in the electronics industry finds ample opportunities for knowledge diffusion and learning through global network integration. That research shows that foreign R&D centers can act as important catalysts for accelerated learning and capability development. Interviews with foreign affiliates of global corporations as well as with independent Asian network suppliers indicate that integration into global innovation networks can improve access to state-of-the-art innovation management practices, tools, ideas, and opportunities for innovation.[49]

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[44] Kiriyama, N., 2012, *Trade and Innovation: Synthesis Report*, OECD Trade Policy Papers, No.135, OECD, Paris, and Onodera, O., 2008, *Trade and Innovation: a Synthesis Paper*, OECD Trade Policy Working Paper No.72, August 7.

[45] Feenstra, R., 1998, "Integration of Trade and Disintegration of Production in the Global Economy", *Journal of Economic Perspectives*, 12(4): 31-50; and Feenstra, R., 2008, *Offshoring in the Global Economy*, Ohlin Lectures, presented at the Stockholm School of Economics, September.

[46] Branstetter, L., 2006, "Is Foreign Direct Investment a Channel of Knowledge Spillovers: Evidence from Japan's FDI in the United States," *Journal of International Economics*, vol. 68, February 2006, pp. 325-344.

[47] Baldwin, R., 2014, *Multilateralising 21st Century Regionalism*, Global Forum on Trade Reconciling Regionalism and Multilateralism in a Post-Bali World, OECD, 11-12 February, 2014: p.39. See also Baldwin, R., 2013, "Trade and industrialization after globalisation's second unbundling: How building and joining a supply chain are different and why it matters", in: Feenstra, R. and A. Taylor (eds.), *Globalization in an Age of Crisis: Multilateral Economic Cooperation in the Twenty-First* Century, University of Chicago Press, Chicago.

[48] Unfortunately, the WTO's concept of standardization is from a bygone era. There is little reason to believe that the people behind the TBT Agreement anticipated the requirements, imposed by the Internet and resulting complex networks and technology systems for the development and use of consensus international standards. In addition, the TBT agreement seems to apply only to governments and a few recognized SDOs, ignoring the reality of ubiquitous, global standards that do not fall under these categories.In its current form, the TBT agreement thus provides an imperfect policy tool for addressing the challenges of international trade for standardization.

[49] For instance, Chang, Shih, and Wei (2006) find that exposure to state-of-the-art innovation management practices of global R&D operations can improve innovation management in Taiwan firms and force them to be "more innovative." (Chang, Yuan-Chieh, Chin-Tay Shih, and Yi-Ling Wei, 2006. "Hooking up Local and National Innovation Networks: A Study of Foreign-Affiliated R&D Centers in Taiwan." Paper presented at "Greater China's Innovative Capacities: Progress and Challenges," co-sponsored by SPRIE/Stanford University and CISTP/Tsinghua University, May 20–21, Beijing, China.) And Shin-Horng Chen shows that the R&D intensity of foreign-owned affiliates in Taiwan's manufacturing industry has increased from 1.5 percent in 2002 to 1.9 percent in 2003. Chen argues that foreign-owned subsidiaries with high export intensity and which rely on Taiwanese original equipment

Competition in the electronics industry combines intense price competition with the speed of new product introduction, with the result that product life cycles become shorter and shorter. Only those companies that succeed in bringing new products to the relevant markets ahead of their competitors will thrive. Of critical importance for competitive success is that a firm can build specialized capabilities quicker and at a lower cost than its competitors[50]. For many electronics companies, competing for scarce global talent thus has become a major strategic concern. Global sourcing for knowledge workers now is as important as global manufacturing and supply chain strategies. The goal is to diversify and optimize a company's human capital portfolio through aggressive recruitment, especially in emerging Asia's lower-cost-labor markets. Over time, global firms realize that, in order to retain these knowledge workers, it is necessary to transfer exciting projects to the new locations in Asia that provide opportunities for learning and knowledge sharing.

All of this implies that innovation systems of global corporations are being opened to outsiders, at least in a few select areas. This has substantially reduced entry barriers and opened up new opportunities for network suppliers to engage in global knowledge sourcing. Research on Chinese IC design firms provides supporting evidence[51]. According to the chief executive officer (CEO) of China's leading IC design company, Spreadtrum, "the availability of IC design tools, semiconductor fab services, and open-source smartphone software [Android] allows Chinese firms to circumvent their weak spots and develop their strengths in hardware, IC design, and integration."[52] Deep integration into the global semiconductor value chain thus enables Chinese firms to globally source technology and capabilities on a scale never thought possible before. In addition, as the global semiconductor industry critically depends on China's huge and rapidly growing market, this enhances China's bargaining power in negotiations about global technology sourcing[53].

In short, participation in GPNs and GINs might provide powerful mechanisms for global technology sourcing and learning for suppliers who are latecomers to these networks. In principle, integration into global networks thus could enable developing countries to overcome "barriers to exporting by accommodating specialization in narrow business functions and niche

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manufacturing/original design manufacturing suppliers "may need to devote more effort to R&D in order to effectively interact with their local suppliers" (Chen, Shin-Horng. 2006. "The National Innovation System and Global R&D Strategies: The Case of Taiwan." Paper presented at "R&D Interplay in Northeast Asia: Global Corporate Strategy and Host Countries' National Innovation System," February 24, Seoul, Korea: pages 15 and 16). In turn, this requires that domestic R&D has reached a critical threshold so that it can "serve as a complement to, rather than a substitute for, the R&D activities of foreign affiliates."

[50] Kogut, B., and U. Zander. 1993. "Knowledge of the Firm and the Evolutionary Theory of the Multinational Corporation." *Journal of International Business Studies* 24(4): 625.

[51] Ernst, D., 2015, *From Catching Up to Forging Ahead: China's Policies for Semiconductors*, East-West Center Special Study, September, chapter one: pages 12 ff.

[52] Interview with Dr. Leo Li, CEO of Spreadtrum, conducted in June 22, 2012, as reported in Ernst, 2015: p.12.

[53] This also explains China's success in the recently concluded expansion of the Information Technology Agreement (ITA-2). See the author's MCTI Think Piece *The Information Technology Agreement, Manufacturing and Innovation – China's and India's Contrasting Experiences*.

activities and … [to] … limit dependence on the degree of industrial development and broader skills set in the country."[54]

It is unclear however at this stage whether and how the current international trade slow-down will affect the "gains from trade" effect. While evidence is still accumulating, it may be advisable for global network participants to prepare for a Plan B to compensate for slower global network-driven trade.

The "Domestic Disintegration" effect

This second scenario considers how global network integration might erode absorptive capacity and innovation capabilities. In fact, an important caveat needs to be added to the first scenario: The gains from trade through global network integration are contingent – or a country's capacity to capture those gains depends -- "on the structure of specialization and the level of development."[55]

There are concerns in fact that integration into global innovation networks may be a poisoned chalice. It is feared that, apart from a few prestige projects that might provide limited short-term benefits, R&D by global corporations may not provide the means for upgrading the host country's industry to higher value-added and more knowledge-intensive activities.

Foreign R&D centers often intensify competition for the limited domestic talent pool, leaving domestic companies on the sidelines. Inward R&D by global industry leaders may also give rise to a reverse "boomerang effect," providing global firms with precious insights into business models and technologies developed by domestic firms. Furthermore, foreign R&D centers typically show limited interest in sharing knowledge with domestic firms and R&D labs. In addition, as global competition is centered increasingly on the development of superior knowledge, "intellectual property" (the commercial embodiment of knowledge) will become more and more intensely guarded[56].

A recent report for the UK's Overseas Development Institute (ODI) argues that global network integration might erode absorptive capacity and innovation capabilities "because of disconnect to the rest of the economy"[57]. In a similar vein, Taglioni and Winkler (2014: p.6) observe that "foreign investors do not actively pursue – and sometimes resist – such integration for several reasons ranging from economic constraints to technological and quality gaps with domestic suppliers to shortages in specialized workers and skills."

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[54] OECD and World Bank, 2015, *Inclusive Value Chains. Policy options in trade and complementary areas for GVC integration by SMEs and low-income developing countries*, Report prepared for G20 Trade Ministers Meeting, Istanbul, Turkey, 6 October: p.14.

[55] Kowalski, P. et al., 2015, *Participation of Developing Countries in Global value Chains. Implications for Trade and Trade-related Policies*, OECD Trade Policy papers, No. 179, OECD, Paris: page 36.

[56] Chen, Tain-jy. 2004. "The Challenges of the Knowledge-Based Economy." In Chen, Tain-jy, and Joseph S. Lee, eds. 2004, The New Knowledge Economy of Taiwan. Cheltenham: Edward Elgar.

[57] Rodrik, D., 2015, *Past, Present, and Likely Future of Structural Transformation*, Presentation at ODI, 23 June, http://www.odi.org/events/4213-economic-transformation-growth-dani-rodrik. The coexistence of a country's global integration through trade and FDI and domestic disintegration has been analyzed quite some time ago for Latin America in Sunkel, O., 1978, "Transnationalization and its National Consequences", in: *Transnational Capitalism and National Development - New Perspectives on Dependence* (Villamil J.J. (Ed.)), pp. 67 - 94, Hassocks, Sussex: Harvester Press.

But domestic players also may be in part responsible for causing the "domestic disintegration" effect. An important under-researched topic is the role that domestic universities and research institutes may play in fostering or hindering domestic knowledge diffusion. For instance, Chinese companies have been complaining that some leading Chinese research universities are more interested in working with MNCs than local companies, "but we don't know whether this is a general phenomenon." [58]Similar concerns were raised in a recent study of the barriers to upgrading India's electronics industry, and in research for the OECD Innovation Policy study on Malaysia[59]. Korea and Taiwan had to struggle with similar problems right from an early stage[60]. While domestic knowledge exchange has improved in both countries, the MNC cooperation bias still seems to continue. Given the advanced level of development that both countries have reached today, this may have also positive effects: close links with global technology leaders now may provide pathways to domestic innovation.

The "Innovation Trap" effect

The third scenario explores how the position of global network suppliers of intermediate goods might constrain their ability and scope for innovation. Taiwan provides an example how participation in GPNs and GINs may impede rather than foster the innovation capacity of Taiwanese firms. Network integration has facilitated the catching-up of Taiwanese firms as fast-followers, especially in the electronics industry. However, as explained below, deep network integration has now become a mixed blessing, unless appropriate policies are put in place to develop domestic capabilities for disruptive and low-cost innovation both at the firm level and across the industry. As for R&D in the electronics industry, until recently its focus has been on incremental innovation. There is a growing recognition that Taiwanese firms must develop new products and services in order to avoid diminishing returns from network integration[61].

Taiwanese firms and policy-makers are still groping in the dark with what precisely that strategy requires, for the time being content with adopting a pragmatic trial-and-error approach until they find something that works. However, a new approach is gradually taking shape which combines market-led innovation and public policy coordination of multiple layers of private and public innovation stakeholders.

Due to its pragmatism and openness to new forms of public policy and private-public partnerships, Taiwan's innovation policy may in fact shed new light on the opportunities and challenges for capturing innovation gains from global network integration. In his chapter for this book, Chen Tain-Jy raises important and largely under-researched questions for the study of

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[58] Xue Lan, email to the author, December 1, 2015.

[59] Ernst, D., 2014, *Upgrading India's Electronics Industry – Regulatory Reform and Industrial Policy. An East-West Center Special Study*, East-West Center, Honolulu: 90 pages; and Ernst, D., 2014, *The role of innovation for Malaysia's economic development*. Background study for the *OECD innovation policy study on Malaysia*, OECD, Paris, forthcoming.

[60] Ernst, D., 1994, *What are the Limits to the Korean Model? The Korean Electronics Industry Under Pressure*, A BRIE Research Monograph, The Berkeley Roundtable on the International Economy, University of California at Berkeley, Berkeley; and Ernst, D., 2010, "Upgrading through innovation in a small network economy: insights from Taiwan's IT industry", *Economics of Innovation and New Technology*, Volume 19, Issue 4: pages 295-324.

[61] Ernst, D. 2013, *Industrial Upgrading through Low-Cost and Fast Innovation – Taiwan's Experience*, East-West Center Working Papers, Economics Series # 133, September.

trade and innovation: How does a firm's position in global networks affect their ability and scope of innovation? And what are the specific challenges that fast followers like Taiwanese firms are facing when they seek to upgrade their innovation capabilities within these global networks?

Chen's paper introduces multiple innovation traps to explain why Taiwanese global network suppliers of intermediate goods are stuck in a position of "passive innovators" – they innovate in collaboration with end users that are typically brand marketers of final goods and services and hence "remain weak in making market-oriented innovations in the sense of putting together different technologies to independently create final products for consumers."[62]

Research on the "innovation gap" effect provides important insights for the study of innovation gains from global networks. It shows that a company's position in a global network affects its access to knowledge and its ability to appropriate innovation rents. Equally important however is the analysis of strategic responses by Taiwanese firms to escape the innovation gap. This indicates that effects of global network integration are "neither inherently productive nor undesirable"[63] - support policies are necessary to strengthen a country's capacity to capture gains from GN integration.

The "Limits to Modularity" effect

The fourth and final scenario examines how global network suppliers might be handicapped by the "limits to modularity" that characterize many of the global networks, in particular the demanding coordination requirements and constraints to interface standardization which might constrain knowledge diffusion.

This pushes the analysis down to a more fundamental level. In fact, recent research has raised doubts that participation in global networks will automatically enhance the innovation capacity of global network participants. For instance, Chesbrough's dynamic theory of modularity demonstrates that, if a firm fails to adjust its organization and innovation management to the requirements of the new architecture, it risks being caught in a ''modularity trap''. Quite often this reflects fundamental conflicts of interest that separate for instance a global system player from its modular suppliers of manufacturing and design services. The dilemma facing a system player is that the more system technology he gives away to his suppliers, the better and cheaper products might become. But, at the same time, he may experience a substantial loss in the control that he can exercise over his suppliers.

A study on the limits to modularity in chip design finds that "…[i]t is …difficult to sustain the assumption, implicit in much of the modularity literature, that modularity is the stable end state of industry evolution, and that this is true across industries and technologies. While modular design has acted as a powerful catalyst for changes in business organization and industry structure, limits to modularity are aplenty, and constrain the convergence of technical, organizational and market modularity."[64]

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[62] Chen, Tain-Jy, chapter in this book; p.14

[63] As argued in the chapter by Sue Helper and Tim Krueger in this book.

[64] Ernst, D., 2005, "Limits to Modularity: Reflections on Recent Developments in Chip Design." *Industry and Innovation* 12(3): 303–35.

To somewhat oversimplify the point to gain clarity, let us focus on interface standardization – a fundamental prerequisite for effective global networks. Research has identified multiple constraints to such interface standardization which might constrain knowledge diffusion. A surprising feature of modular systems is their considerable rigidity. Once deployed, interface standards are difficult to adjust. When performance gains from a given design architecture approach a limit, it becomes necessary to establish a new architecture. But a defining characteristic of modular systems is that any transition to a new generation of design architecture requires fundamental changes in system components, which consequently will break down established interface standards[65].

Chip design provides an important example of the tight limits to interface standardization. Based on standard interfaces and design rules, the division of labor used to be reasonably simple during much of the 1990s. The resulting separation of chip design from fabrication has been one of the favorite examples of modularization proponents. Engineers designed chips and handed the definition to the mask makers, who then sent the masks to the wafer manufacturers (the silicon foundries). And (most of the time, at least) the result of having this modular division of labor was a chip that could be manufactured at an acceptable yield.

However, this easy phase of modularization of the semiconductor industry has vanished permanently. As process technology has dramatically increased in complexity, intense interactions are required across all stages of the semiconductor value chain, and it is no longer possible to work with entrenched standard interfaces and design rules. All participants in the semiconductor industry know that they need to find a way to organize collective and integrated solutions through effective interoperability standards. But implementing such standards is a tortuous process, due to conflicting interests of different stakeholders. Furthermore, technological uncertainty makes consensual implementation of interoperability standards extremely difficult, as does the fact that the industry is now vertically specialized[66].

In short, limits to modularity provide powerful arguments for skepticism that participation in modular global networks will *automatically* enhance the innovation capacity of global network participants. While modularity in principle facilitates independent innovation within components, this requires that local suppliers master the necessary capabilities. Thus, an important insight of the above research is that the deeper a company is integrated into global networks, the more important are policies to strengthen local networks.

Public policies thus are required in order to enhance the capacity of companies within a country to reap the hidden potential gains for innovation from global network integration. The World Bank argues that "GVC participation is a necessary but not a sufficient condition for development. While GVCs open doors, they are not magical. Most of the work still has to be done at home with domestic pro-investment, pro-skills, pro-jobs, and pro-growth reforms."

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[65] Chesbrough,. H.W., 2003, "Towards a Dynamics of Modularity. A Cyclical Model of Technical Advance", in: Prencipe, A., A. Davies and M. Hobday, eds, The Business of Systems Integration, Oxford: Oxford University Press.

[66] Recently, however, attempts to avoid being trapped by prematurely frozen design parameters have led to new approaches to improve the flexibility of system-on-chip (SoC) design, for instance, through reconfigurable processors. But it remains to be seen how viable these new approaches will be.

(Taglioni and Winkler, 2014: p.3). And the afore-mentioned ODI report concludes: such policies need to be"*…pragmatic, opportunistic, often "unorthodox" and promotes domestic manufacturing industries – such as protection of home market, subsidisation of exports, managed currencies, local-content rules, development banking, special investment zones....*"[67]

Note however that, as Susan Helper and Tim Krueger observe in their chapter: "[M]any trade agreements forbid items on this list, especially local content rules." (p.13). For instance, the WTO Agreement on Trade-Related Investment Measures (TRIMs) prohibits local-content requirements because they might "restrict and distort trade".[68] And the TPP, in its chapter 9 on investment establishes investment rules "requiring non-discriminatory investment policies and protections that assure basic rule of law protections, while protecting the ability of Parties' governments to achieve legitimate public policy objectives." Chapter 9 specifically prohibits "'performance requirements' such as local content or technology localization requirements."[69]

Case study research is required to establish what are the real effects of local content rules and other support policies recommended in the afore-mentioned ODI report[70].

Conclusions and Implications for Policy and Research

The proliferation of increasingly complex and diverse GPNs and GIN raises important but unresolved challenges for policies that seek to foster economic growth, competitiveness and prosperity through productivity-enhancing innovation. Most research on global networks focuses on trade in value-added and value capture, but offers only vague insights into innovation gains that might result from integration into these networks.

Based on the evidence presented in this chapter, I argue that it is time to move beyond value capture research. Instead, more effort should be invested in exploring head-on whether and how global network integration might foster or erode a host country's absorptive capacity and firm-level innovation capabilities. Case study research has shed some light on the drivers, the geographic extension, and the diverse manifestation of these networks. Collecting these data requires deep industry knowledge. And it is a time-consuming and costly affair, which explains why research has been limited to a handful of industries.

The chapter highlights an important blank spot in our knowledge: How are networks that span developed and developing worlds, distributing innovation gains among countries at different stages of development, and their firms? The chapter summarizes what is known by introducing four alternative scenarios. These scenarios are useful as signposts for further research. In essence, they highlight a fundamental tension between *global knowledge sourcing* which

[67] Rodrik, D., 2015, *Past, Present, and Likely Future of Structural Transformation*, Presentation at ODI, 23 June, http://www.odi.org/events/4213-economic-transformation-growth-dani-rodrik

[68] https://www.wto.org/english/tratop_e/invest_e/invest_info_e.htm

[69] https://ustr.gov/about-us/policy-offices/press-office/press-releases/2015/october/summary-trans-pacific-partnership

[70] In line with the infant industry argument, Aghion (2014: p.498) argues that "adequately targeted sectoral intervention, e.g. to more skill-intensive or to more competitive sectors, can enhance growth", especially for developing countries who need to overcome latecomer disadvantages. For a negative assessment, see Hufbauer, G, J. Schott, C. Cimino, 2013, *Local Content Requirements: Report on a Global Problem*, presentation at PIIE, October 7. http://www.iie.com/publications/papers/hufbauer20131007ppt.pdf

requires trade liberalization, and *domestic capability development* which requires supporting industry and innovation policies.

However, we need more specific and fine-grained information in order to provide sound policy advice on what type of domestic capabilities and institutions are needed to capture the innovation gains from global networks. This is true in particular for the major challenge "from the outside"--namely, emerging RTAs and attempts to establish a new architecture of mega-regional trade agreements, like the TPP that seek to create and harmonize new international benchmark standards for national policies, rules and regulations, for instance for intellectual property, technical standardization, government procurement, taxation, and competition policy. We need in-depth empirical research to assess the role that trade agreements like RTAs and TPP could play in enhancing or constraining the innovation gains from global networks.

The following questions deserve priority attention in further research:
1. How should one measure the innovation gains that a country or a firm might capture from integration into global networks (GNs)? And which combination of those measures should we use to measure long-term developments?

i) By type of innovation (product; process; marketing; organizational);
ii) By complexity (incremental; architectural; modular; radical[71]);
iii) Firms introducing products new to the market, manufacturing and services;
iv) Firms introducing products new to the market, by firm size;
v) Input indicators (R&D; quality of innovation infrastructure, including standardization and certification);
vi) Measures of industrial upgrading[72] ("firm-level upgrading" from low-end to higher-end products and value chain stages; "industry-level linkages" with support industries, universities and research institutes). Policy challenge: How to enable firm-level and industry-level upgrading to interact in a mutually reinforcing way ("virtuous circle")?;
vii) How important are three other forms of "industrial upgrading" to guide policies for upgrading a country's position in GNs[73]?

- inter-industry upgrading proceeding from low value-added industries (e.g. light industries) to higher value-added industries (e.g. heavy and higher-tech industries);
- inter-factor upgrading proceeding from endowed assets (i.e., natural resources and unskilled labor) to created assets (physical capital, skilled labor, social capital);
- upgrading of demand within a hierarchy of consumption, proceeding from necessities to conveniences to luxury goods.

[71] See page 15 **Appendix I: innovation matrix**
[72] Ernst, D., 2014, "Trade and Innovation in Global Networks – Regional Policy Implications", chapter 3 in Jos Leijten, ed., *Can Policy Follow the Dynamics of Global Innovation Platforms?* The International Innovation Policy Network of the Six Countries Programme, Delft: pages 5 and 6.
[73] For the concept of "industrial upgrading" see Ernst, D., "Beyond the Global Factory Model - Innovative Capabilities for Upgrading China's IT Industry", *Int. J. Technology and Globalization, Vol.3, No.4, pp.437 – 459.*

2. What indicators are needed to measure transfer of technology and knowledge sharing among different participants in GNs (flagships; first-tier suppliers; lower-tier suppliers) and across different sectors?

3. What type of case studies are needed to examine firms that differ in size, nationality and business model the following questions: How does a firm's position in GPNs and GINs affect its ability and scope of innovation? And how does a firm's innovation capacity shape its position in these networks?

4. What policies might be best suited to upgrade a country's position in global networks GNs, in which combination and in which order?

- Should such policies focus primarily on the demand for innovations or on the supply of innovation capabilities?
- Should policies focus primarily on attracting FDI? Or are supporting industrial and innovation policies needed?
- How important is liberalization of business services as a potential catalyst for host country upgrading through innovation?
- How important is *flexible policy implementation*, i.e. a more bottom-up and interactive approach to industrial policy ("smart specialization" [74]) in which the private sector discovers and produces information about new activities, and the government provides incentives for the search to happen, and for the effective implementation?

5. How important and feasible is effective harmonization of international standards, especially for inter-operability standards and certification? In light of the persistent diversity of national standards systems and policies, will the international standards system remain in a "multi-speed mode" for the foreseeable future? And if so, how might this affect the scope for knowledge sharing within GNs?

6. What research is needed to improve our knowledge about the impact of "standard-essential patents" (SEPs) for the distribution of innovation gains within GNs?

7. Will GN integration enhance or constrain the space for domestic innovation and industrial support policies? For developing countries that seek to expand their participation in GNs, will they need to transition much faster than in the past in favor of strong IPR protection and FDI-led development? And how might this affect their domestic capability development?

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[74] Foray, D., 2015, *Smart Specialization. Opportunities and Challenges for Regional Innovation Policy*, Routledge, London and New York.

8. What indicators are needed to assess whether mega-regional trade agreements are likely to foster knowledge sharing and the dissemination of innovation gains from GN integration?

9. What research is needed to establish the role (if any) of domestic content requirements (DCRs)? Will prohibition of DCRs increase the dynamism of host country clusters by reducing their insulation from outside ideas and competitors (as argued by Paul Romer)? Or will such prohibition constrain the development of dynamic, spill-over rich clusters in host country economies?

10. Finally, what indicators are needed to determine whether the growth of GNs requires stronger and more harmonized IPR regulations, as they might raise the certainty of investment, reduce contracting costs, and permit technologies to be deployed more efficiently across borders within these networks? Conversely, what research might help to assess how relevant are concerns by developing countries that stronger and more harmonized IPR regulations might restrict technology transfer and knowledge absorption within GNs?

Appendix I: Innovation Matrix, by complexity

Innovations differ with regard to opportunities and barriers to learning; they also differ in the capabilities that a firm needs to implement a particular type of innovation. It is useful to distinguish between *incremental*, *modular*, *architectural*, and *radical* innovations (Ernst 2008a, drawing on Henderson and Clark 1990). The boundaries between these four types of innovation are fluid. For instance, incremental and radical innovations are about the extent of changes caused by innovation, while modular and architectural innovations are about where the change is happening. They could therefore overlap.