Chapter 7

Upgrading in global value chains: The role of knowledge-based capital

Knowledge-based capital has become a driver of success in global value chains (GVCs). The value created by a GVC is unevenly distributed and depends on the ability of participants to supply sophisticated and hard-to-imitate products and services. Increasingly, such products or services stem from forms of knowledge-based capital such as brands, basic R&D, design and the complex integration of software with organisational structures. Knowledge-based capital also allows companies to shape the architecture of a GVC in order to capture a larger share of the value created. Policy makers in OECD countries and in many emerging economies therefore increasingly focus on investments in knowledge-based capital so as to upgrade to higher-value segments of GVCs and improve their position in the value chain.

This chapter links the work on GVCs to the OECD work on Knowledge-Based Capital; it is based on the same background material used for Chapter 5 of the publication 'Supporting Investment in Knowledge-based Capital, Growth and Innovation' (OECD, 2013)

The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

Innovation and upgrading in global value chains

Patterns of upgrading

Innovation, through the introduction of a new or significantly improved product (good or service), process or method, has long been viewed as central to economic performance and social welfare.[1] The empirical evidence confirms the links between innovation, value creation and economic growth (OECD, 2010). In the global value chain (GVC) framework, innovation has often been discussed in terms of (economic) upgrading and the efforts of companies and (developing and emerging) countries to increase the value they create and capture in GVC activities (Gereffi, 1999). Four types of GVC upgrading have traditionally been identified (e.g. Kaplinsky and Morris, 2002):

- *Process upgrading* is achieved when firms can undertake tasks with significantly greater efficiency and lower defect rates, and process more complex orders than rivals. An example is Hon Hai precision, the world's largest original equipment manufacturer (OEM), renowned for its ability to carry out large-scale production under short deadlines and rigorous specifications for major electronics brands such as Apple, Dell, Samsung and Sony.
- *Product upgrading* is achieved when firms can supply higher value-added products than rivals owing to their superior technological sophistication and quality and also introduce novel products faster than rivals. Examples are ASUSTek, an inventor of netbooks that captured the demand for low-cost, easy-to-use portable PCs (Kawakami, 2012), or Toyota, which introduced the first mass-produced hybrid vehicle, the Prius.
- *Functional upgrading* is achieved when firms can provide competitive products or services in new segments or activities of a GVC which are associated with higher value added. For firms previously specialised in production, this means becoming competitive in upstream or downstream activities such as design or marketing. For example, Lenovo acquired sophisticated R&D capability and the recognised ThinkPad brand through its acquisition of IBM's PC branch. For its part IBM upgraded from a PC manufacturer to a provider of technology and consultation services. Li and Fung, a Hong Kong-based intermediary of consumer goods upgraded its function as a supply chain management firm by acquiring product development, marketing and branding functions.
- *Chain upgrading* is achieved when firms are able to participate in new GVCs that produce higher value-added products or services, often leveraging the knowledge and skill acquired in the current chain. Recent examples are Samsung, the world's largest semiconductor producer, which decided to invest USD 20 billion over ten years in new industries such as solar panels, light-emitting diodes (LEDs) and electric-car batteries, and Nestlé, the food industry giant that has invested intensively in health-oriented processed food associated with higher profit margins and larger room for disruptive innovation than conventional packaged food (*The Economist*, 2009; 2011).

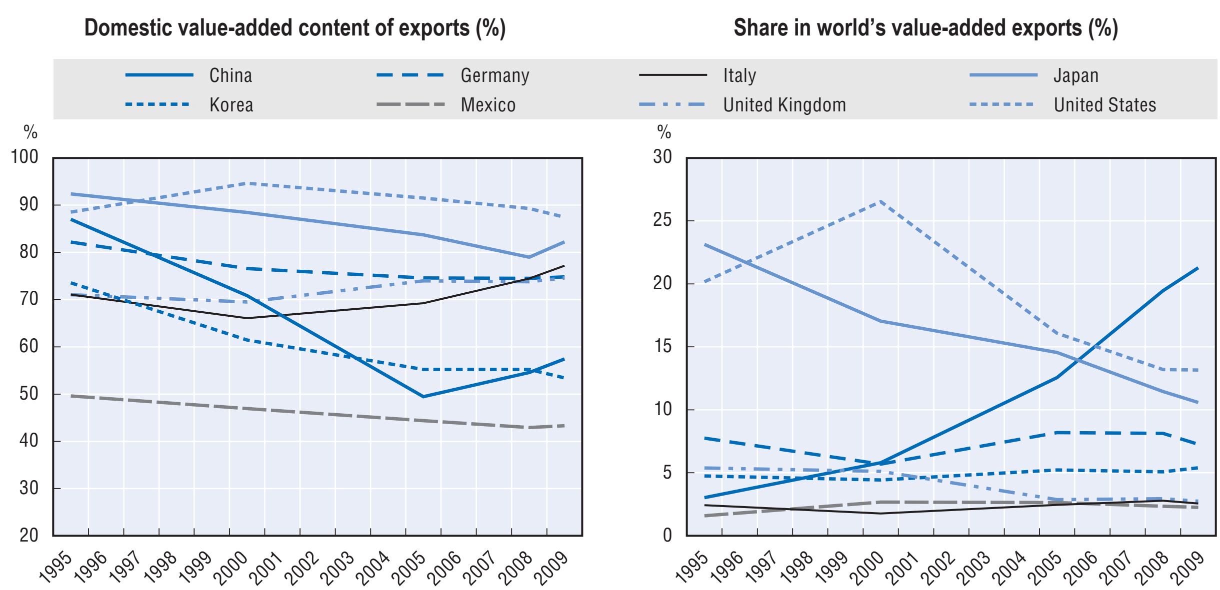
Fernandez-Stark et al. (2012) also distinguish "end-market upgrading" which involves moving into new higher-value end market segments (in terms of geographical location or industry), such as textile suppliers moving from manufacturing apparel to reaching customers in the medical, defence or construction industries. In addition, integration in GVCs is sometimes considered the first step in economic upgrading in developing countries (see Chapter 5).

Process upgrading is often considered to be the first stage in upgrading, as it is based on learning by doing (Gereffi, 1999). Later, as firms build up technological capabilities, they become competitive in more sophisticated products (product upgrading). Functional upgrading is achieved when firms become able to design new products or establish their own brand. Finally, chain upgrading occurs when firms have sufficient technological background and business know-how to expand their activities to new and more profitable industries.

Successful upgrading depends on a company's acquisition and/or development of capabilities to explore new and original features and varieties in each segment of the value chain. When a critical mass of a country's firms has been able to upgrade the economy also upgrades (Fernandez-Stark et al., 2012). Emerging countries often mainly want to move up the value chain and create and capture more value and broader economic benefits through their activities in GVCs (see Chapter 5). For developed countries, the question is how to retain their competitive advantages (and develop new ones), especially in higher value-added activities, and how to continue to compete in the global economy. As the growth potential of sources such as capital accumulation and technological imitation is exhausted, innovation becomes the most important source of economic growth.

Process, product, functional and chain upgrading are all undertaken to create and capture more value from GVC activities. Upgrading trajectories and innovation dynamics at the country level become apparent when looking at the (domestic) value-added content in countries' exports. This indicator provides insights into how much value an economy creates from its exports and is basically the result of the different upgrading strategies of the firms located within its borders. Figure 7.1 shows the evolution in the domestic value added content of exports in the electronic and optical machinery industry between 1995 and 2009 for a number of countries.

Figure 7.1. Upgrading and value creation in GVCs, electrical and optical machinery (ISIC30-33), 1995-2009



1. Some caution is warranted in comparing figures for China before and after 2005, since data availability only allows for distinguishing between processing and non-processing exports from 2005 onwards. This likely affects the results (see Chapter 2).

2. Estimates only available for 1995, 2000, 2005, 2008 and 2009; in-between years are interpolated.

Source: OECD/WTO (2013), OECD-WTO: Statistics on Trade in Value Added, (database), doi: 10.1787/data-00648-en (accessed April 2013).

StatLink *http://dx.doi.org/10.1787/888932835138*

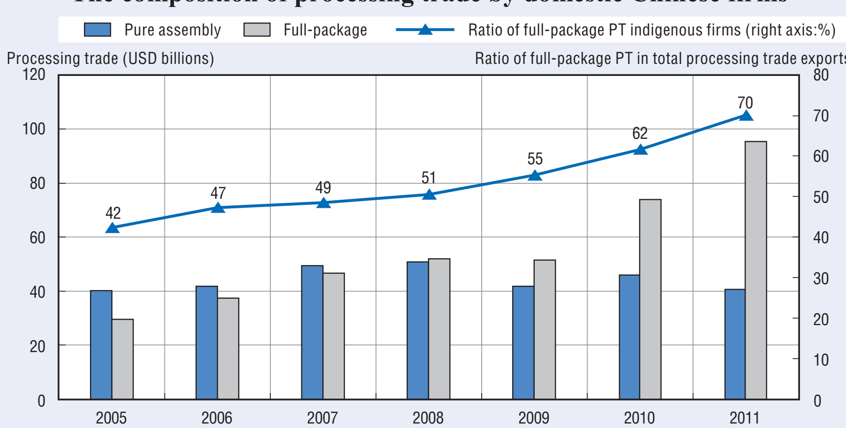
The figure largely confirms that developed economies generally specialise in higher value-added products and activities in this industry. The domestic value-added content of exports of the People's Republic of China and Mexico but also Korea are significantly lower than those of Germany, Japan and the United States. Moreover, the domestic value-added content of exports decreased between 1995 and 2009 as a result of the growing importance of imported intermediates and GVCs (Johnson and Noguera, 2012). Finally, in contrast to other countries, China shows a significant variation in the domestic value-added content of exports over time. Between 1995 and 2005, the domestic value added content of China's electronics exports dropped significantly, most likely because of fast-growing non-processing trade of low value added (see Chapter 5). Since 2005, however, China has succeeded in upgrading its electronics exports in various ways (Box 7.1) and the domestic value-added content of its exports has risen. In fact, China now accounts for nearly 25% of the world's total value added generated by electronics exports.

Box 7.1. China: Upgrading in GVCs

China's participation in GVCs has helped to make it the world's largest exporter. Through processing trade and the attraction of multinational enterprises (MNEs), China has been able to tap into advanced technology that was not available in domestic markets (Breznitz and Murphree, 2011). Upgrading has been an important policy priority for China for several years, and a range of evidence suggests that this is indeed under way.

Process upgrading: China's processing trade is shifting from simple contract assembly to "full-package" manufacturing, with Chinese firms controlling processes from material procurement to product design. Chinese firms now import parts and components and decide on the quantity, price and specification of products to be exported to foreign firms. This upgrading of processing exporters into more autonomous multi-functional service providers has been also observed in other Asian economies and is an important early stage of GVC upgrading.

The composition of processing trade by domestic Chinese firms



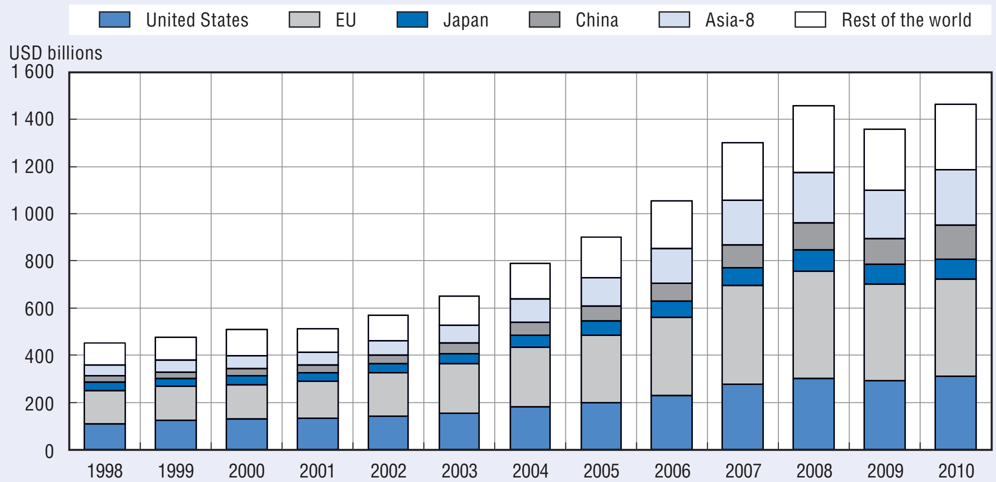
Source: China Customs Statistics.

Functional upgrading: from assembler to parts provider. China's share in world exports has increased not only in final products but also in parts and components. From 1995 to 2007, China's share in world exports of parts and components increased by 9.2%, while those of Japan and the United States dropped by 7.1% and 6.3%, respectively. A substantial share of China's exports in radio, television and communication equipment, electronic machinery and office, accounting and computing machinery involves intermediate goods, indicating that China has become a key supplier of parts and components.

A new role in the knowledge-intensive segments of GVCs? China is now the world's second largest spender on R&D after the United States (OECD, 2011b). The business sector accounted for 73% of China's R&D investments in 2009. Triadic patents[1] held by Chinese residents increased at an average annual rate of 29% between 1999 and 2009. However, Chinese firms' patents, especially in the United States, are largely held by a handful of export-oriented firms in computer, communication and consumer electronics industries, such as Foxconn, Huawei and ZTE (Eberhardt et al., 2011). China's exports of commercial knowledge-intensive services (business, financial and communication services) have also expanded. While the United States and the EU still account for half of these exports, China had increased its share to nearly 10% of the world total by 2010.

Box 7.1. China: upgrading in GVCs *(continued)*

World exports of commercial knowledge-intensive services (USD billion)



Note: Asia-8 includes Chinese Taipei, India, Indonesia, Korea, Malaysia, Philippines, Singapore, and Thailand. EU excludes Cyprus[2], Estonia, Latvia, Lithuania, Luxembourg, Malta, and Slovenia. China includes Hong Kong.

Source: Science and Engineering Indicators 2012, National Science Foundation.

The future of China's upgrading: China's upgrading may differ from that of other Asian emerging economies. First, its large and fast-growing domestic market facilitates the upgrading of GVC activities with an eye to the domestic market. While Chinese firms absorb advanced knowledge by participating in foreign MNEs' GVCs, they can use this knowledge to develop new capabilities and new products for the domestic market. This enables them to upgrade their functions within GVCs. Second, China was able to leverage its large market to attract foreign investments embodying the latest technology and develop a rigorous cycle of imports, digestion, absorption and innovation. This allowed Chinese firms to improve their capabilities and keep up with the world's technological frontier (Breznitz and Murphree, 2011). Knowledge spillovers contribute not only to production but also to Chinese firms' innovation capability (Ito et al., 2011). Collaboration and competition with foreign MNEs are likely to remain important for China's upgrading, as MNEs are expected to localise more segments of their GVCs as they seek to penetrate the Chinese market (Brandt and Thun, 2010). Third, competition with MNEs in the domestic market gives Chinese firms incentives to invest in technology and other knowledge-based assets. The concentration of investments in state-owned-enterprises and other state-controlled enterprises is partly due to strong existing capabilities (Zhang et al., 2009), but raises some concerns that this may lessen the efficiency of China's upgrading by preventing profit-oriented deployment of knowledge and investment. China's upgrading efforts will certainly continue. According to a recent policy report, "China sees itself building its future prosperity on innovation in which everyone's creative potential is tapped. Its success will lie in its ability to produce *more value, not more products*, enabling it to move up the value chain and compete globally in the same product space as advanced countries." (World Bank and the Development Research Centre of the State Council of People's Republic of China, 2012, p. 15).

1. Triadic patents are a set of patents taken at the European Patent Office, the Japanese Patent Office and the US Patent and Trademark Office.

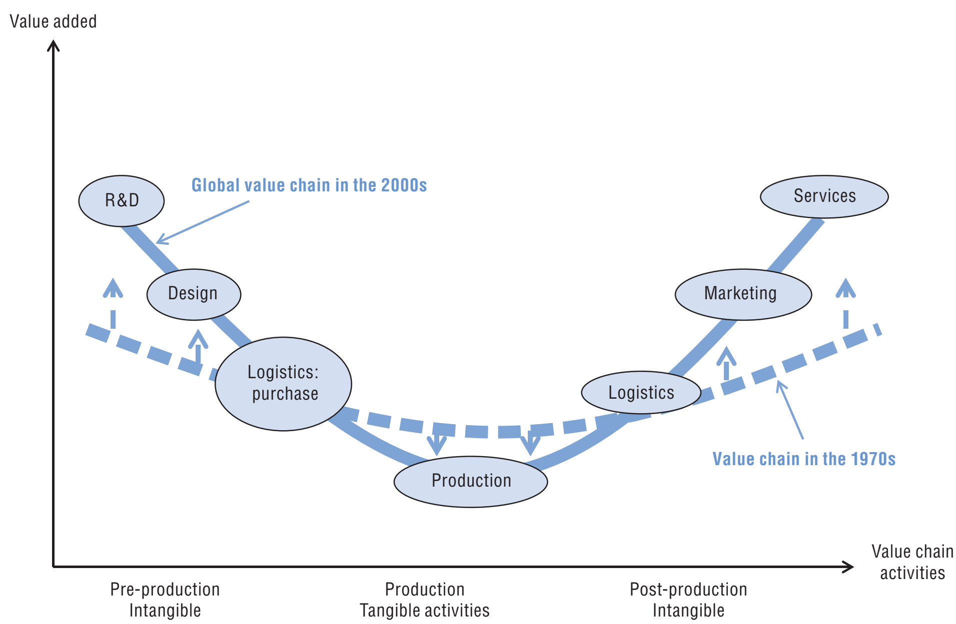
2. Note by Turkey:
The information in this document with reference to "Cyprus" relates to the southern part of the Island. There is no single authority representing both Turkish and Greek Cypriot people on the Island. Turkey recognises the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of the United Nations, Turkey shall preserve its position concerning the "Cyprus issue".

Note by all the European Union Member States of the OECD and the European Union:
The Republic of Cyprus is recognised by all members of the United Nations with the exception of Turkey. The information in this document relates to the area under the effective control of the Government of the Republic of Cyprus.

Functional upgrading as a (new) way to create more value in GVCs

Case studies of specific products, often in the electronics industry, have demonstrated that value creation in a GVC is often unevenly distributed among activities (Linden et al., 2009; Ali-Yrkkö et al., 2011). The most value creation in a GVC is often found in upstream activities, such as the development of a new concept, R&D or the manufacturing of key parts and components, or in downstream activities, such as marketing, branding or customer service. Certain value chain activities create more value added when a company innovates to differentiate its products and services from competitors. Final assembly, which is generally offshored, often to emerging economies, represents only a small part of value generation. In general, activities that can be offshored tend to be commoditised and create relatively less value added. Moreover, activities that involve well-established standards and high modularity, such as final assembly of electronics or machinery, can be carried out by many competing firms, again lowering costs. This is the basic idea behind the so-called "smiling curve", originally used in 1992 by Acer's founder Stan Shih to illustrate the problems of IT manufacturers in Chinese Taipei that were then specialised in manufacturing activities (Figure 7.2).

Figure 7.2. The smiling curve: Value added along the GVC



Source: Based on Shih (1992), Dedrick and Kraemer (1999), and Baldwin (2012).

Some consider that there has been a tendency in OECD countries for the "smiling curve" to deepen, moving from relatively flat (value all along the chain) to U-shaped, with fabrication and assembly accounting for a much lower share of value added (e.g. Baldwin, 2012). The offshoring of labour-intensive activities (often in manufacturing and assembly) to low-wage economies has in fact decreased the cost of these stages. When companies that offshore these activities use their advanced technologies in these countries, the cost of these activities decreases further. The distribution of value added along the value chain does not necessarily follow the smile curve, however. Seppälä and Kenney (2013) show, for a number of products in the precision metal industry, that manufacturing activities still capture a large part of the value added.

Moreover, in practice, advanced economies still compete in many parts of the value chain, including in resource-intensive sectors such as agriculture, mining and food processing and in segments of low-technology industries including textiles. Italy, for example, continues to have a strong revealed comparative advantage in the production of textiles and clothing. Typically, this reflects specialisation in niche activities, continuous innovation, high productivity and high quality and enables firms in advanced economies to compete with firms in emerging economies with much lower costs. The generation of value here depends on the ability to supply sophisticated and hard-to-imitate products or services.

Position in the value chain is thus an issue of interest to many policy makers. Emerging economies for example find that they do not create/capture a lot of value from their large manufacturing activities. GVCs have changed the nature of global competition as companies and countries no longer only compete for market share in high value-added industries but increasingly also for high value-added activities within GVCs. Countries often see functional upgrading as the most direct way to increase the benefits they obtain from their participation in GVCs. Functional upgrading allows firms and countries to move to industries and activities that create more value added. But clearly there is no one-size-fits-all approach to upgrading since where the value is being created will differ across industries and value chains.

Functional upgrading can feed back into process and product upgrading. Sophisticated R&D, design or marketing allows firms to enhance the efficiency of their production processes and introduce new products. For example, electronics manufacturing firms in Chinese Taipei upgraded from original equipment manufacturers (OEM) to original design manufacturing (ODM) when they started to provide pre-production services such as R&D and design. This functional upgrading allowed them to engage in product upgrading with the invention of netbooks and a range of quality improvements in own-brand notebook PCs such as Asus and Acer (Sturgeon and Kawakami, 2010; Kawakami, 2012). However, functional upgrading requires heavy investments in knowledge-based capital. The specialisation of developed economies in higher value added activities largely reflects the larger endowment of these countries in human and knowledge-based capital. Policies supporting functional upgrading going against the principle of comparative advantage risk being unsuccessful.

Knowledge-based capital as driver for innovation and upgrading in GVCs

Higher value-added activities are often concentrated in parts of the value chain that make intensive use of human capital and knowledge-based capital, also known as intangible assets or knowledge-based assets. These assets involve tacit, non-codified knowledge in such areas as R&D, branding, design and the complex integration of software with organisational structures. The tacit properties of those activities make them difficult to imitate or reproduce. Knowledge-based capital is also at the heart of the manufacturing competitiveness of more mature economies (see Chapter 6). It is the source of the advanced knowledge and capabilities needed to develop sophisticated and complex products. More advanced capabilities also allow for greater (product) upgrading possibilities (Hausmann and Hildago, 2011; Tacchella et al., 2012). To move to higher value-added activities and enter higher-value segments of GVCs requires more knowledge-based capital. Policy makers in OECD and many emerging economies understand that knowledge-based capital is an important source of value creation in GVCs.

What is knowledge-based capital?

Knowledge-based capital, generally called intangible assets in the business sector, is the stock of investments in knowledge-based assets. While policy has often focused on R&D, human capital and software, the range is considerably broader. Its three main categories are computerised information, innovative property, and economic competencies (Corrado et al., 2005). Table 7.1 shows their outcomes in terms of capabilities and resources.

Table 7.1. Classification of knowledge-based capital and generated value

Knowledge-based capital	Type of investments (expenditure)	Stock of competencies (resource)
Computerised information		
Computer software	In-house development or acquisition of software	Computerised process, information and knowledge management system
Computerised database	In-house development or acquisition of database	Dataset assisting corporate strategy including new product development, marketing
Innovative property		
Scientific R&D	Science and engineering research (measured by in-house or outsourced R&D in manufacturing and selected industries)	Knowledge and intellectual property rights (IPR) leading to new or higher-quality products and production processes (see Box 7.2 for a discussion of innovative property in the pharmaceutical value chain)
Creative property	Development of entertainment or artistic originals (measured by non-scientific R&D: development cost in entertainment and book publishing industries)	Knowledge and IPR leading to sophisticated artistic and cultural creation
Design	Physical appearance, quality and ease of use of products and workspace layout (measured by outsourced architectural and engineering designs, R&D spending in social science and humanities)	Knowledge and IPR leading to better commercial appeal, product differentiation, improved efficiency
Economic competencies		
Brand equity	Spending on advertising and market research (measured by outsourced advertising and market research)	Reputation, image, customer recognition and relationship
Firm-specific human capital	On-the-job training, tuition payment for job-related education	Firm-specific and tacit manufacturing, processing and managerial skill
Organisational structure	Spending on organisational change (measured by outsourced management consulting services, etc.)	Flexible and competitive business organisation, network with other firms, universities, government, etc.

Source: Based on OECD (2012a).

Investments in knowledge-based capital differ from investments in physical capital in various ways (OECD, 2012a):

- *Lack of visibility*. By definition, knowledge-based capital lacks physical embodiment. This makes it difficult to assess the stock of specific knowledge-based capital based on past investment flows.
- *Non-rivalry*. Much knowledge-based capital can be used simultaneously by many users without creating scarcity or diminishing its basic usefulness. Examples include software or new product designs.

- *Partial excludability*. Owing in part to its virtual nature, property rights to some types of knowledge-based capital cannot be as clearly defined and enforced as they can be for tangibles. Insofar as they cannot preclude others from enjoying the benefits of these assets, owners may fail to fully appropriate the returns to their investment.
- *Uncertainty and perceptions of risks*. Investment in knowledge takes place throughout the innovation process, but particularly in the early stages of basic research, invention and experimentation. Sunk costs can be large, and failure is frequent (Lev, 2001).

Box 7.2. The role of scientific knowledge and networks in the pharmaceuticals value chain

The pharmaceutical sector is a highly globalised, innovation-driven industry with extensive co-operation and competition between large and small companies. The pharmaceutical value chain activities range from the exploration of new treatments to testing and approval processes to production, marketing and distribution. Biotechnology firms increasingly carry out upstream activities, such as basic research and acquisition of patents for new discoveries. These firms are often spin-offs from universities or other research institutions and conduct focused research. Traditional pharmaceutical companies – often referred as "Big Pharma" – commercialise these new discoveries as own-brand drugs. They take these discoveries through testing and approval by national authorities such as the US Food and Drug Administration (FDA). They acquire patents and commercialise the drug through their global sales and marketing network. In contrast, generic drug companies, another group of key players in the industry, generally do not conduct R&D but produce drugs with the active ingredients contained in the brand-name drugs once the patents have expired. Biotechnology firms, Big Pharma and generic drug companies compete in different areas: biotechnology firms in diagnosing new problems and providing innovative solutions; Big Pharma in identifying market potential and relevant discoveries, then building systems to commercialise new technologies; generic firms in terms of cost efficiency in production based on established technologies.

Haanes and Fjeldstad (2000) discuss the kinds of knowledge-based capital that support the competitive advantage of these three players in the pharmaceutical value chain. The competitive advantage of biotechnology firms depends on advanced technological knowledge. This knowledge is built up not only through basic research but also through formal and informal collaboration on R&D with universities, other biotechnology firms and other actors with relevant technological competencies. A rich research network is thus a crucial asset of successful biotechnology firms. Big Pharma's capabilities for identifying commercially promising breakthroughs stem from knowledge of the latest technologies and market environments and of networks of biotechnology firms and other actors able to produce novel solutions, as well as a reputation as a reliable collaborator. Big Pharma companies' ability to commercialise breakthroughs swiftly is supported by its experience in laboratory testing and regulatory approval procedures. Finally, large networks of customers and recognised brand names are important for marketing their drugs globally. Generic drug companies that thrive on the basis of cost competitiveness rely on efficient procurement networks to reduce material costs and a wide network of customers.

Knowledge-based capital is crucial for upgrading in GVCs. Indian pharmaceutical firms such as Ranbaxy or Dr Reddy's first participated in GVCs as cheap suppliers of generic drugs for the Indian market, then upgraded to generic drug suppliers in advanced economies. More recently, they have become pharmaceutical firms with capabilities to invent and develop patented drugs. Bower and Sulej (2005) argue that this upgrading was supported by advanced technological knowledge obtained through research alliances and joint ventures with firms from advanced economies and by an array of business-related skills and distribution networks obtained through the acquisition of Western firms.

Investment in knowledge-based capital has been rising since the 1980s. In the United States and the United Kingdom, investment in knowledge-based capital now exceeds investment in physical capital. The intensification of competition (due to the reduction of regulatory barriers to entry and greater openness to foreign trade and investment) and the advent of information technology are considered factors in the growing importance of knowledge-based capital. Other potential drivers include the rise in educational attainment, which facilitates the production and effective use of knowledge-based capital, as well as the fact that many household products are more knowledge-intensive and increasingly dependent on software-based technologies. While these trends are present in most advanced countries, the share of business investment in knowledge-based assets differs across economies (OECD, 2012a; 2013), as does its composition.Knowledge-based capital contributes significantly to labour productivity growth in several developed and some emerging economies. For instance, it contributed between 24% and 30% of annual labour productivity growth in Germany, the United Kingdom and the United States between 2000 and 2006 and 16% in China in the same period (Hulten and Hao, 2012).[2]

Knowledge-based capital as a resource for upgrading GVC activities

Patterns of upgrading in GVCs are largely determined by different types of knowledge-based capital. For example, value creation through superior productivity and processing capabilities (i.e. process upgrading) is supported by computerised information in the form of software and systems that enable the management of efficient and more accurate production. Process upgrading can also be based on innovative property, such as use of know-how to design efficient production lines, or on economic competencies, such as competitive procurement networks. The different types of knowledge-based capital favour complementary forms of process upgrading. For instance, Procter & Gamble uses computerised information in the form of modelling and simulation programmes to design efficient factory and production line layouts (Siemens, 2011).

Product upgrading is supported by computerised information in the form of computer-aided-design (CAD) software to enhance design capability or by databases on customer preferences or product sales that enable firms to develop new products or services that capture customer needs. Large retail firms such as Amazon, Tesco or Zara leverage their supply chain network to collect data on consumer preferences in order to introduce new products faster than rivals (McKinsey, 2010a). Product upgrading to raise quality and add sophisticated functions is also supported by innovative property, such as advanced technology. Design also plays a significant role in product upgrading, especially in industries with mature technology or in which firms rely on similar technology (Box 7.3 discusses the importance of design in the textiles industry). Finally, economic competencies such as marketing skills, distribution networks and brand image are important for the rapid introduction of new products.

Functional upgrading requires non-production capabilities in the upstream and far-downstream segments of GVCs, such as new concepts, basic R&D and product design, as well as branding and marketing. This broad range of capabilities can be collectively regarded as a firm's innovative property, as successful commercialisation of new ideas is as important as cutting-edge technology for a successful innovation (Corrado and Hulten, 2010). Superior innovative capability relies on the integration of many forms of knowledge-based capital. For example, Apple upgraded from an electronics manufacturer to innovator and retailer on the basis of core technology, good product design, favourable brand image and its i-store network.

Chain upgrading requires superior managerial skills and flexible organisational structures; successful firms are often able to respond rapidly to potential opportunities or threats. They are also exceptionally able to co-ordinate and reconfigure their physical assets and knowledge-based capital in order to shift core competences to new areas. Firm-specific management skills and flexible organisational structures facilitate the necessary reallocation of internal resources.

Box 7.3. Design and value added in the value chain

Design is increasingly recognised as an important knowledge-based asset for a firm's competitive advantage. It is not only an essential input for new product development, along with R&D and marketing (Hertenstein et al., 2005), but can itself ensure a firm's competitive edge by strengthening an emotional connection with customers and establishing corporate identity and brand (Kotler and Rath,1984; Noble and Kumar, 2008). For some products, brand and design are inseparable. Design helps firms to differentiate their products and move away from cost-based competition. For example, design enabled Sony to charge 25% more than its competitors for its Walkman (Czarnitzki and Thorwarth, 2009). Design has a positive effect on corporate performance and innovation; expenditure on design is associated with productivity growth in UK firms (Cereda et al., 2005) and with Dutch firms' sales of new products (Marsili and Salter, 2006). Incorporating design into the early stage of new product development also improves financial performance (Gemser et al., 2011).

Design may also affect how value added is distributed among participants in a GVC. Vervaeke and Lefevre (2002) illustrate this for the textile industry in the Nord-Pas de Calais region of France, an area traditionally known for textile design. Until the 1960s this was a sub-function of the engineering section of manufacturing firms. Design was the work of mostly anonymous in-house designers or purchased from drawing shops in Paris and refined by in-house designers. As mass production began, manufacturers set up specialised design sections with stylists directing and defining the trends for collections and draughtsmen/women making up patterns and working out designs. Control over design allowed manufacturers to establish their brands and increase value added in new product development.

However, since the mid-1990s, chain stores, supermarkets and mail-order firms have been expanding their own design capabilities and brand strategy. Distributors as lead firms in buyer-driven GVCs started controlling product design by prescribing styles to manufacturers and leveraging their access to consumers, As a result, many manufacturers lost their design capability and became subcontractors. Although they still engage in intermediate stages between design and manufacturing, such as the production of prototypes, much of the value added related to product development has shifted from manufacturers to distributors. Some manufacturers maintain their own collections and mostly specialise in top-end products under registered trademarks. While this strategy enables them to profit from their design investments, it requires strong capabilities in design, production of top-end products and marketing.

Non-replicability of knowledge-based capital largely defines the value of upgrading

The competitive advantage of firms and their upgrading potential are eroded if knowledge-based capital is easily replicated. Replication is likely to be more difficult when intangible assets have the following characteristics:

Firm-specificity and non-separability: Some types of knowledge-based capital are inseparable from certain firm characteristics. This indicates that these assets are firm-specific and difficult to trade. Firms need to build them in house through investments over a period of time.

Latecomer disadvantage: It is difficult to replicate knowledge-based capital that has been built up through investments over a long period. To build a comparable level of knowledge-based capital in a short period will incur disproportionately high costs. Also, if knowledge-based capital results in increasing returns to scale, latecomers will have difficulty accumulating new knowledge, compared to firms with a larger initial stock of knowledge-based capital (Dierickx and Cool, 1989).

Causal ambiguity: The link between different types of knowledge-based capital and competitive advantage can be ambiguous, making it hard for rivals to identify which types they need to replicate in order to catch up. The ambiguity is especially marked if knowledge-based capital is tacit, integrates different types of knowledge-based capital or is firm- or relationship-specific (Reed and Defilippi, 1990).

Path dependency: Certain types of knowledge-based capital, such as advanced technology or competitive organisational structures, reflect a firm's individual history of technology investments, entrepreneurial activities and successes and failures, which are practically impossible for rivals to replicate (Barney, 1991).

Computerised information (software and databases) that is available in markets is unlikely to be the source of upgrading. Crowd computing[3] has significantly reduced the investments required to exploit the latest software and datasets, and web communities provide abundant information on their effective use. However, firms' datasets on customers and product sales, which they exploit for marketing and new product development, are protected as a very valuable corporate asset. Exploiting these data also requires investments in new capabilities and organisational change. Such assets are therefore largely non-replicable, at least until the technology and the ability to capture and analyse such data become widespread. Computerised information is also often integrated in a firm's organisational structure and thus largely firm-specific. Moreover, the combination of information and communication technology (ICT) and organisational capital contributes more to a firm's productivity growth than investment in only one of these (Brynjolfsson et al., 2002).

While innovative property, and in particular technological knowledge, can be replicated to some extent, sophisticated technology and design are considered important sources of competitive advantage. In general, innovative property is more replicable if it is codified as standards or well-defined routines. For instance, management know-how on the cost and quality of production is often transferred to suppliers (Javorcik, 2004). Innovative property is harder to replicate if it contains complex and abstract knowledge or is embodied as tacit knowledge in specific employees or corporate systems. Advanced technology embodied in workers as tacit skills is not easily transferrable. Firms that risk imitation by a rival have strong incentives to increase the share of tacit knowledge and non-codified know-how in their production process (Thoenig and Verdier, 2003). Innovative property can also be strongly path-dependent. For example, a long tradition of sophisticated design allows firms in Italy's Lombardy region to be global leaders in their market segments (Czarnitzki and Thorwarth, 2009).

Many economic competencies possess the characteristics described above. A firm's brand equity – reputation or image – is built through strategic expenditure and accumulated expertise. Because of its cumulative and path-dependent nature, it is hard to replicate. Furthermore, creating a brand is a rather unclear process (e.g. the contribution of marketing to a firm's brand image is not immediately clear). Similarly, firm-specific skills and organisational structure are not separable from a firm's other organisational features and are therefore non-tradable. They are also tacit and are developed through the firm's history of entrepreneurial activities and a process of trial and error. Although their superficial components are often documented and can be learned, it is often impossible to define their contribution to the firm's competitive advantage.

In Table 7.2 the different types of knowledge-based capital are related to their upgrading potential and ease of replication. For example, economic competencies, such as superior management, brand equity and organisational structure, are generally more difficult to replicate than innovative property or computerised information. This suggests that chain upgrading based on such assets can ensure more value than upgrading supported by novel technology or datasets. In practice, however, it is often the combination of several types of knowledge-based capital that is the source of firms' competitive advantage.

Table 7.2. Upgrading of GVC activity and relevant intangibles

Type of upgrading	Essential knowledge-based capital	Replicability	Value created from upgrading
Chain upgrading	Firm-specific management skill (acquired from entrepreneurial trial and error), Flexible organisational structure	Low	High
Functional upgrading	Sophisticated technology and design, Recognised brand, marketing ability, Retail and collaboration networks		
Product upgrading	Advanced production technology and quality management skill, good design, "Big data" on consumer preference		
Process upgrading	Rich know-how in process management, Efficient procurement network, software and other ICT processing complex tasks	High	Low

Source: Based on Kaplinski and Morris (2002).

Competitive dynamics in GVCs

Knowledge-based capital increasingly constitutes an integral part of companies' business models. Sustained competitive advantage is increasingly based on innovation, which in turn is driven by investments in R&D, design, organisational capital, employee skills, marketing/sales experience, etc. (OECD, 2010). The higher value added that firms generate in GVCs largely hinges on the (continuous) development of superior capabilities and firm-specific "resources" which are often intangible, non-tradable and difficult to replicate (Wernerfelt, 1984; Dierickx and Cool, 1989). Korkeamaki and Takalo (2010) calculated the commercial value of Apple's iPhone and estimated that patentable technologies (i.e. innovative property) explained about 25% of the total value. A large part of the remainder is explained by "soft technologies" (Bloom and Van Reenen, 2010), i.e. capabilities such as design, engineering, management, marketing, etc., which are partially built on previous innovations and products that reflect the cumulative nature of innovation (e.g. the Apple name and corporate image based on earlier products such as the iPod and the Mac notebook).

Knowledge-based capital is increasingly important in the governance of GVCs since firms can use their specific capabilities to shape the industry architecture and to capture a larger share of value. Superior capabilities allow firms to innovate and compete in their own market segment, but also to change the competitive conditions of the whole value chain. Firms are often able to manage linkages with other firms within a GVC so as to make themselves less replaceable while making other firms more dependent on them. Because the latter have to co-operate with them to create value, such firms can leverage their position in GVCs and capture more value.

As industries and products become more fragmented and decentralised, economic competencies in terms of system integration skills can leverage companies' innovation activities in GVCs. The lead firm integrates the different stages of the value chain and makes the different elements work together. The example of Apple shows that its strong design capabilities enabled it to take the lead in integrating the different components and services into its different products. Lead firms in electronic GVCs have used standards not only to transfer knowledge to their suppliers but also to lower barriers to entry in the corresponding segment of the GVC and thus increase competition among suppliers (Shapiro and Varian, 1999).

In some GVCs, individual firms have succeeded in providing inputs that are indispensable and non-substitutable (Teece, 1986; Jacobides et al., 2006; Simon, 2009). Such firms enjoy the fruits of innovations by other participants in the GVC through increased demand for their products or services. For example, McKinsey (2010b) described how Japanese companies achieve high value added in a number of GVCs: "In 30 different technology sectors with revenues of more than USD 1 billion, Japanese companies control 70% or more of global market share. They have done so by creating an array of "choke point" technologies on which much larger industries depend. Mabuchi Motor, for instance, makes 90% of the micro motors used to adjust car mirrors worldwide. Nidec makes 75% of the world's hard-disk drives. Japanese companies own nearly 100% of the global market for the substrates and bonding chemicals used in microprocessors and other integrated circuits."

Activities in network industries have increasingly achieved the same dominance. Providers such as Microsoft, Nintendo or Apple supply the infrastructure on which the value created by many other GVC participants, such as programme developers, is based. When Nintendo attracted many users in the US market in the late 1980s, many game developers wrote games for the Nintendo Entertainment System (NES) and made the system even more popular. Because those developers obtained more demand for their games on NES than on rival systems, they not only paid royalties to Nintendo but even promised not to make their game available on other systems for two years following its release (Lev, 2001). Branding is a more general case of such dominance: only a few firms have successfully built recognised brands. Firms that attribute their brand to a final product act as the guarantor of quality (Jacobides et al., 2006) and capture a lion's share of the value-added generated by the GVC (Gereffi, 1999).

The importance of knowledge-based assets in GVCs

Knowledge-based capital and upgrading at the firm level: Survey results for Japan

There has been little analysis of the importance of knowledge-based capital for GVC upgrading by companies and countries. A survey recently conducted by Japan's Ministry of Economy, Trade and Industry (METI)[4] provides some initial findings. The results show, first, that manufacturing firms in Japan consider economic competencies such as manufacturing skills, brand equity and agile organisations a more important source of competitive advantage than cutting-edge technology or computerised information (Figure 7.3). The Japanese firms that are most engaged in GVCs, i.e. those that export or import intermediate goods or own offshore plants, view such competencies as more important than firms that have no foreign trade or foreign plants. They also place greater emphasis on cutting-edge technology and "big data" as sources of competitive advantage than firms oriented towards the domestic market.

Second, the survey results reveal that many firms engage simultaneously in different types of upgrading, with process and product upgrading the most frequent combination. Efforts to move to higher value-added activities (i.e. functional upgrading) and to enter new industries or value chains (i.e. chain upgrading) mostly involve product or process upgrading. However, the share of firms engaging in functional or in chain upgrading (6% and 13%, respectively) is markedly smaller than that of those engaging in process or in product upgrading (63% and 70%, respectively). This indicates that functional and chain upgrading are more challenging, most likely because they require large investments in knowledge-based capital.

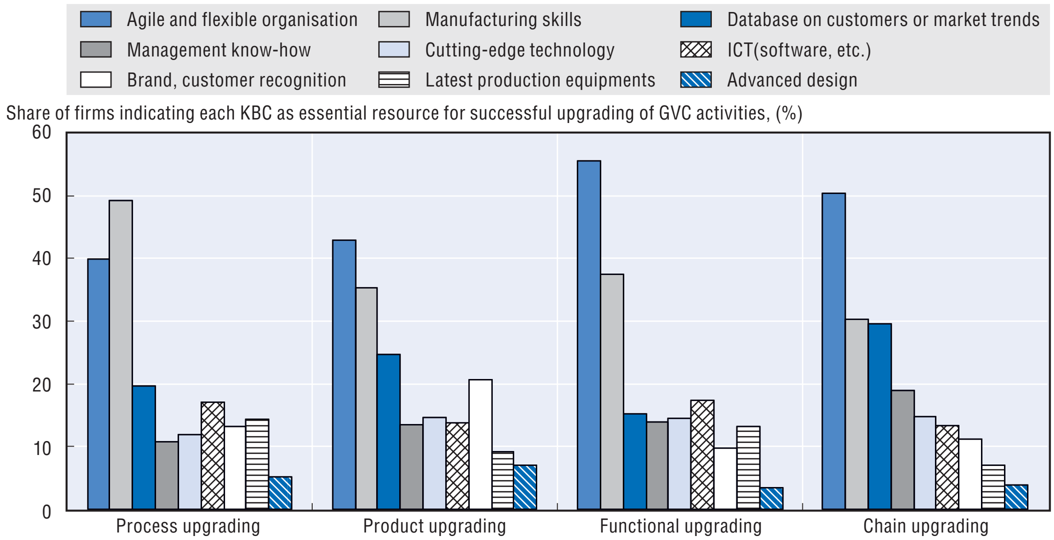
Third, firms in Japan consider agile and flexible organisations as the essential knowledge-based assets for functional and chain upgrading. In general, the survey results suggest that the categories of knowledge-based capital that are more difficult to replicate (e.g. organisational structure, firm-specific manufacturing skills) are at the heart of upgrading (Figure 7.4). Many firms also consider the development of databases as an essential resource, a sign that the systematic use of "big data" to strengthen competitiveness is gaining importance in Japan.

Figure 7.3. Knowledge-based capital and the competitiveness of manufacturing firms in Japan

Note: The shares do not add up to 100% because firms are allowed to select multiple forms of knowledge-based capital they consider essential. The figure shows the share of firms that indicate the form of knowledge-based capital concerned to be essential to competitiveness.

Source: Japanese Ministry of Economy, Trade and Industry survey on global value chains, November 2012.

Figure 7.4. Knowledge-based capital and GVC upgrading in firms in Japan



Note: The shares do not add up to 100% because firms are allowed to select multiple forms of knowledge-based capital as essential resources. The figure shows for each group of firms engaging in specific types of upgrading, the share of firms that indicate each form of knowledge-based capital to be essential for upgrading.

Source: Japanese Ministry of Economy, Trade and Industry survey on global value chains, November 2012.

Knowledge-based capital and the export competitiveness of countries

While data on physical capital have long been available, data on knowledge-based capital at the economy level have only recently become available.[5] These data are largely limited to developed economies, and this should be kept in mind when interpreting the results of the econometric work described below. The analysis tests knowledge-based capital as a factor of production against more traditional determinants of export specialisation such as physical and human capital. It also explores its interaction with GVC activities such as offshoring on the hypothesis that knowledge-based capital allows countries to create and capture more value in GVCs. It finds that the export competitiveness of countries in a world of GVCs is to a large extent determined by these assets.

The analysis extends the model used in Chapter 6, which demonstrates the importance of outsourcing and offshoring for countries' export competitiveness, proxied by measures of revealed comparative advantage (RCA). In the extended model, knowledge-based assets are included as a factor of production that may contribute to the specialisation patterns of countries. Like the other factors of production, knowledge-based capital (measured at the country level) is included dependent on the intensity with which knowledge-based capital is used at the industry level in order to capture differential effects across industries.[6] Export competitiveness is again measured on the basis of RCA both in gross and value added terms to capture the unequal distribution of value along GVCs (Table 7.3).

Table 7.3. The effect of knowledge-based capital on the export competitiveness of countries

Variables	RCA in gross exports (symmetric) I	RCA in gross exports (symmetric) II	RCA in gross exports (symmetric) III	RCA in value added (symmetric) I	RCA in value added (symmetric) II	RCA in value added (symmetric) III
Domestic demand index	0.024*** (0.009)	0.020** (0.009)	0.019** (0.009)	0.023** (0.009)	0.019** (0.009)	0.018* (0.009)
Physical capital endowment × physical capital intensity	0.003*** (0.000)	0.003*** (0.000)	0.003*** (0.000)	0.004*** (0.000)	0.003*** (0.000)	0.003*** (0.000)
High-skill endowment × High-skill intensity	3.077*** (0.475)			3.064*** (0.483)		
Outsourcing Index (broad definition - intermediate use intensity)	0.111*** (0.010)	0.127*** (0.010)	0.125*** (0.010)	0.081*** (0.010)	0.097*** (0.010)	0.095*** (0.010)
Offshoring Index (Broad definition - Intermediates import intensity)	0.159*** (0.036)	0.172*** (0.035)	0.161*** (0.035)	0.094*** (0.035)	0.107*** (0.035)	0.096*** (0.035)
Knowledge-based capital endowment × High-skill intensity		0.040*** (0.005)	-0.01 (0.009)		0.041*** (0.005)	-0.007 (0.010)
Knowledge-based capital endowment × High-skill intensity × Intermediates import intensity			0.685*** (0.097)			0.665*** (0.097)
Knowledge-based capital endowment × Intermediates import intensity			-0.286*** (0.042)			-0.278*** (0.042)
Observations R-square	6585 0.316	6585 0.317	6585 0.323	6585 0.308	6585 0.31	6585 0.315

Note: Robust standard errors are reported in parentheses. Significance levels are indicated by: *** at 1%, ** at 5%, and * at 10% level.

Source: OECD calculations.

The econometric results show first that knowledge-based capital enhances the export competitiveness of skill-intensive industries. The more a country invests in knowledge-based capital, the more likely it is to develop a comparative advantage in international trade in such industries (Table 7.3, column II).[7] This finding is in line with the positive effects of factors of production such as physical and especially human capital (Table 7.3, column I) and underlines the importance of knowledge-based capital as a productive resource.

Second, the positive effect of knowledge-based capital is larger in industries that are high-skill- and offshoring-intensive (Table 7.3, column III) and indicates a strong complementarity between knowledge-based capital and integration in GVCs. The results show that offshoring magnifies the positive effects of knowledge-based capital in terms of export specialisation. Countries with knowledge-based assets are likely to benefit more from their integration in GVCs through offshoring of higher-skill and higher-technology industries. As discussed above, these assets allow companies to innovate faster and better, to position themselves in higher value-added activities in GVCs and to govern the architecture of their GVCs. These advantages at the firm level determine the export specialisation and competitiveness of countries.

An extension of this exercise measures separately the impact of each of the three components of knowledge-based capital (computerised information, innovative property, and economic competencies) on export specialisation (Table 7.4 shows the results in terms of RCA in value added).[8] Economic competencies stand out as the category of knowledge-based capital with the largest impact on export specialisation in skill-intensive industries, followed closely by computerised information and innovative capabilities.

This clearly shows that superior corporate strategies and competitive organisational structures matter a lot for export specialisation at the industry level, perhaps more than the often-mentioned technological leadership and R&D. Results again seem to be largely driven by industries that are both high-skill- and offshore-intensive in all three components. All three forms of knowledge-based assets allow for a higher level of specialisation, especially in industries with more open input markets.

Table 7.4. The effect of different categories of knowledge-based capital on the export competitiveness of countries

Variables	RCA in value added (symmetric)					
	Computerised information		Innovative property		Economic competencies	
	I	II	III	I	II	III
Domestic demand index	0.023** (0.009)	0.022** (0.009)	0.021** (0.009)	0.020** (0.009)	0.017* (0.009)	0.016* (0.009)
Physical capital endowment × Physical capital intensity	0.004*** (0.000)	0.003*** (0.000)	0.004*** (0.000)	0.003*** (0.000)	0.003*** (0.000)	0.003*** (0.000)
Outsourcing index (broad definition - intermediate use intensity)	0.092*** (0.010)	0.090*** (0.010)	0.092*** (0.010)	0.091*** (0.010)	0.100*** (0.010)	0.099*** (0.010)
Offshoring index (Broad definition - Intermediates import intensity)	0.104*** (0.035)	0.098*** (0.035)	0.108*** (0.035)	0.101*** (0.035)	0.111*** (0.035)	0.092*** (0.035)
Knowledge-based capital endowment × High-skill intensity	0.150*** (0.027)	-0.062 (0.049)	0.058*** (0.010)	-0.022 (0.018)	0.162*** (0.015)	0.005 (0.029)
Knowledge-based Capital endowment × High-skill intensity × Intermediates import intensity		2.913*** (0.488)		1.104*** (0.179)		2.154*** (0.303)
Knowledge-based capital endowment × Intermediates import intensity		-1.193*** (0.211)		-0.447*** (0.077)		-0.944*** (0.128)
Observations	6585	6585	6585	6585	6585	6585
R-square	0.306	0.309	0.307	0.31	0.316	0.322

Note: Robust standard errors are reported in parentheses. Significance levels are indicated by: *** at 1%, ** at 5%, and * at 10% level.

Knowledge-based capital and upgrading of countries in GVCs

The results of countries' process, product, functional and chain upgrading can be captured in the domestic value-added content of countries' exports.[9] The idea is that knowledge-based capital allows companies and countries to create and capture more value through their exports. The model is similar to the one used above, but the estimation procedure is somewhat different.[10] The effect of knowledge-based capital (on the country level) is dependent on the industry's skill intensity in order to capture differences across industries (Table 7.5). The estimation is carried out for total knowledge-based capital as well as for the three categories: computerised information, innovative property and economic competencies.

The results underscore the importance of knowledge-based capital for upgrading in GVCs. Countries with a larger endowment of knowledge-based capital are more likely to create and capture more value from their exports. Each category of knowledge-based capital has a positive effect on upgrading. As in the case of export competitiveness the results suggest that economic competencies have the largest impact, followed here by innovative property and computerised information. As such, the results are largely in line with conjectures regarding the non-replicable nature of knowledge-based capital and its link to the value of upgrading. Another interesting result is that the effect of R&D is smaller than that of innovative property as a whole, which confirms the important role of non-R&D-based innovation, such as design, for value creation.

Table 7.5. The effect of knowledge-based capital on GVC upgrading

	Ratio of value-added to gross exports (VAX)						
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
h × All KBC	0.9158*** (0.1937)					1.3840** (0.6963)	1.3865** (0.6873)
h × Computerised information		0.5746*** (0.2081)					
h × Innovative property			0.7913*** (0.2078)				
h × R&D				0.5135** (0.2058)			
h × Economic competencies					1.0086*** (0.2427)		
f × Financial development							0.229 (0.9469)
Physical capital stock per hour worked	0.3634*** (0.0437)	0.4472*** (0.0463)	0.3953*** (0.0436)	0.4262*** (0.0438)	0.3811*** (0.0492)	0.3478*** (0.0743)	0.3390*** (0.0789)
Country-Industry fixed effects	yes	yes	yes	yes	yes	yes	Yes
Year fixed effects	yes	yes	yes	yes	yes	yes	Yes
Country-year fixed effects	No	No	No	No	No	yes	Yes
Industry-year fixed effects	No	No	No	No	No	yes	Yes
Number of observations	682	682	682	682	682	682	682
R-squared	0.995	0.994	0.995	0.994	0.995	0.997	0.997

Note: Robust standard errors are reported in parentheses. Significance levels are indicated by: *** at 1%, ** at 5%, and * at 10% level.

Policy considerations

Although the main actors for upgrading in GVCs are firms, governments can support upgrading in GVCs in various ways. Policies to support the upgrading process are largely similar to policies to enhance productivity. Therefore, governments should strengthen product market competition to strengthen the incentives for firms to: enhance productivity; foster a dynamic business sector that allows new, innovative firms to emerge, experiment and grow; invest in productivity-enhancing public goods such as education, research and infrastructure; and provide the framework conditions that support business investments in such areas. Well-designed demand-side policies, such as innovation-oriented competitive public procurement, can also help strengthen the innovation system and ensure that innovation meets public needs.

A particularly important driver for upgrading in GVCs is investment in knowledge-based capital. Investments in knowledge-based capital not only drive productivity growth, they also determine the extent to which the final product of a value chain can be differentiated in consumer markets, which in turn determines the total value the GVC can create. Business investment in knowledge-based capital underpins much of the knowledge economy. Accordingly, many policy areas affect these investments. Framework conditions are crucial, as they provide the overall context for investment in knowledge-based capital and for the efficient reallocation of resources to new sources of growth, including those that rely on knowledge-based assets.

In addition, policies to increase business investment in knowledge-based capital must be founded on evidence that businesses would otherwise underinvest in knowledge-based capital. For firms, the ability to internalise fully the returns to investments in knowledge-based capital varies among the different types of assets. The strongest evidence for private underinvestment concerns R&D-related spending. But positive externalities, which can lead to socially suboptimal investment, also exist for design and other forms of knowledge-based capital (many businesses' designs are copied, an indication of spillover of value).

Knowledge-based capital as a source of value creation in GVCs has several implications for policies to increase the gains from global engagement. The recognition that assets such as data, design, brands, management and organisational arrangements play an important role in capturing value in GVCs opens the way to policy thinking that goes beyond policies oriented towards technology and tangible capital. The breadth of knowledge-based capital points to the need for a broader concept of innovation than the conventional view dominated by R&D. A wider perspective on innovation's drivers could require the redesign of some long-standing innovation programmes.

For example, most OECD governments operate programmes that facilitate firms' access to research or technology-related advice and information, often from universities and public research organisations. These schemes – such as innovation vouchers, know-how funds and technical extension services – tend to focus on technological information, typically by creating links to academics in science, technology, engineering and mathematics (STEM) disciplines. The work on knowledge-based capital suggests that an exclusive focus on STEM disciplines is too narrow. Businesses also interact with academics for reasons other than technological development.

Policy frameworks might also facilitate collaboration on non-R&D-based innovation. Collaboration on R&D by private firms and public research entities is increasingly common in OECD countries, owing to the growing complexity of innovation and need for complementary knowledge. Collaboration can help government laboratories or universities to obtain funding for research activities and help ensure that their research is commercially relevant, while firms gain access to these institutions' accumulated knowledge. New OECD evidence shows that such collaboration is associated with stronger productivity growth in firms in R&D-intensive sectors. While maintaining the critical role of universities in fundamental research, policy might enlarge the focus of collaboration-enabling programmes beyond R&D. Policies that facilitate links between GVC participants and the local knowledge base (research and training institutions) can lead to positive feedback loops between knowledge-based capital and the upgrading of GVC activities. Such linkages enhance firms' ability to absorb knowledge from counterparts in a GVC.

Evidence suggests that countries that are more successful at channelling resources to the most productive firms also invest more in knowledge-based capital. Entrepreneurial activity is essential to the process of reallocating labour and all forms of capital to their most productive uses. Having efficient mechanisms to reallocate tangible resources takes on heightened importance – to implement and commercialise new ideas, firms require a range of complementary tangible resources to test ideas (e.g. to develop prototypes), develop marketing strategies and eventually produce at a commercially viable scale. Innovative firms can play a key role in diversifying countries' participation in GVCs and in supporting the upgrading process. The use of knowledge-based capital in the upgrading of value chains will also require experimentation by firms of all sizes with new business models and organisational forms. Countries with more stringent regulations in product, labour and (to a lesser extent) credit markets, tend to invest less in knowledge-based capital while investment in knowledge-based capital is also positively correlated with debtor-friendly bankruptcy codes.

Financing is also a key area because it supports innovation and diversification. In traditional debt markets, tangibles (assets such as equipment and structures) have well-defined market prices and readily serve as collateral. The increasing importance of knowledge-based capital underscores the need for market-enhancing policy instruments to address shortfalls of early-stage risk capital that affect young knowledge-based capital intensive firms and the need for better ways for firms to communicate the value of knowledge-based capital in their business models.

Lowering barriers to international trade and investment also encourages more efficient resource allocation by increasing knowledge diffusion and technology transfer across borders. As knowledge is partly embodied in – and can spill over from - imported intermediate goods, reductions in tariffs on intermediate inputs are associated with significant productivity growth in downstream manufacturing sectors. Reductions in tariffs on foreign high-technology intermediate inputs boosts the productivity of sectors closest to the technology frontier, but has no impact on sectors more distant from the frontier. And across service sectors in OECD countries, higher restrictions on foreign direct investment (FDI) are associated with lower allocative efficiency.

Because of the specific economic features of knowledge-based assets, especially its intangible nature, certain key policy settings will also need to be updated in the fields of taxation, competition, corporate reporting, intellectual property and in policies that enable the exploitation of data as an economic asset. In the highly interconnected, knowledge-driven economy of GVCs, high-quality intellectual property rights (IPR) are an increasingly important framework condition. These help protect the critical knowledge-based capital that enables firms to create value and compete in global markets and help to avoid easy replication by rivals of new design and technologies. A sound and high-quality IPR regime, combined with good enforcement, is therefore important. However, there are concerns that certain features of IPR regimes may be hindering innovation and competition and have not kept pace with technological change. In a world increasingly based on knowledge assets, IPR regimes must be coupled with pro-competition policies and efficient judicial systems to help erode the rents arising from monopoly protection. There is also a need for greater mutual recognition and compatibility across IPR systems internationally, for instance to permit cross-border copyright licensing.

The rise of knowledge-based capital also amplifies the importance of some framework policies already understood to be essential, such as in education. Attention must likewise be given to complex regulatory issues, for instance in connection with data privacy and security. Indeed, as new technologies develop, based on knowledge-based capital new regulatory challenges are likely to emerge.

Notes

1. The innovation literature traditionally distinguishes between four types of innovation: process innovation, product innovation, marketing innovation and organisational innovation (OECD, 2010).

2. Hulten (2010) adapted this framework to Microsoft and reported that KBC explained more than 40% of its productivity growth.

3. Using the power of people out in the web to undertake tasks that are hard for individual users of computers to do alone (Miller, 2012).

4. In November 2012 Japan's Ministry of Economy, Trade and Industry (METI) surveyed Japanese enterprises on their engagement in GVCs. Information was obtained from 2 269 firms, of which 54% were manufacturing firms, 51% were exporters and 37% possessed offshore plants, on their various activities related to GVCs, their efforts to achieve higher profit margins and the forms of KBC they consider essential for successful upgrading.

5. On-going work should also provide finer measurements of these assets (OECD, forthcoming). The data for knowledge-based capital come from Corrado et al. (2012) who calculated detailed measures of its three components (computerised information, innovative property and economic competencies) for 14 European countries and the United States. The sample used to test the hypothesis is therefore much smaller than the one used in Chapter 6.

6. In the absence of data on knowledge intensity at the sectoral level, they are proxied by high-skill intensity. More detail is provided in Annex 7.A1.

7. Column I of the OLS results reproduces results in Chapter 6 for the subsample of 14 countries used in this experiment. Column II replaces high-skilled labour endowment with intangible capital endowment, dependent on high skill intensity at the industry level. As in the model used in Chapter 6, other controls include external economies of scale, and the country's capital endowment, dependent on capital-intensity at the industry level. Column III introduces two interaction variables to measure separately the impact of KBC endowment on specialisation in industries that are both high-skill- and offshoring-intensive.

8. Under the same specification, each component enters the equation when the other two are excluded.

9. There is no widely agreed measure of GVC upgrading. The measures used so far have largely depended on data availability. The new results on trade in value added allow for more complete measurements.

10. Comparing differences at two points in time (or, in other words, at two different levels of KBC endowment) yields the estimator in question, much as in the previous model. More detail is provided Annex 7.A2.

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Annex 7.A1
Econometric model on the effect of knowledge-based capital and export competitiveness

The data

The purpose of this exercise is to extend the empirical framework used in Chapter 6 to include measures of knowledge-based capital and its interaction with offshoring activities. The data for knowledge-based capital come from Corrado et al., (2012) who calculated detailed measures of its three components for 14 European countries and the United States. [1] The size of the sample that is used to test the hypothesis is therefore much smaller than the one used in Chapter 6.

Gross export data are sourced directly from the WIOD International Supply and Use Tables. Export value-added is extracted from the same tables using the OECD inter-country input-output (ICIO) system comprising all three components of domestic value-added (direct, indirect and re-imported), and calculated as gross exports minus foreign value-added according to:

$$\mathbf{x_{it}}^{VA} = \Sigma_j\, \mathbf{x_{ijt}}^{VA} = \Sigma_j\, (\mathbf{x_{ijt}} - \mathbf{V_{jt}}\, \mathbf{B_{jit}}\, \mathbf{x_{ijt}})$$

where $\mathbf{x_{it}}^{VA}$ is the sum across partner countries *j* of bilateral vectors of domestic value-added $\mathbf{x_{ijt}}^{VA}$ embodied in gross exports $\mathbf{x_{ijt}}$ from country *i* to *j* at year *t*. Each element of the vector corresponds to one sector of the economy. $\mathbf{V_{jt}}$ is a diagonal matrix representing value-added shares of the partner country *j* at year *t*. And $\mathbf{B_{jit}}$ is a block matrix representing total requirements in gross output from country *j* for a one unit increase in country *i*'s demand. $\mathbf{B_{jit}}$ is part of the global Leontief inverse matrix $\mathbf{B_t}$ sourced from WIOD. For more details on the OECD inter-country input-output system see (OECD, 2013).

The model

The relationship between revealed comparative advantages (RCAs), country endowments, and sectoral sourcing activities, is modelled using the benchmark linear OLS model of Chapter 6, augmented to include measures of intangible capital endowment and its interaction with offshoring activities. The preferred specification is:

$$\mathrm{SRCA}_{ist} = \beta_0 + \beta_1\, \mathrm{D}_{ist} + \beta_2\, (\mathrm{K}_{it} \times \mathrm{k}_s) + \beta_3\, (\mathrm{IK}_{it} \times \mathrm{h}_s) + \beta_4\, \mathrm{Int}_{ist} + \beta_5\, \mathrm{Imp}_{ist} + \\ + \beta_6\, (\mathrm{IK}_{it} \times \mathrm{Imp}_s) + \beta_7\, (\mathrm{IK}_{it} \times \mathrm{h}_s \times \mathrm{Imp}_s) + \mathrm{c}_{it} + \mathrm{c}_s + u_{ist}$$

1 **Years**: 1995-2009; **Countries:** Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Ireland, Italy, Netherlands, Slovenia, Spain, Sweden, United Kingdom, United States; **Industries:** ISIC Rev.3 sectors AtB, C, 15t16, 17t18, 19, 20, 21t22, 23, 24, 25, 26, 27t28, 29, 30t33, 34t35, 36t37, E, F, 50, 51, 52, H, 60, 61, 62, 63, 64, J, 70, 71t74, L, M, N, O, P.

where the dependent variable $SRCA_{ist}$ stands for the Symmetric Revealed Comparative Advantage index in country *i*, sector *s* and year *t*, calculated as $(RCA_{ist}-1)/(RCA_{ist}+1)$. The adjustment was introduced by Laursen (1998) to render Balassa's RCA index comparable on both sides of unity.[2]

Regressors

D_{ist} *Domestic demand index:* The index corresponds to the domestic share of sector *s* in country *i* total consumption, relative to the share of the sector in total world consumption in year *t*:

$$D_{ist} = (D_{ist}/D_{it}) / (D_{st}/D_t)$$

The index is designed to measure the weight of this sector in domestic consumption relative to the world average. It is introduced as a control for external economies of scale, capturing factors such as better infrastructure for the needs of the industry, the availability of cheaper inputs, or a history of growth. Domestic demand D_{ist} is calculated as the sum of final demand by households, non-governmental organisations (NGOs) and the government. *Source:* WIOD Socio-Economic Accounts.

$K_{it} \times k_s$ *Capital endowment × industry intensity:* Capital endowment at the country level (K_{it}) is captured conditionally in an interaction term with the industry's capital intensity (k_s). Capital endowment is measured relative to the size of the labour input (capital stock divided by the number of hours worked in the country to take into account part-time employment). Capital intensity is calculated at the industry level as expenditure shares in value added from a single reference country, averaged over 15 years. The reference country used is the United States, subsequently excluded from the sample. *Source:* WIOD Socio-Economic Accounts.

$H_{it} \times h_s$ *Skilled labour endowment × industry intensity:* The impact is captured by an interaction between skill-intensity at the industry level (h_s) and abundance of high skills at the country level (H_{it}). Endowment is measured at the country level as hours worked by high-skilled workers relative to total hours worked in the economy. High skill intensity at the industry level is calculated as expenditure shares in total labour compensation from a single reference country averaged over 15 years. The reference country used is the United States, subsequently excluded from the sample. *Source:* WIOD Socio-Economic Accounts.

Int_{ist} *Outsourcing index:* Intermediate use intensity (intermediates expenditure I_{ist} excluding expenditure for energy as a share of gross output GO_{ist}) relative to the sectoral average of the same ratio across all countries in the same year: $Int_{ist} = (I_{ist}/GO_{ist}) / (I_{st}/GO_{st})$. *Source:* WIOD International Supply and Use Tables.

Imp_{ist} *Offshoring index:* Import intensity in intermediate use (share of imported intermediates I^{imp}_{ist} in total intermediates I_{ist}) relative to the sectoral average of the same ratio across all countries in the same year: $Imp_{ist} = (I^{imp}_{ist}/ I_{ist}) / (I^{imp}_{st}/ I_{st})$. *Source:* WIOD International Supply and Use Tables.

2 The asymmetry it addresses is that standard RCAs range from zero to one if a country is not specialised in a given sector, while the index ranges from one to infinity otherwise.

$IK_{it} \times h_s$ *Intangible capital endowment × skill intensity:* Intangible capital endowment at the country level (IK_{it}) is captured conditionally in an interaction term with the industry's skill intensity (h_s). The index therefore varies over countries and years in a single dimension (knowledge-based capital) disentangling its impact over an invariable set of industries that are both high-skill- and offshore-intensive. Intangible capital is calculated as the sum of three categories of assets: investment in computerised information; innovative property; and economic competencies for which recent data exist only at the country level (Corrado et al., 2012), relative to the size of the labour input (number of hours worked in the country). Intangible capital intensity is proxied by high skill intensity at the industry level, corresponding to expenditure shares in total labour compensation from a single reference country, averaged over 15 years. The reference country used is the United States, and it is subsequently excluded from the sample. *Source:* WIOD Socio-Economic Accounts.

$IK_{it} \times h_s \times Imp_s$ *Intangible capital endowment × skill intensity × offshoring intensity:* Intangible capital endowment at the country level (IK_{it}) is captured conditionally in an interaction term with the industry's skill intensity (h_s, see above) and with the industry's offshoring intensity (Imp_s). Offshoring intensity at the industry level is calculated as import intensity of intermediate use (share of imported intermediates in total intermediates; *Source:* WIOD Supply and Use Tables) from a single reference country averaged over 15 years. The reference country used is the United States, which is subsequently excluded from the sample. Notice that, to facilitate the interpretability of this three-way interaction, variation of high-skill and offshoring intensity over countries and time is suppressed, with values by sector taken from a single reference country (the United States, subsequently excluded from the sample), and averaged over time. The equation is complemented with a two-way interaction of knowledge-based capital endowment with offshoring intensity (see below), to ensure that the main effects are marginal to their interaction effect (the so-called *principle of marginality*).[3]

$IK_{it} \times Imp_s$ *Intangible capital endowment × offshoring intensity:* Intangible capital endowment at the country level (IK_{it}) is captured conditionally in an interaction term with the industry's offshoring intensity (Imp_s).

$c_{it} + c_s$ *Country × year fixed effects and sector fixed effects*: These are included to capture systematic deviations of SRCAs across sectors in certain countries, as well as across countries in certain sectors. A sector might systematically have low SRCAs across countries because a single country dominates world production and exports; that asymmetry will be absorbed by the sectoral fixed effect. Similarly, a country's exports might be very little diversified and dominated by few sectors; the average RCAs across sectors will therefore be low, an outcome that will be absorbed by the country fixed effect interacted with year to ensure that variations across time of this structure is suppressed.

Notice that because both the independent and dependent variables are index numbers, normalised for various types of asymmetries, the level of the coefficients in the results is not directly interpretable. Coefficients for the same regressor can nevertheless be compared in an ordinal way between two sets of regressions, adding some insights to the discussion.

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3 See Nelder, J. A. (1977), A Reformulation of Linear Models, *Journal of the Royal Statistical Society*, Vol. 140 (1), pp. 48–77.

Annex 7.A2
Econometric model on the effect of knowledge-based capital and GVC upgrading

1. The data

Data on the domestic value added content of exports are obtained from OECD-WTO TiVA Database and are partly estimated based on the inter-country input-output (ICIO) system. The data are on an annual basis from 1995 to 2009 for 18 industries.

The measures of knowledge-based capital come from Corrado et al. (2012) as in the previous econometric model. The study produced "harmonised" estimates of knowledge-based capital investment for the EU27 and included estimates for the United States. It also estimated the stock value of knowledge-based capital for 14 EU economies and the United States.

2. The model

While the estimates of knowledge-based capital are only available at the economy level, a recent approach that explores within-economy variation across industries is employed following Rajan and Zingales (1998). A country industry "Difference-in-Difference (DID)" approach enables a stronger inference of causality than the usual cross-country regressions because it involves comparisons within an economy and is therefore free from the problems caused by omitted country factors.

This framework is applied to the relation between industry-level VAX and economy-level stock of knowledge-based capital. The following equation is estimated:

$$VAX_{ijt} = \beta\left(h_{ij} \times KBC_{jt}\right) + \gamma X_{ijt} + \alpha_{ij} + \alpha_t + \epsilon_{ijt}$$

The left-hand side is the domestic value added content of exports (VAX) for industry i in economy j at time t, transformed as continuous variable. The first term on the right-hand-side is the interaction of industry i's knowledge-intensity (proxied by the labour compensation share of engaged personnel with tertiary education, obtained from the EU-KLEMS database) and the stock of knowledge-based capital of an economy j at the time t. The knowledge-based capital stock per hour worked by engaged personnel is expressed in log values. The second term is a vector of control variables which may influence both VAX and KBC. In the standard regression, only the economy-industry level physical capital per hour worked by engaged personnel is included. The third and fourth terms represent economy-industry fixed effects and time fixed effects. The former fixed effects control for unobserved heterogeneity specific to each industry in each economy—such as the unique history or initial integration into GVCs by an industry in an economy. The latter fixed effects control for change in world's economic condition at each point of time. The last term is an error assumed to be independent and identically distributed across economies and industries but potentially correlated across times. Heteroscedasticity-consistent standard errors are used to correct for the potential effect of serial correlation.

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