The impact of technology on barriers to industrialisation in developing countries

Background Paper

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Background Paper 6
1 September 2018

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Citation:
Malherbe, S. *The impact of technology on barriers to industrialisation in developing countries*. Pathways for Prosperity Commission Background Paper Series; no. 6. Oxford, United Kingdom.

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Abstract

In the next two decades, technology will redraw the manufacturing map of the world. One potential cause for this change – automation – has received much attention. At the same time, new technologies are removing the barriers that have excluded most developing countries from industrialising. This change, much less often discussed, is equally important. A key element is the globalisation of agglomeration benefits, a process described in the paper.

The paper reviews evidence that a radiation of manufacturing into new locations occurred under propitious conditions, and predicts that it will occur again, involving a larger group of developing countries.

As legacy factors such as geography and starting conditions become somewhat less important, other factors will be pivotal to manufacturing location. This establishes a clear agenda for countries aspiring to join the ranks of manufacturing exporters.

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Introduction

In the next two decades, technology will redraw the manufacturing map of the world. There are two major causes of that. One cause – automation – has received much attention. The other cause is that new technologies are removing the barriers that have hitherto excluded most developing countries from industrialising. This change, which has received much less attention, is potentially equally important. The new geography of manufacturing will reflect the interplay between these two factors.

This paper explores the barriers to industrialisation and traces the impact of new technologies. It finds early signs of a widening global manufacturing system that includes a larger number of countries in cross-border value chains. But entry will not be automatic. While some legacy factors such as geography and starting conditions will become somewhat less important, other factors will become pivotal. Global economic policy and conditions are critical to the speed of these changes. There is much at stake. For the rapid industrialisers, manufacturing for export has been the launch pad to middle-income status. In future, many of the benefits of manufacturing for the rest of the economy will not be automatic. The new industrialisers will have to position themselves carefully, first, to attract manufacturing and, second, to ensure that the maximum benefit is captured.

The challenge

In the last three decades, manufacturing growth in the developing world, led by China, has been unprecedented. After 1990, the manufacturing output of countries outside the Group of Seven (G7) advanced economies increased more than six-fold. Much of this output was exported: between 1992 and 2011 global trade tripled as a proportion of global output[1]. As Baldwin points out, in 1990 the G7 economies[2] accounted for some two-thirds of global manufacturing and gross domestic product (GDP); by 2010, G7 share in global manufacturing and GDP had fallen below 50%[3].

China's growth as a manufacturing exporter set off a demand supercycle that drove high demand for commodity, agricultural and non-tradable products across the developing world. In this way, developing world manufacturing stimulated three of the other pathways identified by the Pathways for Prosperity Commission – agriculture, the domestic economy and services. It is not coincidental that, since 1990, more than a billion people have been lifted out of extreme poverty.

But the process has been extraordinarily concentrated. A group of six to 12 countries[4], led by China, accounted for the lion's share of manufacturing growth. Most developing countries, and virtually all low-income countries, have only benefitted as consumers and suppliers of commodities. The rising commodity prices through which these benefits were transmitted, turned out to be a temporary phenomenon, whereas the shift in manufacturing activity has continued well beyond the financial crisis of 2008.

This raises a critical issue: Are most developing countries permanently excluded from the global manufacturing system? Or is there a path to participation for poorer countries? The thesis advanced by this paper is that new technology will open such a path for a large number of countries.

A metaphor from evolutionary biology is apt here. In nature, species adapt to new environments so as to fill all available ecological niches over time – a process known as 'adaptive radiation'. What we foresee is adaptive radiation of an economic kind. New technologies and business models will allow manufacturing value chains to spread to new countries – as long as policy is conducive.

[1] Francois et al (2015). Total exports in value added terms as a percentage of global GDP increased from 6,1% in 1992 to 18,9% in 2011. Trade is measured in value added terms to avoid double counting. Since 2011, though, the growth in trade has fallen to match growth in global GDP. IMF (2016).

[2] United States, Great Britain, Canada, Germany, France, Italy and Japan.

[3] Baldwin (2016).

[4] Depending on the observer.

The promise of global value chains, partially fulfilled

As developing countries rose to prominence in manufacturing after 1990s, so did the way of organising production known as global value chains (GVCs). In a GVC, the manufacture of a product is divided into different stages or components of production, each performed in a different country and often by a different company[5]. The full value chain of a product also includes pre-manufacturing stages such as design, and post-manufacturing stages such as marketing and distribution. An archetypal, if venerable, example of a GVC is the assembly of a standard computer disk drive in Thailand from components manufactured in ten other countries and then imported into Thailand.[6]

Given the ubiquity of GVCs today, it can be hard to recall how radical a change it was. The developing world pioneers in manufacturing – Korea, Taiwan, Hong Kong and Singapore – followed a different and in some respects far more difficult path: that of import substitution by building the full value chain of a manufacturing sub-sector – a process that could take many years.

The promise was that GVCs would dramatically lower the barriers to countries aspiring to manufacture for export. According to the Organisation for Economic Co-operation and Development (OECD):

> Through access to networks, global markets, capital, knowledge and technology, integration in a GVC can be a first step to economic development. This is often easier than building a complete value chain.[7]

But, for most countries, this is a promise unfulfilled. GVCs have been concentrated to an extraordinary extent. GVCs generally occur in a few regional blocks. These are often referred to as Factory Asia (China, Japan and countries producing intermediate products), Factory Europe (the EU, including the close manufacturing relationship between Germany and Poland) and Factory North America (including the US-Mexico nexus). It has been difficult for countries outside these regions, for example, those in South America, South Asia and Africa, to join in. Amador and Cabral (2017) were not alone in finding that "value-added trade networks are very centralized and asymmetric, with hierarchical structures dominated by a few central countries that act as hubs."

What is the cause of the deep concentration patterns we observe? How can these networks be opened to more countries? To start answering these questions, we have to understand why GVCs became prominent when they did.

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[5] Amador (2014) provides the following useful definition: "Goods and services are produced in separate stages located in different countries and are assembled either sequentially along the supply chain or in a final location." Another is an adaptation of the definition of the Global Value Chain Initiative at Duke University by the Department of Foreign Affairs and International Trade of Canada, to the effect that "A global value chain describes the full range of activities undertaken to being a product or service from its conception to its end use and how these activities are distributed over geographic space and across international borders."

[6] Some components were also manufactured in Thailand. Hiratsuka (2006).

[7] OECD (2013).

Three triggers for the emergence of GVCs

The logic of GVCs is simple: fragmenting production means that a component is produced by a group company or an outside firm in another country. Locating production stages in different countries allows each stage to achieve optimal scale and specialisation and to access lower labour costs.

Firms had known long before the 1990s that labour costs between countries diverged dramatically – in some accounts, as much as forty-fold. Why then, were GVCs so long in coming? The answer lies in costs. In the 1960s and 1970s, large US retailers, as well as multinationals such as General Motors and Volkswagen, pioneered manufacturing in low-cost countries with the intention of returning the products to home markets[8]. But this did not become the norm. Firms would only spread out production if the locational advantages of the new production sites exceeded the costs of relocation and fragmentation. For most of the post-War era, high tariff barriers, high transportation costs and poor and expensive communications made off-shoring and fragmenting production prohibitively expensive.

Over time the cost of operating GVCs plummeted.[9,10] The communications required for the synchronisation of dispersed production became ubiquitous and cheap. While distance still mattered, the secular trend of transportation costs was firmly downward. Container shipping introduced in the 1950s materially reduced the cost and complexity of inter-modal supply lines. Between the 1950s and the 1990s, ocean freight costs fell cumulatively by 65%. As the changing composition of world trade resulted in a rising ratio of value to weight, effective air cargo costs also fell[11]. Since 1990, transportation costs have fallen by another quarter, when expressed as a percentage of the value of the products traded.[12]

Policy change was an important spur. Trade liberalisation occurred across a wide front. Reciprocal tariff reductions were negotiated, the North American Free Trade Agreement was signed (1994), China acceded to the World Trade Organization (WTO) (2001), ten new member states joined the EU (2004) and a raft of regional trade agreements were signed. These changes enabled freer cross-border movement of goods, including intermediate goods. As the new production networks became evident, individual governments responded by establishing special export zones, investing in logistics infrastructure, simplifying border processes and further reducing tariffs.

This history is well known. The reason to recap it here is to point out that the GVC-infused trade boom of the 1990s was caused by a cycle of mutually reinforcing changes in **technology**, firm **business models**, and **policy**. This occurred against a backdrop of rapid growth in global output and investment, particularly in sectors for which GVCs are particularly well suited.

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[8] Gereffi and Sturgeon in Low et al.

[9] See Amador et al (2014). See p10 for air cargo and shipping. Also note that the 1990s saw historically low oil prices.

[10] Blinder (2006) discusses the role of technology in enabling trade more generally.

[11] Today 35% of global trade by value is transported by air. WTO and Institute of Developing Economies and Japan External Trade Organization (IDE-JETRO) (2011).

[12] Francois et al (2015).

In the next phase of global manufacturing, the same will hold: technology, business models and policies will need to co-evolve to radiate economic activity across the globe. While new global and regional trade arrangements were critical spurs in the rise of GVCs, national level policy changes were also vital. National policies will be an even more important differentiator in the next phase. Further, global and regional trade policies would need to remain as permissive as those adopted during 1990-2010.

As firms adopted new modes of production and new business models, the activities that make up 'manufacturing' changed. The scale of these changes became evident once economists became better at tracking activities in the new value chains.

A breakthrough: trade statistics that bring GVCs into sharp focus

Traditional ways of counting trade obscure the existence of GVCs. This is because traditional measures of exports and imports tally up the total, or gross, value of the products traded. In the export statistics of a country, say China, which has assembled an e-tablet from imported components of $90 and then exports it for $100, that export is reflected as $100, even though China has added value of only $10. While the components trade is also reflected in traditional statistics, this is also at gross levels. More importantly, these statistics do not relate the origin of imported components to the exported final product. In this way, trade statistics omit the true history of how and where a product was made, and hence where value was added. From a country perspective, it is the extent of value added within its borders that contributes to national income and correlates with gains in employment. Therefore, tracking where value is added and how these sites are linked, is critical in a world of geographically dispersed production.

New approaches developed in the last decade address this issue. Measures of trade in value added (TiVA) quantify exports according to the value added in that country rather than by gross value. Economists have compiled world input-output tables, or WIOTs[13], that track the use of foreign inputs in manufacturing processes in different sub-sectors, for different countries. These measures, though imperfect, result in a far more comprehensive picture of the chain of production stages across countries and of the value added contributed at each stage.[14]

The new data confirmed the growth of GVCs between 1990 and 2011. Los et al (2015) analysed 558 value chains[15] covering 40 countries and a large number of sectors. In the 13 years covered by the study, 84% of value chains became more fragmented and international, with the share of foreign value-added (FVA) in final exported products increasing by 20%. Between 2011 and 2014, though, the incidence of GVCs plateaued.[16]

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[13] WIOTs, in turn, were derived from national input-output tables and export and import data.

[14] See, for example, the World Input-Output Database (WIOD) and the OECD-WTO TiVA database . These estimates are not perfect: they are sub-sector-wide, rely on national input-output tables that are infrequently updated, and have to be linked through assumptions to import data. Still, they constitute a serious and widely used effort to decompose gross exports and imports into their value-added components. This data is available for only a sub-set of countries.

[15] Each of the 558 value chains represents a certain manufacturing sub-sector and one of 40 countries of final assembly. The study covers the period 1995–2008. See also Francois et al (2015).

[16] Timmer et al (2016).

GVCs are not equally important in all sectors.[17] GVCs have become prominent in electronics, machinery, transportation equipment (including automobiles) and chemicals – sectors that account for 45% of global trade. In these sectors, more than a quarter of final product value is sourced offshore. It has been noted that these sectors are closely linked to investment activities. A second category is labour-intensive early offshorers such as textiles, apparel and leather products: these sectors display a fairly high and stable share of FVA in final exports. A third group includes moderate users of GVCs: rubber and plastics, other manufacturing, and wood and other non-metallic minerals fall into this category. Finally, in food and a few other sectors, GVC use is both minor and static. The findings are broadly confirmed in other studies.[18]

Services to the fore

One of the most important findings of the trade in value added data pertains to the role of services in manufacturing. It has long been known that services play an important and growing role in manufacturing. For example, it has been recorded that some 40 services are involved in the manufacture of a Sandvik power tool[19]. In trade parlance, these services are 'embodied' in the final physical product.

The surprise is the size of the services component. Using the new value-added measure of trade, the OECD has found that services account on average for *one-third* of the value of manufactured exports.[20] Many of these services – commercial, financial and logistical – appear *in situ* to be non-tradable, but turn out to be exported on a massive scale!

These 'hidden' services exports are at least as large as visible services exports.[21] Once both types are added together, the full importance of services in global trade becomes evident. Whilst traditional trade statistics estimate services to account for slightly less than 20% of world trade, the value-added lens revealed that services actually represent *approximately half of the value of all trade*.[22] To that could be added the vast 'establishment trade' in services – services rendered to companies by their foreign affiliates that are not invoiced.[23]

Because this paper explores the role of these services in determining the location of manufacturing, and how that is changing, it is useful to distinguish between two types of services.

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17 The findings and data in this paragraph are drawn from Los et al (2015).

18 Francois et al (2015).

19 Kommerskollegium (2010).

20 OECD (2013).

21 Francois et al (2015).

22 Francois et al (2015). Low (2013) has similar if slightly lower findings.

23 Low (2013).

Product-agnostic commercial services are a threshold for GVC participation. Services that provide the co-ordination and logistics required for a GVC are often said to be 'the glue' that holds supply chains together.[24] Examples are communications, transport, trade facilitation and cross-border contracting. These services, complex as they may be, are mostly not customised to a particular manufacturing process or product. The availability of globally efficient commercial services is now a threshold requirement for aspiring manufacturing centres.

Other services are a source of locational advantage – or disadvantage. Some services are specialised inputs into the manufacturing process. Expert machine tool repair is an example. Because the manufacturer has to buy in these services, availability and cost become important factors in location decisions. The availability of such 'agglomerating' services are a key advantage of incumbents. Conversely, their absence is a barrier for prospective manufacturing nations.
The thesis of this paper is that new technology will play a critical levelling role with respect to both the threshold and the agglomeration services. This factor will tend to broaden the locational choices of manufacturers.

[24] See, for example, Low (2013).

How firms decide where to manufacture

Business decisions determine the shape of manufacturing supply networks. To unlock the 'black box' of firm decisions, industrialising nations have to master two perspectives. The first is to understand that the manufacturer is a risk-averse risk-taker. The second is clarity about the relocation trade-off the manufacturer makes when deciding where to produce.

The manufacturer as risk-averse risk-taker

A manufacturer locating production in another country: invests in the sunk costs and fixed capital of the production facility; employs staff; contracts with suppliers for critical services; shares intellectual property (IP); and trades across borders. Baldwin (2013) refers to these activities as "the trade-investment-services-IP nexus".

Each of these activities creates commercial risk for the manufacturer. Managing these risks requires legal and policy safeguards. In these matters, the host country's commitments must be unwavering. Over the last two decades, a package of commitments consistent with the interests of both manufacturer and host country has crystallised. We call this the **baseline legal-institutional package.**

- With respect to trade, the key insight is that, in cross-border manufacturing with its flow of inputs and intermediate products, a tax on imports is a tax on exports. Therefore the country needs to commit to predictable and low trade barriers. This is most credible in the context of a regional trade agreement or WTO commitment.
- With respect to investment, manufacturers require the safeguards, *inter alia* against expropriation, contained in bilateral investment treaties.
- With respect to intellectual property, manufacturers and their customers need reassurance that their IP will be respected.
- Finally, as the manufacturer will be contracting with local firms for a multitude of services, contracts need to be enforceable.

This four-part set of legal and policy assurances makes up the baseline legal-institutional package.

The relocation trade-off

The baseline legal-institutional package is important, but does not guarantee that firms will in-locate. That depends on the relocation trade-off – that is, the decision rule for a manufacturer when considering relocating a production stage. It stands to reason that:

- A firm will relocate if the locational benefits exceed the costs of relocation.

The **costs of relocation** are costs incurred by separating a production stage and running it in another country.[25] Such relocation and fragmentation costs have three main drivers:

[25] A small adjustment enables the same framework to be used where the manufacturer is deciding whether to relocate an already separated stage. Then the six factors are assessed in relative terms between the two contending locations.

- **Transportation and trade:** country-specific logistics costs, the cost of transporting the product between countries, and tariffs;
- **Co-ordination of the production process:** these costs are driven by complexity and ICT capacity and cost;
- **Knowledge transfer and oversight:** these require costly management time and face-to-face communication.

The one-off costs of locating to a new country should also be taken into account. These are experienced as particularly high if the firm is a sector pioneer in that country.

The **locational benefits** are the savings and advantages accruing from the plant relocation and also have three main components:

- **Factor costs:** Labour cost savings are the archetypal reason for shifting production to a low-income country;
- **Benefits internal to the firm:** A firm generates gains from specialisation and scale when it locates all its activities pertaining to a particular stage in one place. This may be further enhanced if the stage is outsourced to a firm that manufactures the particular component for a number of customers;
- **Benefits 'around the firm', or agglomeration effects:** Some benefits accrue from having a number of firms in one location and – importantly – intensify as the number of firms increases. The classic agglomeration drivers are specialised skills, specialised inputs and 'knowledge spill-overs' – or learning – between firms in a similar industry. While not all agglomeration drivers are services, a significant proportion are.

This simple framework explains the rise of cross-border manufacturing after the 1990s. As related above, trade tariffs were dismantled and transport costs reduced relative to value. Further, vastly better communications and information processing enabled cost-effective co-ordination between different stages of production. It was now feasible to split production costs into finer stages to access locational advantages.

The trade-off teaches us that GVC growth will not be inexorable: GVC growth depends on a shift in the balance of factors and can under certain circumstances reverse – for example a significant increase in trade barriers.

It is important to consider *when* manufacturers make relocation choices. Given the large sunk costs of relocating in most industries, manufacturers do not reconsider factory location on a continuous basis. They do so only occasionally – when production is expanding or they are considering installing a new generation of production equipment. For this reason new GVC activity is the most dynamic when trade in the relevant sector is growing and investment spending is high. More generally, new GVC activity is associated with growth in overall trade: international trade is highly geared to investment expenditure, particularly the categories in which cross-border value chains are prevalent, such as machinery and transportation equipment.[26]

[26] Freund (2016). The plateauing of production fragmentation during 2011-2016 occurred during a period of weaker overall demand growth, a change in the composition of imports and subdued investment spending in most countries. IMF (2016).

The relocation trade-off and where manufacturing happens

The relocation trade-off explains why many countries with low factor costs and the baseline legal-institutional package have still not broken into manufacturing for export. Sometimes poor **country-specific logistics** have been a disqualifier: the physical route from factory to quay-side or airport tarmac was too long and uncertain, customs delays were prohibitive, stevedoring and despatch were poor, or the number of effective on-connections too few.[27] These problems can be solved by a combination of determined government action, market participation and information-intensive services.

A more stubborn barrier to participation is created by **agglomeration effects**.[28] One example is a supply industry providing services and physical inputs customised for a particular type of manufacturing; another is a labour pool with the codified and tacit skills specialist to that type of manufacturing. Manufacturers require these specialist inputs and skills to function; and they strongly prefer those markets to be 'thick' – that is, to have many suppliers.

Thick supply and skills markets have many benefits for a manufacturer. They protect the manufacturer against the exercise of market power by a supplier, offer the dynamic gains from rivalry and provide the reassurance of having multiple potential suppliers. For markets to be thick on the supply side, they need to be thick on the demand side, with many firms demanding much of what they offer. Another example of proximity benefit works in a similar way: the transmission of practical knowledge as people and ideas move between manufacturers in the same industry.

These agglomeration forces explain why, counter-intuitively, we often find factories that produce similar products clustering together – whether in a town in northern Italy or in the industrial estates of Bangkok. These forces have played a powerful role in factory location since the start of the Industrial Revolution.

What agglomeration forces have in common is that the more factories of a certain type cluster together, the stronger the benefits. This creates a considerable barrier for manufacturing entrants: if they do not have the benefits of agglomeration forces to start with, how do they ever attract enough manufacturers to develop it? This 'chicken-and-egg' dilemma was memorably identified by Paul Collier in his book *The Bottom Billion*. Written during the rise of China as a manufacturing powerhouse, he pointed out that countries with no manufacturing, and hence no agglomeration benefits, but low labour costs, would find it difficult to compete with a China-type incumbent with both low labour costs and mature agglomeration benefits.

Much has changed since 2007, when *The Bottom Billion* was published. For one, real manufacturing wages in China have more than doubled. Further, we have seen the Chinese manufacturing model evolve to rely heavily on offshore manufacturing. Still, the agglomeration deficit identified by Collier remains a signal disadvantage for most developing countries. But a more profound change is in the making.

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[27] And the reverse for the importation of inputs.

[28] Long studied by urban economists, these forces have been recognised as an important factor in the shape of international trade since the ground-breaking work of Krugman and Venables in the 1990s.

How technology is removing barriers to manufacturing entry

New tech-driven business models are changing the relocation trade-off. Holding automation constant, these changes generally increase the feasibility of relocating manufacturing to developing country entrants. The main areas of impact are:

- The globalisation of agglomeration benefits;
- Internationalising commercial services;
- Catch-up opportunities in country-specific logistics.

Technology is critical to all these trends. New business models relying on zero-marginal cost connectivity will reduce the forces currently favouring incumbency and regional concentration.

Another change should be noted. As devices become more valuable and smaller, and a larger proportion of domestic spend is on such devices, transportation costs keep falling as a proportion of the value of exported goods. Although not explored in this paper, this trend may also shift the relocation trade-off.

The globalisation of agglomeration benefits

In future, specialised inputs and skills, as well as learning opportunities, will be transmitted throughout global networks rather than within particular locations. In other words, many agglomeration benefits will become globally available.

Specialised inputs and skills in manufacturing are major drivers of production uptime, process consistency, and cost and quality outcomes. Hence the rush to digitise and internationalise skills and inputs which have until now mostly been locally provided. Various actors are contributing to this trend: large manufacturers seeking consistency and productivity gains; original equipment manufacturer (OEM)[29] suppliers of production machinery seeking to reduce the total cost of ownership of their machinery; and first-tier service providers seeking to provide global operational coverage to their manufacturing clients.

Machinery maintenance is one such specialised input. Apart from being a direct cost, maintenance is the main determinant of availability/uptime in manufacturing. It is also the archetypal 'proximity' service: expertise needs to be applied on the shop floor. Therefore factories employ specialist mechanics and technologists or rely on local maintenance firms with the right capabilities. For complex interventions, the supplier of the equipment flies out experts from home office to the site of breakdown. This is a costly approach: it is commonly 24 hours before the problem is fixed and production can resume. Moreover, as a rule of thumb 50% of the time of these expensive specialists is spent travelling rather than working.

These factors create a strong preference for building plants in established manufacturing locations. However, new technology and business models are reinventing how machinery is maintained.

[29] OEMs such as Siemens and ABB.

Remote diagnostics uses data obtained from built-in sensors and transmitted to a global service capability to remotely analyse machinery performance. This allows for early identification of underperformance and more accurate fault diagnostics. This data-rich approach enables maintenance to be performed in an entirely new way. Traditionally, maintenance is done on a schedule, driven either by a calendar or usage milestones. Remote diagnostics allows for maintenance to be triggered by the condition of the machinery rather than by a pre-planned schedule, an approach known as condition-based maintenance, or CBM. It also allows for a complementary approach known as predictive maintenance, or PDM, which anticipates mechanical failure and triggers preventative action. These innovations result in material efficiency improvements.

Tele-maintenance, which goes one step further, is the "restoration of a failure or degraded state of a remote system without the need to physically access the remote location."[30] Direct maintenance and repair is handled by a specialist engineer based at head office or, increasingly, in a call centre in a country like India. The remote specialist directly executes device control and software repairs. Where physical adjustments or replacements are required, the specialist works with a general maintenance person on the factory floor. Here, too, technology is transformative. A simple video camera on the maintenance person's safety glasses enables the specialist to 'see' exactly what the maintenance person is seeing, allowing him to guide the maintenance person to the solution. In a more advanced approach, the maintenance person could be equipped with augmented reality spectacles that impose a video image onto the machine being fixed. For example, this would allow either the remote specialist or a pre-prepared electronic tutorial to guide the maintenance person in 3-D to replace a part.[31] With this approach the remotely located specialist imparts both codified and tacit knowledge to the on-site maintenance person: this is notable because tacit knowledge is often considered difficult to transmit in the absence of on-site presence.

The new technologies are spawning **new business models**. SKF Remote Diagnostic Services is one of a number of global industrial companies that offer advanced maintenance systems through a cloud-based service to any manufacturer with internet access – at a fraction of the cost of a manufacturer developing it on its own. Similar services could be provided in future through a maintenance contract explicitly guaranteeing the total cost of ownership of the asset, including technician time and consumables. The reach is extraordinary. Siemens Remote Diagnostics Service has more than 670 units in power generation and mechanical drive applications across the globe in its network. This allows service providers to compile extensive cross-sectoral performance data sets from which improved operating and maintenance approaches can be derived.

Savings and reduced downtime have driven these changes. The impact on the shape of GVCs is unintended but profound. In particular, sensitivity to distance is reduced by eliminating an important category of site visits.

Many in-factory services can be provided or augmented long distance. Examples are supply chain management, warehouse planning, inventory management, production scheduling and quality

[30] Sanchez et al (2011).

[31] For example, Augmented Reality Training Demonstration by Scope AR using the Epson Moverio BT-100 at https://www.youtube.com/watch?v=eVV5tUmky6c

assurance. New technologies and new business models are co-evolving on an ongoing basis, usually motivated by the commonplace business imperatives listed above. The likely outcome is a gradual and inexorable reduction in the agglomeration deficit.

Globally networked services also reduce the role of proximity in knowledge spillovers. In the past, knowledge would 'spill over' when a foreman moved from a better-performing factory to a struggling one. Increasingly, though, learning does not require proximity. Consider the maintenance networks described above. Once the factory is part of a dense data and knowledge-sharing network with similar facilities around the globe, it will have less need to learn from the factory next door. One knowledge network would be exchanged for another.

Internationalising commercial services

As cross-border manufacturing boomed, so did the commercial services that stitch these value chains together. Of all commercial services delivered in the world, the proportion dedicated to trade has doubled since the early 1990s. Strikingly, commercial services are now a bigger cost item than transportation in global exports.[32]

The bulk of commercial services for trade is still produced within national economies. To see how this might change, consider the evolution of the business process outsourcing (BPO) sector. Currently, the BPO sector, with sales of $24.6 billion in 2017[33], accounts for less than one percent of the global commercial services sector.[34] But the changes that powered the rise of BPO are set to drive cross-border provision of hitherto nationally provided commercial services.

Generic commercial services are as a rule digitisable and hence could be managed and housed offshore. In this category fall services such as standard contracting, vendor management, inventory administration, logistics arrangements, trade finance, personnel administration, book-keeping. The BPO sector has thrived by adding sophistication to these service lines. For example, in its accounting offering, the outsourcer HCL Technologies includes embedded analytics and compliance services.

Commercial services for manufacturers. BPO providers also offer services tailored for manufacturers. These include specialised sourcing and procurement, compliance management and manufacturing operations support. Services under the rubric of manufacturing operations support include master production scheduling, material requirement planning, forecasting, product lifecycle management (PLM) and inventory management.

Outsourcing business models are designed for global reach. Tata Consultancy Services helps the train system manufacturer Bombardier Transportation manage 300 sites in more than 60 countries. Tata's rival, WNS, offers a "single global back-office" which provides finance and administration, human resources and procurement services for manufacturing operations based anywhere. The company also provides manufacturers with a comprehensive supply chain management function. By engaging such offshore service, a manufacturer can ensure consistency and integration across all its dispersed operations.

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[32] Including related trade services. Francois et al (2015).

[33] Statista.com. Another $64.3 billion in revenue was earned by the IT outsourcing sector.

[34] This does not take into account the far larger financial sector.

As traded services become the norm, manufacturing will become geographically split from some of its supporting services. Services previously embedded in manufacturing will become more separate, visible and internationally contestable.

By globalising agglomeration benefits, these changes remove an important barrier to the further dispersion of manufacturing operations. But in the long run, there is also a challenge for aspiring manufacturing nations. Related services will no longer automatically follow the manufacturing operation, but will have to be competed for separately. Tradable service competitiveness will become as important as manufacturing competitiveness.

Catch-up opportunities in country-specific logistics

GVCs hold lean inventories across the chain, and yet the system has to be able to fulfil unanticipated demand peaks at short notice. This places a premium on in-country logistics as well as efficiencies in processing imports and exports.

Some of the country-specific issues that drive logistics performance are undeniably 'hard': the physical rail, road and port infrastructure that moves goods. Yet even countries with similar physical infrastructures can have radically different border processing times. Average national processing times per cargo range from six hours to more than a month, caused in part by differences in information and administrative processes. These processes are sufficiently important to impact the volume of trade. The OECD (2013) estimates that every extra day required for the processing of exports and imports reduces a country's trade by 4%.

Table 1 compares the time and cost of import and export procedures of three groups of countries: the four early industrialising Asian Dragons[35]; a group of five component-producing countries that are active in 'Factory Asia'[36]; and the countries of Sub-Saharan Africa – sub-divided into countries on Africa's east coast, those on the west coast, and those that are land-locked.

Table 1: Time and cost of border processes for imports and exports of three groups of countries

	Imports		Exports	
	Time (days)	**Cost**	**Time (days)**	**Cost**
Asian Dragons	**1.2**	**$333**	**0.5**	**$261**
Asian component producers	**5.4**	**$478**	**3.8**	**$403**
Sub-Saharan Africa	**10.0**	**$987**	**7.8**	**$807**
East coast	8.0	$927	5.2	$771
West coast	10.8	$945	8.9	$739
Land-locked	9.7	$1 068	8.3	$919

Source: World Bank Doing Business Database, 2018

[35] Korea, Hong Kong, Singapore and Taiwan.

[36] Thailand, Malaysia, Indonesia, Philippines and Vietnam.

It is evident that the countries already participating in Factory Asia – Thailand, Malaysia, Indonesia, Philippines and Vietnam – have relatively fast and low-cost border procedures for goods. Notably, those performances still lag behind those of the four Asian Dragons.

What is striking is how much catch-up African nations need to do. Border processes in African nations on average take twice as long and are twice as expensive as those in Asian GVC participants. Take a manufacturer considering an African country for an intermediate production stage with imported inputs: it would have to accept an increase of eight days of working capital for every production run as well as a longer response time to demand peaks. That is a devastating liability for a region already somewhat distant from global mass markets.

Even the nations on Africa's east coast are well behind their Indian Ocean counterparts. Africa's manufacturing champion, Ethiopia, still has a considerable handicap: while its export processing is fairly competitive, its time to import is almost ten days longer than that of its Asian competitors and the cost per import consignment triple the Asian GVC norm. GVCs rely on raw and intermediate imports, making barriers to importing as harmful as barriers to exporting – a critical point for Ethiopia when it seeks to diversify its manufacturing into GVCs.

A combination of technology and process re-design can remove these handicaps. The OECD estimates that streamlining customs and port procedures such as documentation processing, inspection and clearance can reduce trade costs by 10%. The most effective measures are single window procedures, pre-arrival processing and advance rulings on goods classification and applicable duties.[37] All these processes are ICT-enabled.

Goods movements can now be precisely tracked by geographic information systems (GIS) and automatic identification systems. Newer technologies such as radio-enabled electronic security seals on shipping containers ensure that supply chains are "connected, secure and efficient".[38]

New business models also offer opportunities. In the last decade, e-commerce platforms have become an important point of origin for cross-border transactions.[39] While e-commerce is particularly important for smaller firms, it offers an appealing possibility for all future trade. For example, a digital signature generated on the e-commerce platform for each transaction could become the common identifier throughout a trade process that connects seamlessly to logistics providers and all customs authorities. In such a world, buttressed by the physical security measures mentioned above, developing countries will be able to sharply reduce import and export times and costs.

[37] OECD (2013). Potential for trade cost protection is proxied by the room for improvement in relative sophisticated OECD countries.

[38] Estevadeordal (2017).

[39] E-commerce is changing the nature of trade itself. Shipments are becoming smaller and more frequent, further magnifying the importance of effective border processes.

Evidence of a radiation of manufacturing opportunities

This paper predicts that as trade costs fall and agglomeration drivers become global rather than local, non-automated manufacturing activities will radiate to more countries. The feasibility of this is demonstrated by the last period of rapid expansion of GVC-intensive trade, between the late 1990s and 2011.

Historically, GVCs formed as networks of value-added trade around a lead country, resulting in strongly regional value chains. However, based on network analysis, Amador and Cabral (2017) concluded that, "over time, as GVCs became more fragmented and sophisticated, value-added networks became denser, more complex and intensely connected. In addition, the hierarchical structure of the networks of foreign value added in exports was somewhat moderated with the entrance of new players and the creation of linkages among them."

In reviewing the evidence, it is useful to distinguish between three ways manufacturing value chains can expand:

- Radiation 1: Expansion of a region to include nearby manufacturing entrants.

Radiation 1 has been observed a number of times since 1990. In East and Southeast Asia, the core group of original manufacturers (Japan and the four Asian Dragons) expanded to include China. Beyond China, regional expansion occurred in three waves: in the early 1990s, Malaysia, Thailand and the Philippines joined regional value chains; in the late 1990s and 2000s, Indonesia and Vietnam; and during the current decade, Cambodia, Lao People's Democratic Republic and Myanmar.[40] Elsewhere, the addition of Costa Rica to 'Factory North America' has been noted. And in Europe, the Czech Republic, Hungary and Slovakia increased participation in regional value chains off a low base.[41] Once connected, countries generally increase their number of inward and outward linkages. Hungary and Slovakia demonstrate that small countries can become competitive in manufacturing by linking to multiple cost-effective intermediate good producers.

Regional-based expansion of this kind demonstrates that agglomeration forces need not be an absolute bar, but that distance may still limit participation in GVCs. To establish whether manufacturing value chains can operate over long distances, we have to consider two other types of radiation:

- Radiation 2: development of value chains that connect two GVC regions.
- Radiation 3: development of value chains that link lead countries with suppliers in countries outside the three main regions.

Evidence on Radiations 2 and 3 was provided by Los, Timmer and De Vries (2015). Using WIOTs, they calculated the growth in the share of FVA in the final products produced in each of the three regions known colloquially as Factory Asia, Factory North America and Factory Europe.

[40] Kimura (2013).

[41] Amador and Cabral (2017).

The authors found that for all three regions value add from outside the region increased dramatically between 1995 and 2008. For products completed in Europe, value added extra-regionally accounted for 17% of the final product value in 2008, an increase of 7.8 percentage points since 1995; for North American Free Trade Agreement (NAFTA), the comparable number is 15.8%, a gain of 6 percentage points; and for East Asia, 17.7%, a gain of 9.5 percentage points. These findings demonstrate that long-distance supply chains are gaining prominence. The European findings are particularly persuasive.[42]

The authors found similar patterns at a country level. For virtually all countries the gain in FVA from sources from outside the home region exceeded the gain in FVA from other countries in the region.[43] This is evidence that proximity became less important.

The authors also found evidence of GVC participation by countries **outside all three regions** – Radiation 3 – in two important sectors: transportation in Germany and electrical machinery in the US.

For transportation equipment (including automotive) completed in Germany, the share of non-German value add (FVA) in overall value increased dramatically by 12,9 percentage points. Most of this increase came from outside the EU and more than a third came from outside the three main regions as defined.

The results for the US electrical machinery sector were equally striking. The study finds that the share of non-US value add increased by 7.1 percentage points, of which three-quarters came from sources outside NAFTA; notably, 42% of the total FVA increase came from countries outside the three established regions.

The elongation of manufacturing value chains reported here occurred during a period that was particularly propitious for GVCs. There is evidence that manufacturing value chains subsequently stabilised or even contracted as global trade growth slowed after 2011.[44] The thesis of this paper is that technological change will create the opportunity for renewed radiation of manufacturing activity in the developing world, provided that global conditions are conducive.

[42] The study could be criticised on two grounds: first, the definition of the Asia region excludes neighbouring countries that would have been part of the 'Factory Asia' GVCs during the period. Therefore, some of the radiation the measure captures would have been of the regional kind (Radiation 1). Luckily, this is not true for the authors' definition of the European region which includes 27 EU members. Hence the emphasis for current purposes on the European results; second, their analysis included certain raw materials, whose price increase could appear in data as an increase in foreign value add. The paper tested for this by excluding all raw materials and found that its overall conclusions still held.

[43] This was true for all countries in the Asian and North American regions, as defined, and for 22 out of the 27 countries in the European region. The study included in the latter all current members of the EU, bar Croatia which was not a member at the time of the research.

[44] See Timmer et al (2016) and Degain et al (2017).

The new world for aspiring manufacturing nations

Technology is changing the game for aspirant manufacturing nations. One aspect, automation, has received much attention. Although the timing and extent of its impact remain deeply uncertain, it is widely assumed that it will be adverse for the manufacturing prospects of developing countries. This paper demonstrates that, by reducing the barriers to participating in GVCs, technology change also holds considerable promise for manufacturing in developing countries. Ultimately these two processes – the one providing access to the factor advantage of poorer nations, and the other undermining that advantage – will play off against one another. A likely outcome over the medium term is a tapestry across sub-sectors and countries in which areas of greater manufacturing opportunity and areas of reduced opportunity are both present.

Global conditions

The positive technology impact explored in this paper will not happen automatically. As the last 25 years have demonstrated, new cross-border manufacturing arrangements evolve and radiate most quickly in a favourable environment. Most conducive is a growing global economy characterised by low and falling trade barriers and ample investment. Therefore, in addition to the national policies summarised below, aspiring industrialising nations have a clear global policy agenda. It is one which runs counter to the protectionist tendencies in some countries.

A to-do list for industrialisers

The GVC pathway requires a mindset diametrically opposed to that of import replacement. Countries need to be open, responsive and efficiency minded, working closely with investing firms and technology providers: in short, a co-evolution mindset joined to a speed imperative. Action is required in four areas:

- The **baseline legal-institutional package** – covering trade policy, investment protection, IP and enforcement of contracts – needs to be in place.
- Equally important are **the quality and competitiveness of communications and information technology** – required for the dynamics set out in this paper.
- Not all services are digitisable: local services such as **in-country physical infrastructure** needs to be competitive.
- All means to bridge the agglomeration deficit should be facilitated. In large part, this means **facilitating the delivery of offshore services.**

A fifth aspect, **building human capital for the manufacturing roles of the future, was not an aspect of this paper,** but is nonetheless critical.

A manufacturing sector increasingly de-linked from its supporting services

Baldwin (2013, 2016) has discussed the 'unbundling' of different aspects of trade. This paper demonstrates what may be the most important 'unbundling' for the foreseeable future: the de-linking of manufacturing from its supporting services as these become digitised and internationalised. In this scenario agglomeration benefits become globally available, as do the key commercial services. This combination of factors will open up manufacturing. But the gains from manufacturing will also fall as services will increasingly be provided from elsewhere. For developing countries this need not be a net loss: countries can become the site for service provision to the global manufacturing sector and beyond. Aspirant manufacturing nations would do well to develop a services strategy as powerful as their manufacturing strategy.

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