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Trade and Innovation in Global Networks – Regional Policy Implications*

by

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Abstract

This Think Piece explores how integration into international trade through global networks of production (GPNs) and innovation (GINs) might affect a region's innovation capacity. As regions across the globe are progressively integrated into those global networks – some certainly more than others – these regions are all faced with a fundamental challenge: How might progressive integration of its firms into GPNs and GINs affect learning, capability development and innovation? Will network integration unlock new sources of industrial innovation? Or will it act as a poisoned chalice that will sap and erode the region's accumulated capabilities?

The paper presents illustrative examples of how "ubiquitous globalization" increases the diversity and complexity of GPNs and GINs, and briefly discusses the underlying systemic pressures and enabling forces. In order to capture the gains for innovation that a region might reap from global network integration, the paper suggests moving from a *one-way analysis of the external impacts on a region's innovation capacity* to an analysis of *two-way interactions*. The paper concludes with Policy Implications and highlights Unresolved Issues for Future Research, including the critically important issues of spillover employment effects and inequality.

About the author

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Overview of topic and why it is important
This Think Piece explores how integration into international trade through global networks of production (GPNs) and innovation (GINs) might affect a region's innovation capacity.

Policy debates typically focus on three specific channels through which trade could strengthen a region's innovation capacity: i) imports, FDI and technology licensing, and ii) learning-by-exporting would both expose the region to foreign technology and intangible knowledge as a source of product and process innovation. In addition, iii) competition may reduce monopoly rents from innovation and create pressure to increase productivity[1].

It is argued that, for these gains from trade to materialize, the following policies must be in place:

- *Trade liberalization* through tariff reduction would lower import prices, improve market access for exporters, and enhance competition.
- A *business environment* that encourages private investment through the provision of "political and macroeconomic stability, quality of regulation", and the provision of infrastructure, R&D capacity and a skilled workforce[2].
- Effective *intellectual property legislation and enforcement* is necessary to enable knowledge diffusion and external knowledge sourcing.

These policy prescriptions continue to shape debates about trade and innovation. A fundamental assumption is the existence of certain preconditions and capacities that are not always present in every region. In fact, recent research has convincingly demonstrated that the success or failure of trade liberalization is determined by the *economic structure* of a country or a region (i.e. its institutions and policies, its market size and sophistication, and the managerial and technological capabilities of its firms).[3] In addition, integration into geographically dispersed global networks of production (GPNs) and innovation (GINs) may also significantly affect a country's or a region's approach to and its experience with trade liberalization. These two parameters - a region's economic structure and its global network integration - encompass what might be called *domestic determinants of gains from trade for innovation*.

As regions across the globe are progressively integrated into those global networks – some certainly more than others – these regions are all faced with a fundamental challenge: How might progressive integration of its firms into GPNs and GINs affect learning, capability development and innovation? Will network integration unlock new sources of industrial innovation? Or will it act as a poisoned chalice that will sap and erode the region's accumulated capabilities?
There is nothing automatic about these processes, and they cannot be left to market forces alone. To cope with market failures identified many years ago by Kenneth J. Arrow[4], appropriate policies need to be in place to develop absorptive capacity and innovative capabilities, both at the firm level and across the industry.

Support policies for local firms will be required. And, as emphasized by Greg Tassey substantial investments are needed in "human science and engineering capital" and "innovation infrastructure."[5] An important objective is to improve the efficiency of a nation's innovation systems and to reduce the risks of innovation through "more comprehensive growth policies implemented with considerable more resources and based on substantive policy analysis capabilities"[6]. Aimed at upgrading a country's or region's innovation system, such generic support continues to matter.

There is however a growing consensus that effective innovation policy in a world of ubiquitous globalization has to move, as Rob Atkinson puts it, "beyond simply supporting factor conditions that all firms can use; it has to go inside the "black box" of the firm to help firms and key industries thrive."[7]

Part One of the paper lays out the *Policy Challenge* that *ubiquitous globalization* imposes on a region's innovation capacity. **Part Two** presents illustrative examples of how "ubiquitous globalization" increases the diversity and complexity of GPNs and GINs, and briefly discusses the underlying systemic pressures and enabling forces. In order to capture the gains for innovation that a region might reap from global network integration, **Part Three** suggests moving from a *one-way analysis of the external impacts on a region's innovation capacity* to an analysis of *two-way interactions*. The paper concludes with **Policy Implications** and highlights **Unresolved Issues for Future Research**, including the critically important issues of spillover employment effects and inequality.

Part One – The Policy Challenge

Rising complexity and increasing uncertainty are two defining characteristics of the new world of international economics. "Ubiquitous globalization" now reaches beyond markets for goods and finance into markets for business services, technology, intellectual property rights, and knowledge workers[8]. The result is an increase in the organizational and geographical mobility of knowledge[9]. However, the new geography of knowledge is not a flatter world where technical change and liberalization rapidly spread the benefits of globalization. Instead, the industrial heartlands in the US, Europe and Japan are intensely competing with a handful of new— yet very diverse— manufacturing and R&D hubs that are emerging in Asia.

Regions differ in their capacity to address this challenge. To understand why, it might be useful to examine first the following three questions: What do we know about how regions differ? What types of innovation are necessary for upgrading a region's growth prospects and prosperity? And how does one measure industrial upgrading?

What do we know about how regions differ?

Research on the geography of production and innovation has long struggled with a simple question: *Why is it that some regions achieve significantly higher growth rates than others?* For instance, Anthony Venable's 2006 Jackson Hole symposium lecture poses three specific questions[10]:

- Why are economic activity and prosperity spread so unevenly?
- Does increasing trade—or spatial interaction more generally – necessarily narrow these differences?
- How should we think about future developments, both for developed and for developing regions?

Regions differ widely across many dimensions. Significant variation exists for instance in industry composition (such as the size of firms and plants), the industry structure (e.g. large OEM with many SME suppliers versus a fragmented industry structure with many SMEs), and the region's degree of specialization versus its diversity. At the same time, wide disparities exist across regions in wages, labor markets and work conditions, and, most importantly, in the spatial distribution of high-growth clusters, jobs, and income levels. Furthermore, regions differ widely in their technology levels and capabilities, in their skill portfolios, and the quality of their Vocational Training and Higher Education systems. Last, but not least, regions may also differ in their R&D capacity, and in their institutional arrangements for intellectual property development and protection, and for standardization and certification.

Research on the causes of regional diversity focuses on the role of initial conditions, the potential for innovation and knowledge spillovers, and the composition of economic activity[11]. Maryann Feldman (1999) emphasizes the impact of science-based related industries on innovation performance[12]. Venables' great insight is that we need a model of the location of economic activity as the outcome of tension between concentration forces and dispersion forces. As he puts it in the revised version of his Jackson Hole lecture, published by the *Federal Reserve Bank of Kansas,* "globalization causes dispersion of activity, so economic development will be in sequence, not in parallel; some countries will experience rapid growth while others will be left behind."[13] Once we substitute "Regions" for "Countries", we are getting closer to the question at hand[14].

A more recent interesting conceptualization can be found in a 2012 NBER paper by Delgado, Porter, and Stern (DPS) which focuses on differences in cluster composition to explain variation in regional economic performance.[15] "Regional clusters" are defined as "groups of closely related and complementary industries operating within a particular region. A key finding is that industries participating in a strong cluster register higher employment growth as well as higher growth of wages, number of establishments, and patenting. An important objective is to ensure that "…the positive impact of clusters on employment growth does not come at the expense of wages, investment, or innovation." (DPS, 2012: p.6)

To get to the root causes of differentiated cluster performance, DPS suggest taking a fresh look at two fundamental determinants of cluster performance:

- *Convergence*, i.e. the potential for growth is *declining* in the level of economic activity as a result of diminishing returns.
- *Agglomeration* which arises from interdependencies across complementary economic activities that give rise to increasing returns. Agglomeration can increase inequality across regions over time.[16]

DPS find that convergence and agglomeration typically coexist, but they occur on different levels[17]: " [W]hile convergence is likely to be most salient at the industry level (or at relatively narrow levels of industry aggregation), strong agglomeration forces operate across industries within a cluster (or across closely related clusters)." The analysis focuses on complementarities, and examines "the agglomeration forces arising among closely related and complementary industries. By sharing common technologies, knowledge, inputs and cluster-specific institutions, industries within a cluster benefit from complementarities."

In short, what really matters for successful regional clusters are "complementarities across related industries." (DPS, 2012: p.6) "Such policies appear to be more effective than those that seek to attract a particular type of investment, offer incentives to benefit a small number of firms, or favor particular high-technology fields such as biotechnology or software if the region has little strength in those areas." (DPS: p.35)

What types of innovation are necessary for upgrading a region's growth prospects and prosperity?

Some basic definitions are in order to establish what *types of innovation* are necessary to upgrade a region's growth prospects and prosperity[18]. *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. Of critical importance are policies that would enable local firms (especially SMEs) to scale-up quickly new ideas, discoveries and inventions in order to be first at the right market at the right time.

In other words, effective innovation policies would first and foremost seek to reduce or remove barriers that may prevent a firm to move from "knowledge generation" (research) via "technology development", "scale-up" (pilot line & prototypes), and "globally competitive domestic manufacturing", all the way up to effective commercialization of new products and services.

Both in the US and in Europe, there is a growing recognition that innovation and manufacturing are closely intertwined, and that the focus should be on a set of enabling technologies (called "Advanced Manufacturing Technologies" in the US, and "Key Enabling Technologies" in Europe). According to recent MIT research[19], these enabling technologies encompass for instance

- Synthesized new materials (e.g., nano-engineering), aw eall as custom-designed and recycled materials
- Continuous manufacturing of pharmaceuticals and bio-manufacturing
- Green sustainable manufacturing
- Mass customization, for instance through Additive Manufacturing (3DP) and reconfigurable robotics which might enable Continuous Manufacturing in small batch sizes and break down the boundaries between fabrication and assembly.
- Integrated solutions through bundling of physical products with services and software.

Innovations in these Advanced Manufacturing technologies are expected to act as enablers of new products and services that might create new niches and new industries. In addition, programmable manufacturing which needs less capital-intensive tooling and fixtures may facilitate manufacturing in smaller, agile and flexible production facilities, closer to end-users.

In turn, this may enhance productivity and flexibility in large-scale manufacturing and supply and distribution chains (for instance through RFID tracking and Human-Robot-interaction).

Furthermore, Advanced Manufacturing technologies are expected to enhance coordination and flexibility in global production and innovation networks.

What is success? Measuring industrial upgrading[20]

In general terms, industrial upgrading is about linking improvements in specialization, local value-added, and forward and backward linkages[21] with improvements in learning, absorptive capacity and innovative capabilities.

Two aspects of industrial upgrading are of greatest policy relevance: "firm-level upgrading" from low-end to higher-end products and value chain stages, and "industry-level linkages" with support industries, universities and research institutes.

For upgrading a region's growth prospects, the challenge is to enable firm-level and industry-level upgrading to interact in a mutually reinforcing way, so that both types of upgrading will give rise to a "virtuous circle". "Firm-level upgrading" is the key dimension - without it, there is little hope that a region can benefit from global network integration. In other words, local firms must develop the capabilities, business models and organization that will allow them to strengthen their absorptive capacity and innovative capabilities. This requires important adjustments in corporate strategy.

But for firm-level upgrading to succeed, upgrading must take place simultaneously at the level of "industry linkages". As Powell and Grodal observe, "collaboration across multiple boundaries and institutional forms" is the norm today, and innovation networks "… are now core components of corporate strategy."[22] This reflects the growing geographic mobility of knowledge and the emergence of IT-enabled governance mechanisms to orchestrate distributed knowledge. To broaden the pool of firms that are fit for sustained firm-level upgrading, regional governments need to foster strong support industries and dense linkages with universities and research institutes.

Finding the right balance between firm-level and industry-level upgrading poses a continuous challenge for policy makers and corporate planners - the "right balance" is a moving target, it is context-specific and requires permanent adjustments to changes in markets and technology. A strategy that neglects one element at the detriment of the others is unlikely to create sustainable gains. The stronger the links between those two elements, and the better they fit, the greater are the chances that local firms can shape markets, prices and technology road maps.

In addition, three other forms of "industrial upgrading" may help to guide regional policies: (i) 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); (ii) inter-factor upgrading proceeding from endowed assets (i.e., natural resources and unskilled labor) to created assets (physical capital, skilled labor, social capital); and (iii) upgrading of demand within a hierarchy of consumption, proceeding from necessities to conveniences to luxury goods[23].

Most research has focused on a combination of (i) and (ii), based on a distinction between low-wage, low-skill "sun-set" industries and high-wage, high-skill "sunrise" industries. Such simple dichotomies however have failed to produce convincing results, for two reasons: First, there are low-wage, low-skill value stages in even the most high-tech industry, and high-wage, high-skill activities exist even in so-called traditional industries like textiles. And second, both the capability requirements and the boundaries of a particular "industry" keep changing over time. An example is the transformation of the computer industry from an R&D-intensive high tech industry to a commodity producer that depends on the optimization of supply chain management.

Part Two – Increasing Diversity – the Dynamics of Global Innovation Networks

We now turn to the dynamics of global innovation networks that shape the opportunities and challenges for regional policies. The root cause for "ubiquitous globalization" is the emergence of a "winner-takes-all" competition model, described by Intel's Andy Grove[24]. In the fast moving ICT industry, success or failure is defined by return on investment and speed to market, and every business function, including R&D, is measured by these criteria. Technology-based competition is intensifying, provoking fundamental changes in business organizations. No firm, not even a global market leader like IBM, can mobilize all the diverse resources, capabilities, and repositories of knowledge internally. This indicates how much the world has changed since Edith Penrose argued in her path-breaking study *The Theory of the Growth of the Firm* that " ... a firm's rate of growth is limited by the growth of knowledge within it" ([1959] 1995: xvi, xvii).

Corporations have responded with a progressive modularization of all stages of the value chain and its dispersion across boundaries of firms, countries, and sectors through multi-layered corporate networks of production and innovation[25]. 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."[26] While the proliferation of global production networks goes back to the late 1970s, a more recent development is the rapid expansion of global innovation networks (GINs), driven by the relentless slicing and dicing of engineering, product development, and research[27].

A defining characteristic of the new geography of knowledge is that both learning and innovation are fragmented ("modularized") and geographically dispersed through multilayered global corporate networks that integrate engineering, product development, and research activities across firm boundaries and geographic borders. It took some time for economic theory to adjust to this important transformation.

Only a decade ago, research on the geographical distribution of patents concluded that innovative activities of the world's largest firms were among the least internationalized of their functions[28]. This finding gave rise to the proposition that innovation, in contrast to most other stages of the value chain, is highly immobile: it remains tied to specific locations, despite a rapid geographic dispersion of markets, finance, and production[29]. Attempts to explain such spatial stickiness of innovation have highlighted the dense exchange of knowledge (much of it tacit) between the users and producers of the resultant new technologies.

Yet, even as this research was in progress, the world was changing, with the emergence of GINs since the 1990s which carry out design and product development as well as applied and basic research. GINs share important characteristics with the GPNs that preceded them[30]:

- *Asymmetry* is a fundamental characteristic. Multinational corporations (MNCs) dominate as network flagships and define network organization and strategy. Control over network resources as well as coordination of information flows and decision making enables the flagship to directly affect the growth, strategic direction, and network position of lower-end participants (e.g., specialized suppliers and subcontractors).

- A great variety of *governance* structures is possible. These networks 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. What matters is that formalized networks do not require common ownership; these arrangements may, or may not, involve control of equity stakes.

Increasing diversity and complexity
An important recent development however is the *increasing diversity and complexity* of these knowledge-sharing network arrangements. GINs now involve multiple actors and firms 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**).

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 United States, the European Union, 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 (**Fig.1)** The company has pursued a two-pronged strategy[31]: it is building a variety of linkages and alliances with leading global industry players and universities, while concurrently establishing its own global innovation network of more than 25 R&D centers worldwide. In the European Union, Huawei has more than 800 R&D specialists across 14 R&D sites in eight countries[32].

Table 1

2. Global innovation networks – increasing diversity

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Hierarchical

- **Intra-firm networks -** Global companies "offshore" stages of innovation to Asian affiliates
- **Inter-firm networks -** Global firms "outsource" stages of innovation to specialized Asian suppliers
- **Asian firms** construct their own GINs (**Huawei**)

International public-private R&D consortia

- **ITRI** – global knowledge sourcing from the erstwhile periphery

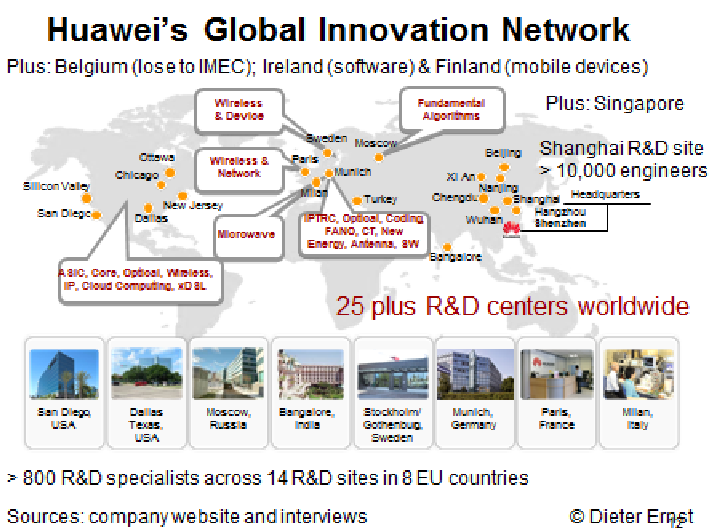
From hierarchical to splintered GINs

- **Foxconn** – contractors can shape strategic direction as junior network flagships

Plus: Informal social networks (students, knowledge workers)

Adapted from Ernst, D., 2009, *A New Geography of Knowledge?*

Figure 1



In fact, Huawei has developed a web of project-specific collaboration arrangements with major suppliers of core components, such as Siemens (as part of China's TD-SCDMA third-generation mobile communications standard) and Alcatel-Lucent (with a focus on 4G TD-LTE development), as well as Intel and Qualcomm. And 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. The choice of these locations reflects Huawei's objective to be close to major global centers of excellence and to learn from incumbent industry leaders: Plano, Texas, is one of the leading U.S. telecom clusters initially centered on Motorola; Kista, Stockholm, plays the same role for Ericsson and, to some degree, Nokia; and the link to British Telecom was Huawei's entry ticket into the exclusive club of leading global telecom operators.

Recent transformations

What matters most for a region like Brabant are three recent transformations in the dynamics of global innovation networks. **First**, **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 (**Tables 2 and 3**).

Table 2

ITRI's global knowledge network – Europe (select examples)

Germany: Brandenburg University of Applied Science; Degussa; Fraunhofer (IPA, IPK); German Aerospace Center; Karl Storz Endoscopy; MANZ AG (display); Physikalisch-Technische Bundesanstalt; Siemens

TUBerlin; University Duisburg-Essen

Netherlands: Aeon Astron Europe B.V.; Centraalbureau voor Schimmelcultures (CBS); Dutch Polymer; Eindhoven University of Technology; KEMA International; Philips Design; TNO; to-BBB Technologies; VU University Medical Center

Russia:Moscow State University; Academy of Sciences (IOFFE, ICPC, PTI···;St. Petersburg State Polytechnical University

ITRI website & interviews © Dieter Ernst 13

Table 3

ITRI's global knowledge network – U.S. (select examples)

Universities: Carnegie Mellon; Case Western Reserve; Columbia; Cornell; Georgia Tech; Harvard; Johns Hopkins Kent State; Lawrence Berkeley National Laboratory; MIT Media Lab; MIT-CSAIL; MIT-Harvard Clinical Consortium; National Renewable Energy Laboratory; Ohio State University; Purdue University; Rensselaer Polytechnic; Texas Tech University; UC Berkeley; UCLA; UC San Diego; UC Santa Barbara; University of Central Florida; University of Cincinnati; University of Illinois; University of Missouri; University of Washington, Seattle; Virginia Polytechnic

Companies: Corning; DuPont; e-Meter Corporation; Eastman Kodak; Exactech; IBM; InVisage; Johnson & Johnson; Qualcomm MEMS Technologies; Texas Instruments; etc

- ITRI's network interacts with & complements Taiwanese corporate GINs (e.g., TSMC)

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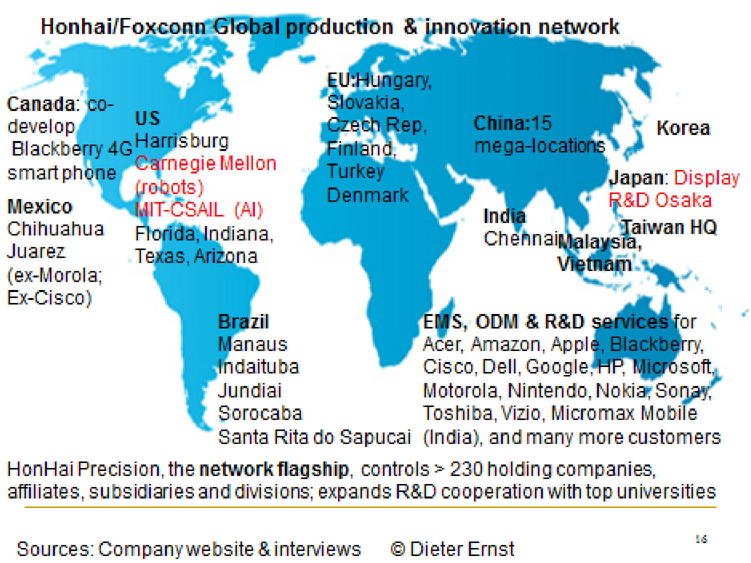
Within Europe, ITRI's global knowledge network concentrates on Germany, the Netherlands, France, where it covers a broad array of science disciplines and technologies. By contrast, ITRI's presence in Russia is heavily focused on the country's leading research institutes for advanced mathematics and physical 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[33].

A **second** recent transformation are **splintered GINs** with diverse network flagships which increasingly complement the erstwhile dominant hierarchical networks. This indicates that vertical specialization within global networks continues unabated. Three different types of splintered GINs are emerging[34]:

- core component suppliers (Intel, MS; ARM; QCM; TSMC) control technology platforms
- Mega-contractors (Foxconn) can co-shape strategic direction and provide integrated solutions
- Mega- distributors (e.g., Arrow Electronics; Avnet) can provide integrated solutions

Figure 2 presents a glimpse at **Foxconn**'s expanding global production and innovation network which illustrates how contractors from the erstwhile periphery of the world economy are now *co-shaping* the strategic direction of GINs as junior partners. HonHai Precision, the network flagship, controls more than 230 holding companies, affiliates, subsidiaries and divisions worldwide, and keeps rapidly expanding R&D cooperation with top universities and research institutes in the US, Japan and Europe.

Figure 2



A **third** recent transformation is the **increasing complexity of global networks**, due to rapid and disruptive technical change. 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". According to Cisco, the "Internet-of-Everything is expected to bring "… together people, process, data and things to make networked connections more relevant and valuable than ever before - turning information into actions that create new capabilities, richer experiences and unprecedented economic opportunity for businesses, individuals and countries."[35]. **Figure 3** highlights the evolution of network connectivity, from digital access to information through email, web browser and search engines through a progressive digitization of business processes and interactions.

Figure 3

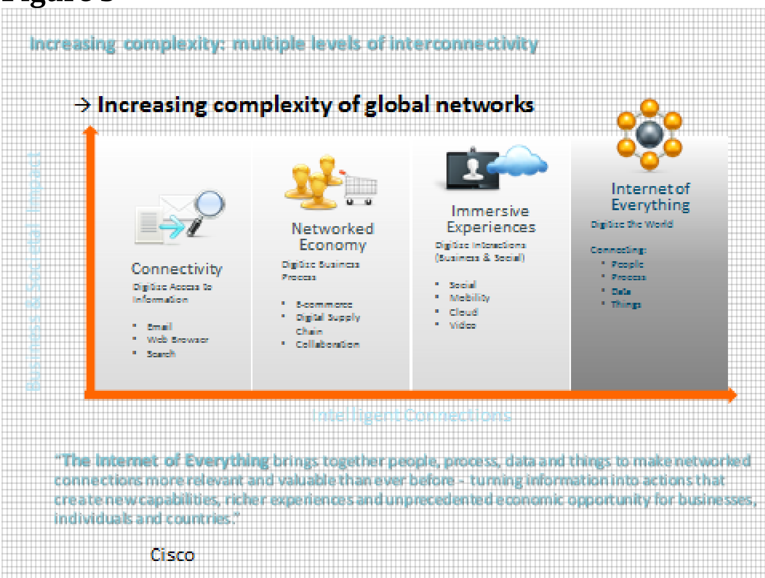
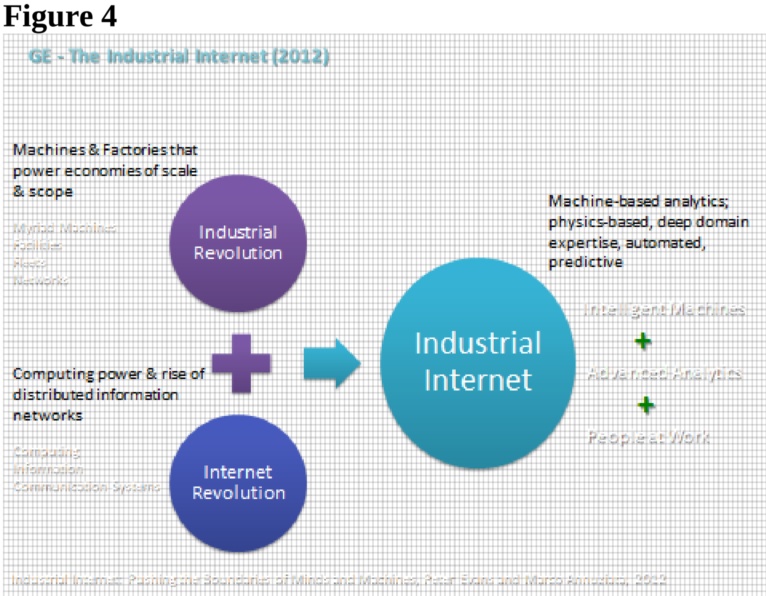


Figure 4



While the vision of an "Internet-of-Everything" certainly exaggerates what will be possible over the next decades, concepts like GE's "Industrial Internet" are already being implemented to increase productivity gains across all stages of the industrial value chain (see **Figures 4 and 5).** And the concept of "Connected Manufacturing" highlights 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."[36] Of critical importance are *interoperability standards* that are necessary to transfer and render useful data and other information across geographically dispersed systems, organizations, applications of components[37].

Figure 5

Drivers and enabling forces

Global corporations construct GINs to cope with increasing pressures to internationalize innovation. Ernst (2009) documents the systemic nature of *driving forces*. Specifically, these networks are expected to:

- enable global corporations to increase the return-on-investment for R&D, despite the rising cost, complexity, and uncertainty of R&D;
- facilitate 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;
- bypass regulations that seek to protect society (especially the losers of globalization) and the environment; and
- perform "regulatory arbitrage", by exploit differences in IPR regimes, incentives, tax laws [especially for transfer pricing], regulations [finance; environment; health].

At the same time, a powerful mix of *enabling factors* facilitates the construction of GINs by reducing uncertainty, as well as transaction and coordination costs. The result has been a rebalancing of the centripetal forces that keep innovation tied to specific locations and the centrifugal forces that place a premium on geographical dispersion. The latter have become more powerful, although the former have hardly disappeared.

There are two root causes of this rebalancing and the resultant increase in the mobility of knowledge: 1) the improvement of the information and communication infrastructure and its extension around the world, and 2) the liberalization of international economic policies that allows this technological change to be exploited more fully by firms and organizational networks. Recent research identifies the following formidable *enabling forces* behind the proliferation of GINs and their increasing diversity[38]:

- Modular design enables vertical specialization, i.e. the progressive slicing and dicing of the innovation value chain
- Liberalization and privatization has created 'deregulated' markets, playing an important role in reducing constraints to the organizational and geographical mobility of knowledge[39]
- ICT-enabled information management has also considerably increased the mobility of knowledge
- Globalizing markets for technology, knowledge workers and innovation finance
- Growing innovative capabilities in emerging economies

Additional powerful *enabling factors* are the progressive globalization of IP protection and standards, as well as new Trade Rules and Dispute Settlement Mechanisms which are currently being negotiated as part of plurilateral and mega-regional trade agreements (TRIPS-Plus; ITA; TISA; TPP; TTIP).

Part Three – Capturing the gains for innovation from global network integration
Economic theory still has a long way to go to catch up with the new world of *Ubiquitous Globalization*. As indicated, current policy documents (OECD, WTO, etc) focus primarily on the impact of exports and imports on innovation. This is important, but it only captures one segment of the external impacts on a country's innovation capacity.

New approaches
However, new approaches are beginning to emerge that help to extend the analysis beyond trade. The *E-15 Initiative* for instance, established in cooperation with the *World Economic Forum* and supported among others by the *Dutch Government*, explores options for strengthening the governance and functioning of the multilateral trade system. Specifically on Trade and Innovation, E-15 has published widely circulated *Policy Think Pieces* that move the debate well beyond the narrow confines of established trade theory[40].

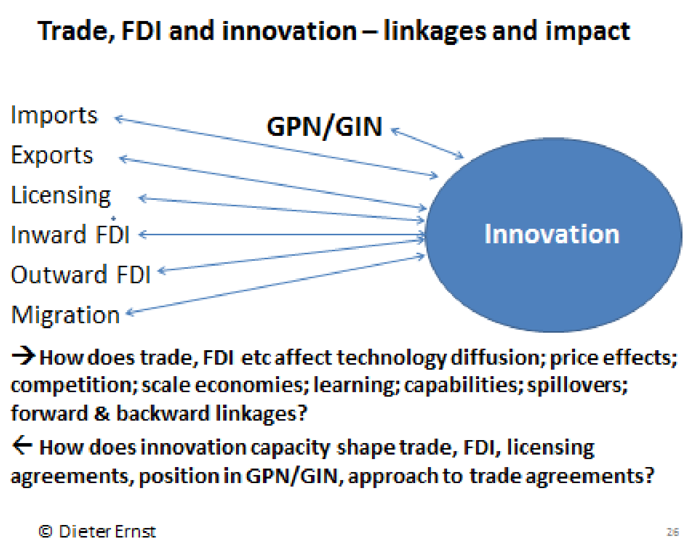
In addition, new research agendas pursued by trade economists can help to address the impact of ubiquitous globalization. Important contributions are Robert Feenstra's analysis of Integration of Trade and Disintegration of Production in the Global Economy[41], and Lee Branstetter's pioneering work on the role of FDI as a channel of knowledge spillovers[42]. More recently, Richard Baldwin and colleagues have broadened the analysis to include the "Trade-investment-service-IP nexus"[43] – a long overdue breakthrough! For Baldwin, " *"Trade in today's world is radically more complex. The information and communications technology revolution has internationalized supply chains, which has created a tight supply-side linkage between trade and FDI: the "trade–investment–service– IP nexus". Today's international commerce comprises complex, two-way flows of goods, services, people, ideas and investments in physical, human and knowledge capital – in addition to trade in raw materials and final goods. These connections make it almost irrelevant to talk about trade without also talking about FDI – at least for many products and markets….*As a result, … *trade and investment are neither complements nor substitutes – they are simply two facets of a single economic activity: international production sharing."*[44]

Research on GPNs and GINs can benefit from these new insights in policy-related trade theory. Some of the analytical tools provided by Feenstra, Branstetter, Baldwin and others, should make it easier to measure the scope and depth of these global networks, and their increasing diversity. These analytical tools might also provide better insights into differences in network structure across industries, and crucially between manufacturing, professional services and natural resources.

Drawing on these new analytical tools, research on GPNs and GINs can shed new light on the impact of these networks on the geographic distribution of innovation. It is possible to conceptualize GPNs and GINs as *institutional innovations* that seek to bundle, coordinate and rationalize the multiple linkages and impacts of Baldwin's "Trade-investment-service-IP nexus".

As illustrated in **Figure 6**, it is time to examine the other side of the Trade, FDI and Innovation link. In order to capture the gains for innovation that regions like Brabant might reap from global network integration, research should move from a *one-way analysis of the external impacts* on a region's innovation to an analysis of two-way interactions.

Figure 6



A central proposition of this paper is that future research should provide guidance for regional policy on two *broad strategic challenges*:

- *How does a region's innovation capacity in a particular industry affect the type of exports and imports it can realize, the licensing agreements it can negotiate, and the volume and sophistication of inward and outward FDI?*
- *And how does a region's innovation capacity in a particular industry affect its approach and position in multilateral and plurilateral trade agreements?*

To provide policy-relevant insights on the above strategic challenges, it is necessary, first, to open the black box of "innovation" in order to understand precisely what type of innovation strategy might be required. Second, future research should revisit in quite some detail what we know about the distribution of gains for innovation from global network integration.

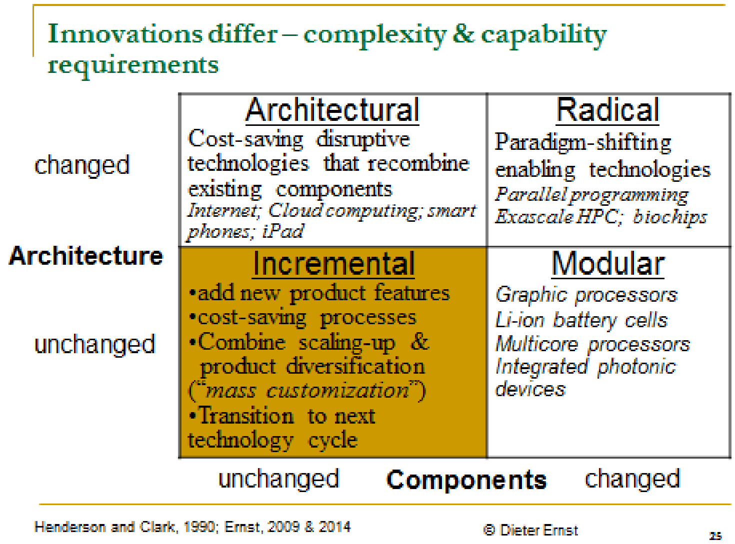
Opening the "Black Box" – Innovations differ

A fundamental insight of innovation theory is that learning and innovation are "the two faces of R&D" (Cohen and Levinthal 1989: 569). Learning by doing establishes routines: "The firm becomes more practiced, and, hence, more efficient, at doing what it is already doing" (ibid.: 570). But a firm's growth depends on a second type of learning ("absorptive capacity"), by which a firm acquires external knowledge "that will permit it to do something quite different."

For an effective conversion of knowledge to productive learning, two important elements are required: an existing knowledge base or competence and an intensity of effort or commitment[45]. In fact, a critical prerequisite for absorptive capacity is that a firm conducts basic research in-house. This differs from the current fashion of "open innovation"[46] , which downplays the importance of a decline in corporate basic research. Cohen and Levinthal (1989) demonstrate that a firm needs to sustain a critical mass of internal basic research "to be able to identify and exploit potentially useful scientific and technological knowledge generated by universities or government laboratories, and thereby gain a first-mover advantage in exploiting new technologies."[47] The same is true for "spill-overs from a competitor's innovation."

In short, R&D is critical to strengthen the absorptive capacity of a region or a firm. However, the requirements for absorptive capacity evolve over time, as a country, a region or a firm moves up from catching-up to upgrading and leadership strategies of innovation. This raises the question: Precisely what type of innovation strategy is needed when and where?

Figure 7



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 (Figure 7)[48].

Incremental Innovations

Incremental innovations take both the dominant component design and architecture for granted, but improve on cost, time-to-market, and performance. Their purpose is to exploit to the greatest extent possible the potential of a given design by introducing relatively minor changes to an existing product or process[49]. These innovations do not require substantial inputs from science, but they do require considerable skill and ingenuity, especially complementary "soft" entrepreneurial and management capabilities[50]

Examples of incremental innovations are improvements of products (adding new product features); cost-saving processes; design changes that allow for "mass customization" by combining scaling-up and product diversification; and organizational adjustments that facilitate the transition to the next technology cycle. Barriers to incremental innovations are relatively low, as tools and methodologies are familiar and investments tend to be limited and predictable. Most importantly, incremental innovations build on existing operational and engineering skills as well as the management of supply chains, customer relations, and information systems.

Modular innovations

Modular innovations introduce new component technology and plug it into a fundamentally unchanged system architecture. They have been made possible by a division of labor in product development: "Modularity is a particular design structure, in which parameters and tasks are interdependent within units (modules) and independent across them"[51].

Examples of modular innovations include the development of graphic processors, Li-ion battery cells, multicore processors, and integrated photonic devices. The barriers to producing such modular innovations are substantial. High technological complexity requires top scientists and experienced engineers in various fields. In addition, investment requirements can be very substantial (more than U.S.$ 5 billion for a state-of-the-art semiconductor fabrication plant), as are risks of failure.

Architectural innovations
Architectural innovations use existing component technologies but change the way they work together. Examples include cost-saving disruptive technologies that recombine existing components, such as the Internet, smart phones, tablets, and cloud computing (which however might also be subsumed under radical innovations).

A defining characteristic of *architectural innovations* is a capacity to leverage a deep understanding of market and user requirements in order to break new ground in product development. This implies that architectural innovations require strong system integration and strategic marketing capabilities, but they are much less demanding than modular and especially radical innovations in terms of their needs of science inputs and investment thresholds.

At the same time, however, architectural innovations tend to have far-reaching implications for the market share and the profitability of innovating firms. As highlighted by Henderson and Clark (1990: 9), architectural innovations can threaten incumbent market leaders; they "destroy the usefulness of the architectural knowledge of established firms, and since architectural knowledge tends to become embedded in the structure and information-processing procedures of established organizations, this destruction is difficult for firms to recognize and hard to correct."[52]

Radical innovations
Finally, radical innovations involve both new component technology and changes in architectural design. Examples include paradigm-shifting enabling technologies, such as *Parallel programming, Exascale High-Performance Computing, and biochips*[53].

The great attraction of radical innovations is that once they have generated intellectual property rights for a blockbuster technology, the innovating firm may become a market leader in a short period of time. The flip side, however, is that "radical innovations require breakthroughs in both architectural and component technology. Radical innovations require dense interaction with leading-edge science, requiring top scientists and engineers who work at the frontier of basic and applied research in a broad range of disciplines. In addition, implementing radical innovations requires a broad set of complementary assets[54], and investment thresholds tend to be extreme.

In short, radical innovations are costly and risky, and failure can destroy even large, well-endowed companies. They are beyond the reach of most companies, but they may well be the subject of public-private consortia coordinated by a regional government in coordination with the central government. [55]

Distribution of gains for innovation from global network integration
Research on Asia's innovation offshoring hubs 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.[56]

A look at earlier research on knowledge diffusion through global production networks explains why this is so. Ernst and Kim (2002) find that global corporations that act as "network flagships" "transfer both explicit and tacit knowledge to local suppliers through formal and informal mechanisms[57]. This is necessary to upgrade the local suppliers' technical and managerial skills so that they can meet the flagships' specifications." Furthermore, "once a network supplier successfully upgrades its capabilities, this creates an incentive for flagships to transfer more sophisticated knowledge, including engineering, product and process development" (ibid.: 1422).

This reflects the increasingly demanding competitive requirements, especially in R&D-intensive sectors of the electronics industry, which are exposed to intense price competition from a very early stage in their product life cycle[58]. Competition in these industries is driven by 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[59].

No firm, not even a global market leader like IBM, can mobilize internally all the diverse resources, capabilities, and bodies of knowledge that are necessary to fulfill this task. As a consequence, global firms increasingly "externalize" both the sources of knowledge and its use. They outsource knowledge needed to complement their internally generated knowledge, and they license their technology to enhance the rents from innovation.

For many high-tech 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. There are concerns however 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 at 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[60].

On a more fundamental level, recent research has raised doubts that participation in modular global networks will automatically enhance the innovation capacity of global network participants[61]. 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''. In other words, if a firm focuses too much on developing products within given interface standards, this may erode the firm's system integration capabilities. A ''modularity trap'' exists, when flagships fail to retain those system integration capabilities that are necessary to incorporate new (interdependent) component technologies effectively into their systems[62]. Chesbrough's ''modularity traps'' quite often reflect fundamental conflicts of interest that separate for instance a global system player and 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, he may get better and cheaper products. But, at the same time, he may experience a substantial loss in the control that he can exercise over his suppliers.

In a study on the limits to modularity in chip design, Ernst (2005) 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."[63] Specifically, two limits to knowledge sharing within modular networks are identified: (a) demanding coordination requirements; and (b) constraints to interface standardization.

(a) Demanding coordination requirements of GINs

As Pavitt (1999) has convincingly argued, activities that require complex knowledge pose very demanding coordination requirements[64]. There are cognitive limits to the process of modularization. Important differences exist between the coordination requirements of ''project execution'' (to design and produce an artifact, e.g. a chip) and of ''technology development'' (to produce the underlying knowledge bases)[65].

Baldwin and Clark (2000: ch. 3) correctly emphasize that modularity in design has created opportunities for vertical specialization (combining disintegration and geographic dispersion) in project execution. Their analysis however neglects the increased knowledge exchange that is necessary to develop design and manufacturing technologies. This, in turn, requires *ex ante* coordination through integration in technology development. Modular product design thus needs knowledge-integrating firms to coordinate specialized bodies of knowledge and increasingly distributed learning processes. It does not reduce the need for system integration.

In other words, modular product design may well increase complexity and hence the need for system integration. Large global network flagships retain diversified technology bases precisely to cope with the demanding coordination requirements of disintegrated and geographically dispersed technology development.

(b) Constraints to interface standardization
A surprising feature of modular systems is their considerable rigidity. Once deployed, interface standards are difficult to adjust. When performance gains from a particular 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[66].

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 and 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 for good. 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. They also know that uncertainty makes this extremely difficult, as does the fact that the industry is now vertically specialized[67].

Why modular global networks may impede innovation
The Taiwanese PC industry provides an example where participation in GPNs and GINs has impeded rather than fostered their innovation capacity. In a recent still unpublished paper, Tain-Jy Chen and Ying-Hua Ku highlight two *pitfalls of modular production* in global networks: an *unequal power structure* and *fragile inter-firm relations*[68].

Power structure
According to Chen and Ku, network flagships seek to incorporate new technologies in such a way that the power structure of the system is maintained. In the PC industry, "the architecture is controlled by two dominant component suppliers rather than branded companies or manufacturers. Intel and Microsoft reap most of the rents of the modular system, which, in turn, allow them to invest in new technologies to maintain the system. They continuously invent new components to upgrade the power of the architecture. However, their inventions mostly belong to cumulative innovations rather than disruptive innovations. The architecture itself is a barrier to disruptive innovations as such innovations may lead to a loss of coordination power embedded within the architecture." (Chen and Ku: p.6)

Inter-firm relations
Because of the openness and low entry barriers of modular networks, Chen and Ku argue that *relational assets* embedded in a modular system are very fragile. According to Dyer and Singh (1998), when components can be designed in isolation, information sharing becomes

unnecessary and, therefore, the value of relational assets evaporates[69]. In a modular system, there is thus little relation-specific knowledge to be accumulated. As a result, "it may even be more advantageous to collaborate with non-network members in making innovations because such innovations are not subject to the constraints of the architecture. Furthermore, the extra-network innovations may be more valuable to network members because they are free from rent-extraction by flagship companies. Expressed metaphorically, a modular system is conducive to 'extra-marital' affairs." (Chen and Ku: pages 6 and 7)

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. An important insight of the above research is that the deeper a region is integrated into global networks, the more important are policies to strengthen local networks. Public policies are required in order to enhance the capacity of companies within a region to reap the hidden potential gains for innovation from global network integration. Some of the policy issues raised by this analysis are addressed in the last part of the paper.

Part Four - Policy Implications

Based on the paper's analysis of the dynamics of global innovation networks and the gains for innovation from trade and global network integration, what policy options are available for upgrading a region's innovation capacity?

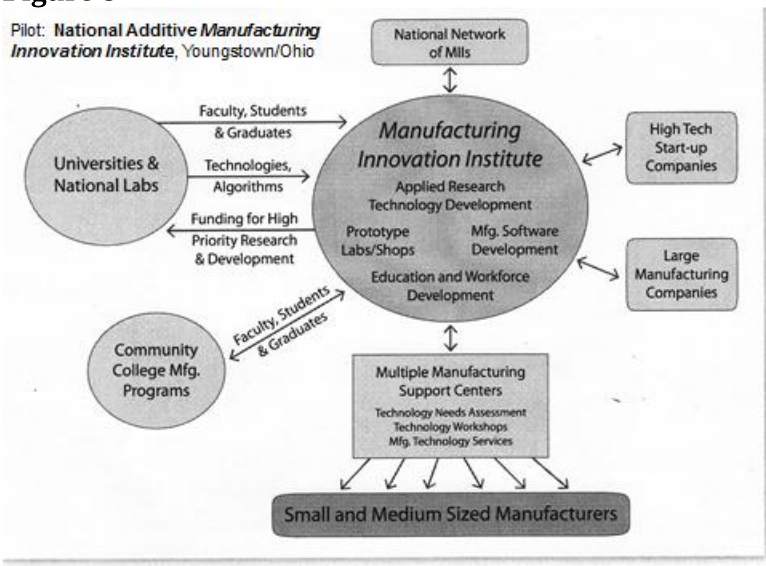
First and foremost, it is necessary to acknowledge that, while integration into GINs can accelerate the development of the region's innovation capabilities, it can also act as a *Poisoned Chalice*. In order to avoid being marginalized in these global networks, policies need to be in place to address *unintended negative consequences of global network integration*. For instance, foreign affiliates may succeed in recruiting the best talent, leaving domestic companies at the sidelines. In addition, foreign affiliates may be interested primarily in "tapping into the local knowledge base" when they invest in R&D labs in the region, which may erode the region's "Industrial Commons". [70] Furthermore, policies need to be in place to counter significant challenges to Privacy and Cyber-Security.

Second, it is important to emphasize the *systemic* nature of policy responses. In order to strengthen a region's *Absorptive Capacity*, it is necessary to coordinate regional policies with trade, FDI and innovation policies. These policies need to be broad-based, and should encompass regulations; investment promotion; R&D tax credits; industrial support policies to foster firm-level managerial and technological capabilities; patient innovation finance; standard development and certification; industrial collective research consortia; industrial associations and research centers; university-industry collaborations; and trade diplomacy.

Systemic policy responses are particularly important if the objective is to foster *radical innovations*. As described in Part Three, radical innovation are beyond the reach of most companies. Radical innovations thus require public-private consortia coordinated by a regional government in coordination with the central government. **Figure 8** highlights an example of a private-public consortium that originated from the US *Advanced Manufacturing Partnership program (AMP)*, the **National Additive Manufacturing Innovation Institute in**

Youngstown/Ohio, established as part of a planned US National Network of Manufacturing Innovation Institutes (NNMIIs)[71].

Figure 8



Source: AMP Steering Committee

Third, *flexible policy implementation* is critical. A broad portfolio of diverse policy approaches is required to enable regions to increase the gains from global network integration. The mix of policies will differ across sectors, sub-sectors and sub- regions. And the appropriate policy mix will have to evolve over time.

Europe's current eighth Framework Program, the so-called Horizon 2020 program , provides a new policy approach, called *"Smart Specialization"* that may provide guidance for greater flexibility in policy implementation. In essence, the concept of *"Smart Specialization"* seeks to develop a more *bottom-up* approach to industrial policy that focuses on 'entrepreneurial discovery' - an interactive process in which market forces and the private sector are expected to discover and produce information about new activities and the government assesses the outcomes and empowers those actors most capable of realizing the potential.[72]

In essence, the concept of "smart specialization" seeks to transform industrial policy into an "interactive process": *"Prioritisation is no longer the exclusive role of the state planner (top down) but involves an interactive process in which the private sector is discovering and producing information about new activities and the government provides conditions for the search to happen, assesses potential and empowers those actors most capable of realizing the potentials. But entrepreneurship in the knowledge economy recognises that value added is also generated outside sole ownership, in spillovers, in networks of complementarity and comparative advantage*." (OECD, 2013:p.18)

In short, the focus of public policy shifts from the selection of priority sectors and areas for public investment to the *facilitation of the joint process of discovery* ("e.g., by providing incentives, removing regulatory constraints" (OECD, 2013: p. 20).

Fourth, it is important to find ways to neutralize the constraints for regional innovation policy that result from reduced national budgetary support due to austerity policies. As emphasized in the TNO paper on *Brainport Eindhoven* by Frans A.van der Zee, "… [a]n important challenge is to overcome existing barriers to really innovate…[by]… increasing public investment in the Brainport region. This especially applies to boosting public R&D expenditure."[73]

In a situation characterized by low demand, falling tax revenue, and fiscal pressures to reduce budget deficits and the national debt, the concept of "Smart Specialization" claims to provide "…a novel avenue to pursue the dual objectives of fiscal constraint and investment in longer-term growth … through innovation."(OECD, 2013: p.23) Yet, there is reason to be skeptical whether such expectations are more than just pipedreams.

In fact, the afore-mentioned Brainport report by TNO demonstrates negative effects of budget cuts at the national level: "The decision at national level to stop regional development support by abolishing the 'Peaks in the Delta' (PiD)-programme brings important challenges for the funding (matching) and the scope of future activities, which not only affect regional development programmes, but also the regional development agencies such as the BOM in North-Brabant and LIOF in Limburg." (van der Zee, n.d.: page 3)

Fifth, an important unresolved policy issue is that the Advanced Manufacturing technologies described in Part One of the paper, provide much less *direct* employment effects than the current manufacturing model. Empirical research demonstrates that ICT and other enabling and emerging technologies reduce *direct* labor requirements of manufacturing[74]. For the US, Pisano and Shih find:" Manufacturing now accounts for only about one in ten American jobs. With increasing productivity,…it is hard to imagine how manufacturing could ever return to the days when it employed about a quarter of the US workforce."[75]

In the US, recent research has identified the following mechanisms for creating *quality spillover employment effect*s of advanced manufacturing:

a. by integrating manufacturing, services and innovation[76].Manufacturing services proliferate and are an important source for quality jobs. Successful firms thus can use transformative technologies to provide packaged solutions.
b. in downstream and upstream industries
c. in smart digital infrastructure platforms.[77]

Sixth, in Europe like in the US the debate about inequalities is heating up, at two levels: geographical (rich versus poor regions) and individual (those included in prosperous developments and those being marginalized). Especially the rich – poor regions issue is important in view of how best to spend a significant amount of regional investment money in less developed regions. In short, regional policy is confronted again with the perennial question raised in the earlier debate between Ragnar Nurkse and Albert O. Hirschman about the trade-offs between balanced and unbalanced growth[78].

Hirschman's concept of "Development as a Chain of Disequilibria" highlights the importance of s strategy that seeks to create a "success breeds success" scenario. In addition, a simple **Stylized Model** demonstrates why regions may differ in their capacity to reap the gains from trade for innovation.

Suppose Region A (the "innovator") possesses all the necessary prerequisites for reaping the gains from trade for innovation, as described in this paper. Region B, on the other hand is a relative latecomer. Region B thus lags behind Region A in the strength of its institutions and policies, its market size and sophistication, and the managerial and technological capabilities of its firms. As a result, Region B will also occupy a lower-tier position in global networks, and hence will be in a much weaker position than Region A to reap the gains from trade for innovation.

For policy-making, this raises two questions:

- Under these conditions, what would need to happen so that Region B can gradually catch up with Region A?
- What kind of linkage effects between Region A and Region B would need to be in place so that conditions are ripe for a "success breeds success" scenario where productivity-enhancing innovation in Region A produces positive spillover effects in region B?

Seventh, another unresolved policy issue relates to important changes in *International Trade rules*. Regions face a fundamental dilemma: In order to reap the benefits of GPN/GIN integration, both the central government and the regional governments need to put in place robust and increasingly sophisticated innovation and industrial policies. In the future, these policies need to address the following issues:

- Is the scope for such policies being enhanced or constrained by increasingly strict trade rules as part of plurilateral and mega-regional trade agreements? [TTIP;TPP; ITA; TISA]
- The spread of GPNs/GINs has increased the role of business services. There is increasing pressure to move beyond GATS and to develop a much more demanding Trade in Services Agreement (TISA) that would impose much greater discipline on national and regional industrial and innovation policies.
- Will TTIP establish *"Investor-State Dispute Settlement"* to replace the WTO *State-to-State Dispute Settlement Mechanism,* and how will this affect the scope for national and regional industrial and innovation policies?[79]

Eighth, a final thought: As emphasized in the above TNO Brainport report, upgrading and scaling up in a region "… implies looking beyond borders" (van der Zee, n.d.: p.5). The TNO report focuses on inter-regional collaboration, "especially in R&D and innovation, with IMEC and Holst Centre as best practice examples."

But, as we have seen, regions around the globe are progressively integrated across national borders into global networks of production and innovation. Brabant is no different, and thus might find it useful to ask: *Are there lessons to be learnt from the contrasting experiences in other countries?*

- The **US innovation system** is strong for start-ups that are in their early stages of development. But it fails to provide incentives & support for scaling-up innovation ("The American company stands alone"[80])

- **Taiwan** (Low-cost & fast innovation in manufacturing services; Multi-layered industrial dialogues)
- **China** (Massive investments in the country's R&D infrastructure and Higher Education have been fast-tracking the speed of learning and capability development; low-cost up-scaling of manufacturing).

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[23] For a discussion of upgrading taxonomies, see Ozawa, T. 2000. "The 'Flying-Geese Paradigm: Toward a Co-evolutionary Theory of MNC-Assisted Growth", in: K. Fatemi (ed.), *The New World Order: Internationalism, Regionalism and the Multinational Corporations,* Amsterdam and New York: Pergamon.
[24] Grove, A. S. 1996. Only the Paranoid Survive: How to Exploit the Crisis Points that Challenge Every Company and Career. New York and London: Harper Collins Business.
[25] On the proliferation of global production networks (GPNs) and global innovation networks, see Ernst, D., 1997, *From Partial to Systemic Globalization. International Production Networks in the Electronics Industry*, report prepared for the Sloan Foundation, jointly published as The Data Storage Industry Globalization Project Report 97-02, Graduate School of International Relations and Pacific Studies, University of California at San Diego, and as BRIE Working Paper #98, Berkeley Roundtable on the International Economy, University of California at Berkeley, http://brie.berkeley.edu/publications/WP%2098.pdf ; and Ernst, D., 2007, "Innovation Offshoring: - Root Causes of Asia's Rise and Policy Implications." , chapter 3 in : In Palacios, Juan J., ed. (Ed.), 2007., *Multinational Corporations and the Emerging Network Economy in the Pacific Rim*. London: Routledge, co-published with the Pacific Trade and Development Conference (PAFTAD), London: Routledge. For an important recent contribution by trade economists, see Baldwin, Richard and J. López González (2013) "Supply-Chain Trade: A Portrait of Global Patterns and several testable hypotheses" NBER Working Paper 18957 http://www.nber.org/papers/w18957.pdf
[26] 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's ICT industry, see Ernst 2004.Yusuf OUP
[27] Ernst, 2007, PAFTAD
[28] Patel, P., and K. Pavitt. 1991. "Large Firms in the Production of the World's Technology: An Important Case of Non-Globalisation." *Journal of International Business Studies* 22(1): 1–21
[29] Archibugi, D., and J. Michie. 1995. "The Globalization of Technology: A New Taxonomy." *Cambridge Journal of Economics* 19(1): 121–40.
[30] See Ernst, D., 2006. *Innovation Offshoring: Asia's Emerging Role in Global Innovation Networks*, Special Study prepared for the East-West Center and the U.S.-Asia-Pacific Council, East-West Center, Honolulu, July:48 pages; and Ernst, D., "Innovation Offshoring: Root Causes of Asia's Rise and Policy Implications." In Palacios, Juan J., ed. 2007. *Multinational Corporations and the Emerging Network Economy in the Pacific Rim*. London: Routledge, co-published with the Pacific Trade and Development Conference (PAFTAD).
[31] Ernst, D., and B. Naughton. 2007. "China's Emerging Industrial Economy: Insights from the IT Industry." In McNally, C., ed. 2007. *China's Emergent Political Economy: Capitalism in the Dragon's Lair*. London: Routledge.
[32] This compares with more than 10,000 engineers in Huawei's Shanghai R&D site.
[33] TSMC for instance has a strong presence in UC Berkeley and at Stanford University, with a heavy focus on leading-edge IC development for advanced computing.
[34] Ernst, 2014, *Power Shift? From hierarchical to splintered Global Innovation Networks*, manuscript, East-West Center, Honolulu
[35] http://www.cisco.com/web/about/ac79/innov/IoE.html
[36] Hartman, C., R. Kuppens, D. Schlesinger, *Connected Manufacturing*, 2006, http://www.cisco.com/web/CA/pdf/Cisco_Connected_Manufacturing.pdf
[37] Palfrey, J. and U. Gasser, 2012, *Interop. The Promise and Perils of Highly Interconnected Systems*, Basic Books, New York
[38] Ernst, D., 2005, "Complexity and Internationalisation of Innovation: Why Is Chip Design Moving to Asia?" In *International Journal of Innovation Management*, special issue in honor of Keith Pavitt (Peter Augsdoerfer, Jonathan Sapsed, and James Utterback, guest editors) 9(1) (March): 47–73. See also Ernst (2009).
[39] Ernst, D., 2005, "The New Mobility of Knowledge: Digital Information Systems and Global Flagship Networks." In Latham, R., and S. Sassen, eds. 2005. *Digital Formations: IT and New Architectures in the Global Realm*. Princeton, NJ, and Oxford: Princeton University Press for the U.S. Social Science Research Council.
[40] Examples include Karachalios, K. and K. McCabee, 2013, *Standards, Innovation and their Role*

in the Context of the World Trade Organization; and Ernst, D., 2014, *The Information Technology Agreement, Industrial Development and Innovation - India's and China's Diverse Experiences*.

[41] 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.

[42] 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.

[43] Baldwin, R., 2013, "Global supply chains: why they emerged, why they matter, and where they are going", chapter 1 in: D.K. Elms and P. Low, eds.,2013, *Global value chains in a changing world*, WTO, Geneva: pages 13 - 60; Baldwin, Richard and J. López González (2013) "Supply-Chain Trade: A Portrait of Global Patterns and several testable hypotheses" NBER Working Paper 18957 http://www.nber.org/papers/w18957.pdf;

[44] Baldwin, R. 2013, "The New Relevance of FDI: The GVC Perspective", in World Economic Forum, *Foreign Direct Investment as a Key Driver for Trade, Growth and Prosperity. The Case for a Multilateral Agreement on Investment*, Geneva: p.13.

[45] Ernst, D., and Linsu Kim. 2002. "Global Production Networks, Knowledge Diffusion and Local Capability Formation." *Research Policy*, special issue in honor of Richard Nelson and Sydney Winter, 31(8/9): p.1425

[46] See Chesbrough, H. W. 2003. *Open Innovation. The New Imperative for Creating and Profiting from Technology*. Cambridge, MA: Harvard Business School Press.

[47] Cohen, W. M., and D. A. Levinthal. 1989. "Innovation and Learning: The Two Faces of R&D." *The Economic Journal* 99 (September): p. 593.

[48] For the original taxonomy, see Henderson, R. M., and K. B. Clark. 1990. "Architectural Innovation: The Reconfiguration of Existing Systems and the Failure of Established Firms." *Administrative Science Quarterly*, March: 9–30. For an adaptation of the taxonomy to highlight differences in capability requirements, see Ernst, D., 2008, "Can Chinese IT Firms Develop Innovative Capabilities Within Global Knowledge Networks?", in Hancock, Marguerite Gong, Henry S. Rowen, and William F. Miller, eds.. *China's Quest for Independent Innovation*. Shorenstein Asia Pacific Research Center and Brookings Institution Press, Baltimore, MD. 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.

[49] Nelson, R. R., and S. G. Winter. 1982. *An Evolutionary Theory of Economic Change*. Cambridge, MA: The Belknap Press.

[50] As defined in Ernst, D., 2007, "Beyond the 'Global Factory' Model: Innovative Capabilities for Upgrading China's IT Industry." *International Journal of Technology and Globalization* 3(4): 437–60; and Ernst (2009): chapter Two.

[51] Baldwin, C. W., and K. B. Clark. 2000. *Design Rules: The Power of Modularity.* Cambridge, MA: MIT Press: p. 88

[52] Henderson and Clark (1990) use the decline of Xerox and RCA to illustrative the destructive power of architectural innovations.

[53] National Research Council, 2012, *The New Global Ecosystem in Advanced Computing: Implications for U.S. Competitiveness and National Security*, The National Academies Press, Washington, D.C.

[54] As defined by Teece, D. 1986. "Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing and Public Policy." *Research Policy* 15(6) (December): 285–305.

[55] For further discussion, see **Part Four – Policy Implications**

[56] 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." And Shin-Horng Chen (2006: 15) 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 manufacturing/original design manufacturing suppliers "may need to devote more effort to R&D in order to effectively interact with their local suppliers" (ibid: 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."

[57] Ernst, D., and Linsu Kim. 2002. "Global Production Networks, Knowledge Diffusion and Local Capability Formation." *Research Policy*, special issue in honor of Richard Nelson and Sydney Winter, 31(8/9): page 1417.

[58] Ernst, D., 2002, "The Economics of Electronics Industry: Competitive Dynamics and Industrial Organization", In Lazonick, William, ed. , *The International Encyclopedia of Business and Management (IEBM), Handbook of Economics.* London: International Thomson Business Press.
[59] 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.

[60] 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.
[61] The following draws heavily on Ernst, 2005, "Limits to Modularity: Reflections on Recent Developments in Chip Design." *Industry and Innovation* 12(3): 303–35.
[62] Chesbrough, H. W. (2003b) 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). See also Chesbrough, H. and Kusunoki, K. (2001) The modularity trap: innovation, technology phases shifts and the resulting limits of virtual organizations, in: I. Nonaka and D. Teece (Eds) *Managing Industrial Knowledge*, pp. 202–230 (London: Sage).
[63] Ernst, D., 2005, "Limits to Modularity: Reflections on Recent Developments in Chip Design." *Industry and Innovation* 12(3): 303–35.
[64] Pavitt, K., 1999, *Technology, Management and Systems of Innovation*, Edward Elgar, Cheltenham: p.XX
[65] See for instance Brusoni, S., 2003, "Authority in the Age of Modularity", *SPRU Electronic Working Paper Series*, No. 101, The Freeman Centre, University of Sussex, June; and Tokumaru, Norio, 2004, "Codification of Technological Knowledge, Technological Complexity, and Division of Innovative Labour", in J.H. Finch and M. Orrillard, eds., *Complexity and the Economy: Implications for Economic Policy*, Edward Elgar.
[66] 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.
[67] Recently, however, attempts to avoid being trapped by prematurely frozen design parameters have led to new approaches to improve the flexibility of SoC design, for instance, through reconfigurable processors. But it remains to be seen how viable these new approaches will be.
[68] Chen, Tain-Jy and Ying-Hua Ku, "Pitfalls of Modular Production: The case of Taiwan's PC industry, unpublished paper, Department of Economics, National Taiwan University, Taipei: 36 pages.
[69] Dyer, J.H. and H. Singh, 1998, "The Relational View: Cooperative Strategy and Sources of Inter-organizational Competitive Advantage", *Academy of Management Review*, 23(4): 660-679.
[70] As analyzed in Pisano, G. and W. Shih, 2012, *Producing Prosperity: Why America Needs a Manufacturing Renaissance*. Boston, MA: Harvard Business Review Press.
[71] Hart, D. M., S.J. Ezell, R.D. Atkinson, 2012, "Why America Needs A National Network for Manufacturing Innovation", http://www2.itif.org/2012-national-network-manufacturing-innovation.pdf
[72] OECD, 2013, *Innovation-driven Growth in Regions: The Role of Smart Specialisation. Preliminary Version*, OECD, Paris. It is interesting to note a certain similarity of the *Smart Specialization* idea with concepts used by the U.S. Defense Advanced Research Projects Agency (DARPA). See Jordan, L.S. and K. Koinis, 2014, *Flexible Implementation: A Key to Asia's Transformation, East-West Center Policy Studies series*, No.70, March. In addition, much of the underlying philosophy seems to draw quite extensively on Albert O. Hirschman's early attempt to place private business owners at the center of information gathering and strategy design. (See Hirschman, A .O., 1958, *The Strategy of Economic Development, New Haven, Conn.: Yale University Press*.)
[73] van der Zee, F.A., no date, *Case 4.- Netherlands, Brainport Eindhoven: 'Top Technology region Spreading its Wings*', TNO : page 3.
[74] Shipp, S.S. et al, 2012, *Report on Emerging Global Trends in Advanced Manufacturing*, Institute for Defense Analyses- Science Technology Policy Institute (IDA-STPI), Washington, D.C.
[75] Pisano, G. and W. Shih, 2012, *Producing Prosperity.Why America Needs a Manufacturing Renaissance*, Harvard Business School Press
[76] National Academy of Engineering, 2012, *Making Value: Integrating Manufacturing, Design and Innovation*, The national Academies Press, Washington, D.C.
[77] Smart industrial infrastructure platforms which create quality jobs may include for instance: broadband enabled new applications (e.g., cloud computing); 4G wireless communications; integrated health information systems; Smart electric grids; Low carbon energy information systems; Intelligent transportation systems; Mobile payments

systems; and Mobile Collaborative Learning Systems. Atkinson, R. and S. Ezell, 2012, *Innovation Economics.The Race for Global Advantage*, Yale University Press.

[78] Nurkse, Ragnar (1961). *Problems of Capital Formation in Underdeveloped Countries*. New York: Oxford University Press, and Hirschman (1958)

[79] Some observers claim for instance that, as part of TTIP, businesses might now be in a position to sue governments in special Arbitration Panels (e.g. the International Centre for Settlement of Investment Disputes [ICSID]) for legislation that businesses considers not to be "fair and equitable treatment".

[80] Berger, S., 2013, ."Lessons in Scaling from Abroad: Germany and China", in S. Berger, *Making in America. From Innovation to Market* (Cambridge, MA: The MIT Press).