Green and Digital: The Twin Transition in GVCs

Roberta Rabellotti (University of Pavia - Italy)

Background paper for UNCTAD 2023 Technology and Innovation Report with Rasmus Lema

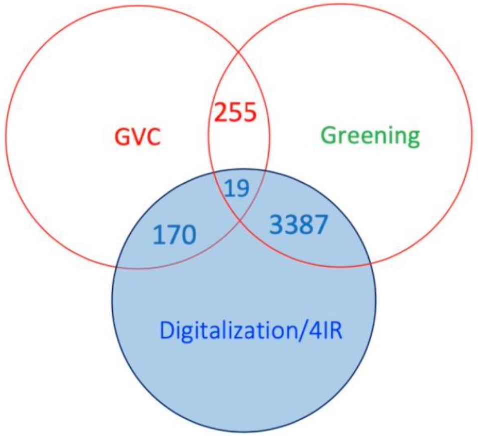
Motivation

- Focus on whether and how the adoption of digital, 4IR technologies can lead to greener manufacturing GVCs in latecomer countries.
- Whereas the general ICTs have become ubiquitous across rich and poor countries, the specific technologies associated with the digital transformation are still concentrated in advanced economies and a few emerging economies, such as China, Brazil and India.
- While it is usual that technological waves start in a restrict group of countries, the current digital transformation is more far-reaching than earlier techno-economic paradigm shifts and therefore it is important for GVC stakeholders in all countries, advanced and emerging ones, to understand the diverse dimensions of the digitalisation of the economic processes as well as its relationships with the greening phenomenon.

Some methodological issues

1. Systematic survey of the literature in Scopus aimed at mapping the key articles on the greening and digitalization in global value chains, identifying potential overlaps of these two separate strands of literature.
2. Focus on latecomer countries and on traditional manufacturing industries, such as agri-food, leather, shoes, textile, apparel, and furniture.

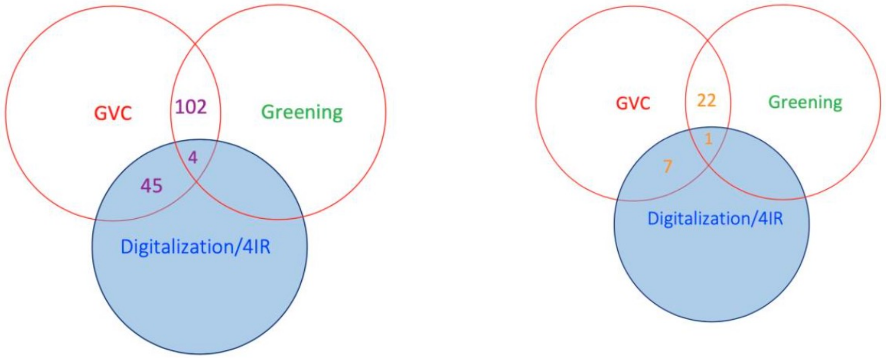
Figure 1. Literature survey: GVC & GREENING & DIGITILIZATION/4IR*



*The list of keywords is available in the Appendix, Table A.1

Figure 2. Literature survey: GVC & GREENING & DIGITILISATION/4IR in latecomer countries and traditional manufacturing industries*

Latecomer Countries | **Latecomer Countries AND Traditional Manufacturing Industries**



*The list of keywords is available in the Appendix, Table A.1

The greening of GVCs

- The greening of GVCs in manufacturing industries is driven by:
  - New patterns of demand preferences and consumer behaviours;
  - New green strategies by lead firms and global buyers;
  - Enforcement of environmental standards and associated patterns of upgrading and downgrading across global supply bases.
- The introduction of sustainability requirements has implications for the entire value chain, including its governance.
- It can open green windows of opportunities for developing country suppliers, but the seizing of these opportunities is not automatic and the failure to do so may leave enterprises worse off than before.

The digitalization of manufacturing GVCs

- The import and adoption of advanced digital technologies is still limited to a small number of emerging economies and the production is limited to an even smaller set of advanced economies plus China.
- A large part of developing countries is completely excluded from the ongoing digital revolution in the manufacturing value chains.
- A lot of heterogeneity also exists within countries at firm level, with only a minority of (larger) companies adopting some I4R technologies, while the majority is still involved only in analog production.
- Even when a minority of firms invests in advance manufacturing technologies, they are unable to establish significant backward and forward linkages within the domestic economy, given the existence of a large digital capability gap between the leading most digitalized companies and their suppliers (Andreoni and Anzolin, 2019).

Opportunities and risks from digitalization in GVCs for latecomer countries

- The digital transformation alters the labour/capital share and influence offshoring decisions because new technology can sometimes reduce the cost of manufacturing in advanced economies while in other situations they can facilitate globalisation of production further.
- Delera et al (2022) find that participation in GVCs is important for learning and acquiring the digital capabilities to integrate these technologies in the manufacturing process. Moreover, in the 5 countries investigated they also show the existence of a productivity premium for firms adopting digital technologies.
- The adoption of IoT and AI could encourage the participation of more SMEs from developing countries in GVCs by bridging distances and reducing costs related to trade, such as tracking of shipments and inventory.
- I4R technologies could favour the decentralization of advanced activities across regional networks of production, increasing the opportunities for peripheral locations of stages such as engineering, design, and software development (i.e. Cloudfactory in Nepal and Kenya).
- Blockchain technologies can improve transparency and traceability along the value chains by reducing information asymmetries, tracking inventories, attributing ownership rights, enabling faster and cost-efficient delivery of goods and enhancing coordination among stakeholders.

The ‘twin transition’ in manufacturing GVCs in developing countries

2 types of environmental upgrading:

- ***Process upgrading***
  - **Upstream inputs** needed for production including substitution of energy-sources, substitution of energy intensive materials or scarce natural resources and substitution of toxic inputs.
  - **Production process** including reduction of waste from the production process, introduction of technology to reduce energy consumption and optimization of the material flow.
- ***Product upgrading***
  - **Product i**ncluding new designs substituting environmentally harmful components, designing recycle products, designing for durability and substitution of environmentally harmful products.
  - **Downstream consumption** including recycling and re-use of waste.

2 types of enabling technologies:

- ***Smart Manufacturing and Service Technologies*** leading to automation and decentralization of tasks: advanced robotics, 3d printing, wireless technologies, and sensors (e.g., Internet of Things - IoT);
- ***Data Processing Technologies*** allowing interconnection and data exchange: big data, blockchain, cloud computing, machine learning and AI.

Environmental upgrading				Smart Manufacturing and Service Technologies	Data Processing Technologies
Type	**Sub-type**	**Indicator**	**Example**		
Process upgrading	**ProcU-1**: Environmental upgrading of the upstream inputs needed for production	Substitution of energy-sources	Sourcing renewable energy		
		Substitution of energy intensive materials or scarce natural resources	Reducing or replacing scarce or energy-intensive materials with eco-friendly alternatives		
		Substitution of toxic inputs	Elimination of sources of pollution such as solvents		
	ProcU-2: Environmental upgrading of the production process	Reduction of waste from the production process	Finding productive uses for formerly unused inputs		
		Introduction of technology to reduce energy consumption	Introduction of machinery or systems that use less electricity or fuel		
		Optimization of the material flow	Introduction of production planning system		
Product upgrading	**ProdU-1**: Environmental upgrading of the product	New designs substituting environmentally harmful components	Introducing eco-friendly parts		
		Designing recycle products	New product architectures for easy disassembly		
		Designing for durability	Longer lasting products and maintenance services		
		Substitution of complete environmentally harmful product	Phasing out of old product and introducing alternative		
	ProdU-2: Environmental upgrading of downstream consumption	Recycling	Partnerships with input providers for deposit arrangements and backfilling		
		Re-use of waste	Using consumed material for a new purpose		

Table 1. Environmental upgrading and digital technologies in manufacturing GVCs (in progress)

Environmental upgrading				**Smart Manufacturing and Service Technologies (e.g., robotics; 3D printing, IoT, Sensors)**	**Data Processing Technologies (e.g., big data, cloud computing; AI, Machine Learning; Blockchain)**
Type	**Sub-type**	**Indicator**	**Example**		
Process upgrading	**ProcU-1**: Environmental upgrading of the upstream inputs needed for production	Substitution of energy-sources	Sourcing renewable energy	• Smart meters for buying and selling electricity to enhance renewable energy uptake • Remote-controlled robotic mobile solar electric generators to increase solar energy collection efficiency and meet the strict environmental standards of organic food production (Despotovic et al., 2017) • PV/wind hybrid power system to increase effective charge time of the batteries, prolong the operating lifetime of the batteries, and decrease the electricity production cost (Ai et al., 2003)	• Big data analytics of energy consumption patterns • AI-enhanced corporate energy systems • Machine learning methods such as SVM, MLP, ANN, regression trees, and random forest for renewable power generation forecasting and decision-making of plant location, size, and configuration (Perera et al., 2014) • CAD-embedded renewable-energy-based system which provides stable output from energy sources, minimizes the dependence of the output upon seasonal changes, and optimizes utilization of different renewable sources of energy available (Stoian et al., 2008)
		Substitution of energy intensive materials or scarce natural resources	Reducing or replacing scarce or energy-intensive materials with eco-friendly alternatives	• Internet of materials for access to raw material information and obtain material certificates. • Control systems for end-to-end tracking of the material flow (using sensors and data analytics), to improving secondary raw materials • Blockchain-powered platforms for peer-to-peer trading in environmental commodities • 3D printing-enabled materials parsimony • Carbon nanomaterials, primarily graphene, nanotubes and fullerenes, for substituting scarce metals such as antimony in flame retardants, Beryllium and silver in electronics, chromium in stainless steel, etc. (Arvidsson and Sandén, 2017)	• Supply chain mapping augmented for blockchain tracking for better product traceability for responsible sourcing of raw materials • Cement-related sciences supported by computationally enabled design and understanding across many length scales, e.g. understanding and tuning the behavior of hybrid and nanostructured cementitious materials as substitutes of traditional energy-intensive materials (Biernacki et al., 2017; Rafiee et al., 2013; Sakhavand et al., 2013)
		Substitution of toxic inputs	Elimination of sources of pollution such as solvents	• High-throughput robot-based system performing automated polymer, namely, the synthesis of organic nanoparticles (NPs) in eco-friendly solvents, reducing or replacing the commonly used environmental	• Block-chain systems to increase efficiency and transparency between producers of raw materials and intermediary goods • Big data-supported cleaner production as a specific tool of green supply chain management to decrease the use of toxic

Product upgrading	**ProdU-1**: Environmental upgrading of the product	New designs substituting environmentally harmful components	Introducing eco-friendly parts	• Biodegradable all-cellulose energy harvesting triboelectric nanogenerators to power commercial electronics and functionalize as a wearable sewing interface to control an electronic piano (Zhang et al., 2021)	• Cloud computing utilizing virtualization to encapsulate collaborative design and manufacturing resources as services, thereby allowing for resource sharing • Machine learning methods incl. artificial neural networks, support vector machines, as substitutes for the traditional trial mixture method that generates waste and wastes raw materials, to predict the critical characteristics of concrete (Naseri et al., 2020; Ni and Wang, 2000; Yu et al., 2018; Mirzahosseini et al., 2019)
		Designing recycle products	New product architectures for easy disassembly	• Computer aided design (CAD) to assist in the creation, manipulation, analysis, or optimization of a design • Cooperative control techniques in an automatic disassembly system to reduce the total disassembling time, taking care of the environment, reusing and recycling materials (Torres et al., 2009) • Vision-based cognitive robotic disassembly automotive cell that is flexible and robust to the physical variations of a product, capable of dealing with any model of product regardless of the level of detail in the supplied information (Vongbunyong et al., 2013) • Advanced-Remanufacturing-To-Order-Disassembly-To-Order (ARTODTO) system, which uses IoT viz. sensors and RFID tags embedded end-of-life products to evaluate different designs of a product for the ease of disassembly and remanufacturing (Joshi and Gupta, 2019)	• Cloud-based design manufacturing platforms to aid the design for disassembly, and provide disassembly guidelines and components recycle classification, where designers can select design guidelines and customize a unique product to meet their specific requirements (Huang et al., 2017)
		Designing for durability	Longer lasting products and maintenance services	• Predictive maintenance allows to replace only the required part at the required time • 3D printing-enabled circular economy to produce long lasting products by remoulding linear models of resource use where discrete material products have an brief 'end of life' (Cooper, 2016) • Green hydrogen bonded networks composing amylopectin, water and salt, which can heal in 2-3s with high recovery ratio in both mechanical and electrical fields under ambient conditions, improving	• Machine learning to develop the algorithms to save maintenance costs, while extending product life and improving supply chain flows • Machine learning aided durability analyses on reinforced concrete structures (Taffese and Sistonen, 2017; Yu et al., 2019) • Blockchain-based information management enables and facilitates the product deletion relationships within a circular economy, where the phases of product lifecycles are

Challenges for developing countries

- Development of complementary, specific skills, such as analytical skills, including science, technology, engineering and math, ICT related skills and soft skills.
- Lack of financial resources;
- Lack of awareness about the potentialities of digital technologies in terms of increasing sustainability;
- The digital capability gap needs to be addressed to facilitate the positive cascade effect along the supply chain deriving from the adoption of I4R technologies.
- Lack of government support and adequate legislative frameworks towards sustainability;
- Removal of possible infrastructural and institutional bottlenecks, such as electricity and connectivity failures as well as clear rules for data ownership and intellectual property protection regulations.
- Lack of global standards and data sharing protocols.

Concluding remarks

- Still very little is known about the extent to which key enabling digital technologies support the process of environmental upgrading in the Global South firms that are inserted into GVCs.
- This is because these techno-institutional waves are still concentrated geographically and the full extent of the ramifications across the Global South remains to be seen.
- This also means that synergy-creation is challenging. In the Global South the digital and green transitions may not be twins, but merely related through the extended family!

Thanks!

https://robertarabellotti.it