Innovative industrial renewal in industrial ecosystems

Lessons from the Emilia Romagna case

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Outline

- Analytical frameworks matter to visualise opportunities and develop innovative industrial renewal pathways
- Opportunities for diversification and innovative industrial renewal are often nested in the productive structure of industrial ecosystems
- Innovative industrial renewal can follow different sectoral and cross-sectoral pathways (increasingly cross-sectoral given digitalisation)
- Industrial restructuring and industrial policy alignment is critical, especially when innovative industrial renewal requires technology fusion
- Challenges of peripheral regions in the digitalisation era

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The Dynamics of Industrial and Economic Renewal in Mature Economies: Implications for Theory and Policy

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Focus

- **De-industrialisation and dualism** across and within regions in mature industrial economies
- **Innovative industrial renewal and restructuring of regions and countries: how do we think about it? what can we learn from transforming regions?**
- **Re-thinking industrial policies, beyond innovation policies:** addressing the very place-specific organisational and technological dynamics of the new production systems

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Introducton to the Special Issue: Towards a production-centred agenda

Antonio Andreoni, Ha-Joon Chang, Sue Konzelmann and Alan Shipman*

1. Introduction

Over the last two decades, the global industrial landscape has been dramatically reshaped by profound structural and technological transformations. Global and regional production networks have redesigned the sectoral composition of economies as well as the geography of production and international trade. Sectoral boundaries have become increasingly blurred, as a result of processes of outsourcing and industrial re-organisation along multi-tiered supply chains. The migration of production to lower-cost countries, via relocation or outsourcing, has created challenges and opportunities for continuing operations in higher-cost countries, in services as well as manufacturing (Milberg and Winkler, 2013; Gereffi and Lee, 2016; Lee *et al.*, 2017; Merino, 2017). Technological change has also played a critical role in triggering forms of 'genetic mutation' of traditional sectors and their boundaries. For example, in some countries, a traditional sector like agriculture has been transformed in a high-tech sector where vertical farming integrates complex automated feed systems relying on sensors and advanced biotechnologies, while self-driving tractors operate through satellite control systems. Similarly, production processes in traditional heavy industries have been augmented by digital technologies and advanced materials, allowing for virtual product and process development, scaling-up and testing (Andreoni and Chang, 2016).

Emerging technologies and their integration into complex technological systems have led to fundamental shifts in patterns of manufacturing production and consumption; and the widespread application of automation, robotics and digital technologies in advanced manufacturing systems—coupled with new developments in nanotechnologies and biotechnologies—have accelerated the pace of technological change, while increasing systemic inter-dependencies between organisations, industries and regions.

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Special issue contributions

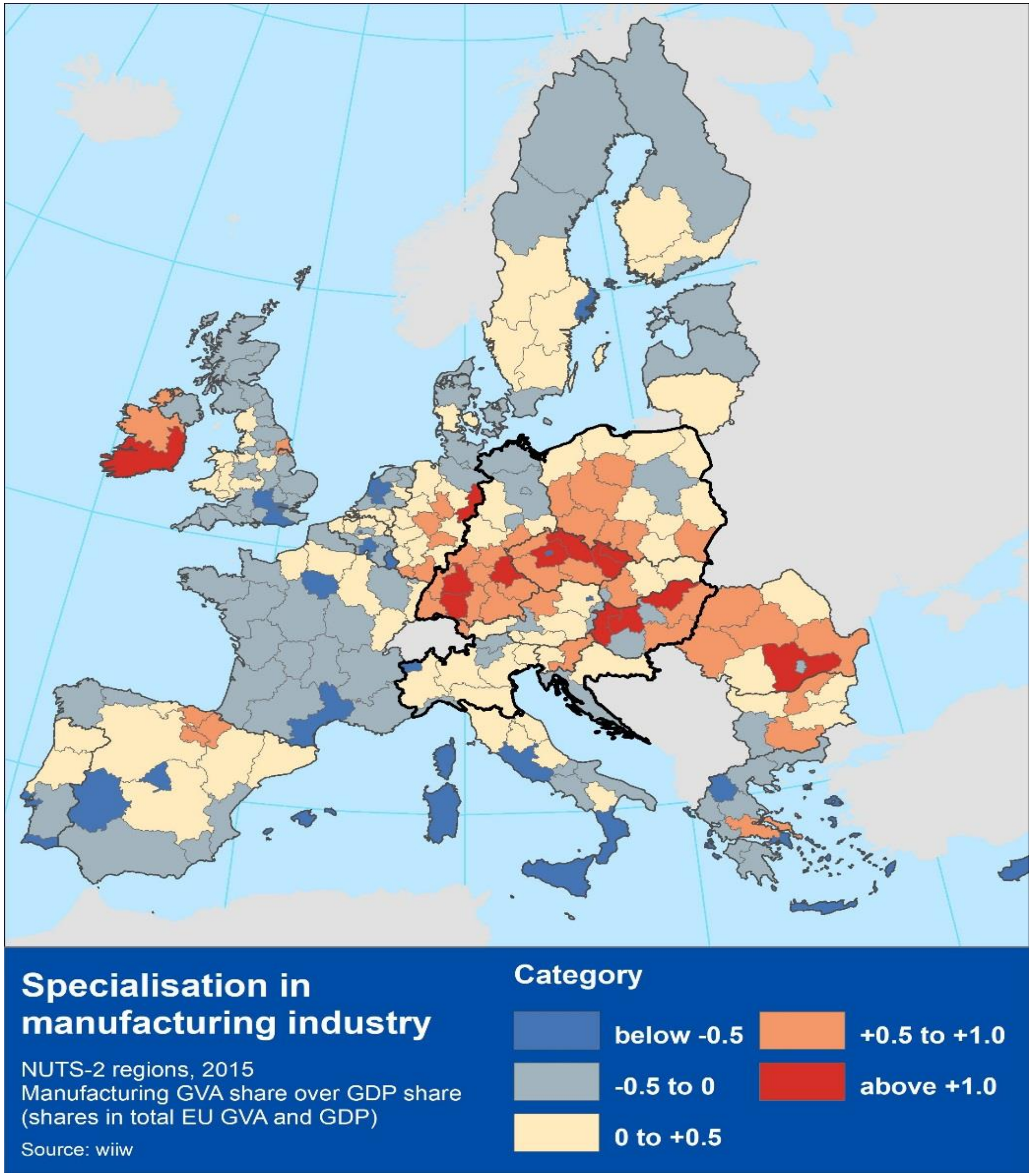
- Theory and practice of **smart specialization** in Europe and how to integrate value creation strategies with value capture strategies (e.g. bottleneck assets) across Europe / US
- **District/agglomeration effects** and the capability/impact on Medium size firms for industrial renewal in Italian districts
- **'home-sourcing'** and the emergence of closer value chains in the Spanish manufacturing industries
- Demand-pull dynamics of renewal though **service outsourcing by foreign manufacturing enterprises** in UK local labour markets
- **industrial ecosystems and diversification dynamics**, the capability-habitat interplay and the variety of possible learning, unlearning and forgetting processes
- management of **technological change** for inclusive growth.

Specialisation in manufacturing (NUTS 2 regions, MVA)

- **emergence of a manufacturing "core" set of regions concentrated around German's southern regions** (Baden-Wurttemberg and Bayern) **and Czech republic**

- **de-industrialisation in certain regions**

- **emergence of fragmented "manufacturing islands"**



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Structural transformations in global manufacturing and technological landscapes .1

- Over the past two decades, profound structural transformations in the **global manufacturing and technology landscapes** have **reshaped** the worlds of production and increasingly challenged established analytical frameworks and policies.

- The **geography of production (ad trade)** has been redesigned along “glo-cal” networks and production cycles involving heterogeneous organisations operating across regional and national boundaries.

- firms have **developed production, technological and market linkages beyond their regional and national systems** (thus making difficult to identify their geographical boundaries), these linkages (especially the technological ones) have involved a limited number of countries, and a few **regional agglomerations within them**

Structural transformations in global manufacturing and technological landscapes .2

- **Sectoral boundaries are also blurring** as a result of global processes of vertical disintegration and industrial reorganization along multi-tiered and modularised supply chains (Milberg and Winkler, 2013; Baldwin, 2016).

- **technological change** and the rapid scaling up and diffusion of emerging technologies, as well as technology system integration within and across sectors, have resulted in the **“genetic mutation” of traditionally defined industrial sectors**

- As a response to these increasingly complex production and technological interdependencies, as well as the need to capture value opportunities in global markets, **firms have experimented new industrial organization models, beyond traditional hierarchical or market forms.**

Systems of innovation literature

- Since the 1980s contributions in **innovation system research and evolutionary economic geography**, as well as others developed at the interface of structural, evolutionary and institutional economics,
- This enormous corpus of research remain largely disconnected, also **concerns have been raised with regard to the capacity of these contributions of fully addressing the types of structural transformations and systemic interdependencies characterizing modern worlds of production.**
- These transformations notably include dramatic changes in platform technologies (digitalization and robotisation), changes in the demand side of innovation (Weber and Truffer, 2017; OECD, 2017), and new industrial organization models characterised by co-opetition, co-adaptive and co-value creation dynamics.

Industrial and innovation system thinking

- The original idea of ***National IS*** (Freeman, 1987; Lundvall, 1992; Nelson, 1993) recognised the role of learning, linkages, interactions among different players (mainly supply side actors) and different institutional settlements, as main drivers of national innovation and competitiveness in developed economies and catching up ones (see the *triple helix* approach in this respect; Carlsson and Stankiewicz, 1991).

- ***Regional IS*** (Cooke et al., 2004) as well as localized learning models (Maskell and Malmberg, 1999) assigned special relevance to the regional scale and, thus, the role of proximity and localised capabilities.

- More recently, the ***Sectoral System of Innovation and Production*** (SSIP) approach (Malerba, 2004; Lee and Malerba, 2017) has stressed the importance of sectoral production systems as well as the role of demand side actors in innovation. Finally, the innovation system framework has been further broadened along the ideas of ***Socio-Technical Systems*** (Geels, 2004) and specified in terms of system functions within the *Technological Innovation Systems* research agenda (Hekkert et al, 2007).

Industrial and innovation system thinking: a critical appraisal

1. the changing geography of production makes more difficult to identify the **“real” boundaries of a national or regional (even a district) system**.

2. sectoral boundaries are constantly redefined by global production chain systems integrating different companies in **complex multi-layered structures**, while the same companies are undergoing forms of “genetic mutation”.

3. Third, understanding technological change in innovation systems today requires a **stronger ‘engineering focus’ on technology platforms**, different types of technologies constituting them, as well as the ways in which challenges in the scaling up of emerging technologies and their commercialisation affect value creation and capture dynamics (Tassey, 2007).

4. Fourth, while IS research tends to focus on relations and networks among heterogeneous actors, the **structure of these networks remain often underexplored, and in some cases there is a tendency to rely on horizontal/flat network representations.**

5. the **political economy** of these systems has remained largely unexplored

Architecture and Dynamics of Industrial Ecosystems

- a **new** stream of research has emerged around various concepts of ecosystems – i.e. **entrepreneurial, business, innovation and industrial ecosystem** > These approaches share the "biological analogy" of co-evolving systems involving a broad range of interdependent supply and demand side actors, co-existing and complementing each other in co-value creation processes.

- Industrial ecosystems as **hierarchic nearly-decomposable systems** involving **heterogeneous agents** operating within **multi-tiered *sectoral value chains*** and contributing to the ***capability domains* of the ecosystem** with closely complementary but dissimilar sets of resources and capabilities.

Industrial Ecosystem and its production space

- These resources and capabilities defines the **production and technological bases** of these organisations and their **areas of specialisation** (Penrose, 1959).

- Thus, the industrial ecosystem is a **structured *production space*** centred mainly on its productive organisations, as well as other public actors, intermediaries and demand-side actors, purposefully involved in ***co-value creation* processes along various *types of diversification* and innovative industrial renewal trajectories.**

- The **geographical boundaries** of the industrial ecosystem are ultimately shaped by the evolving interdependencies linking organisations within the ecosystem and by the new linkages consolidating beyond that.

Outline

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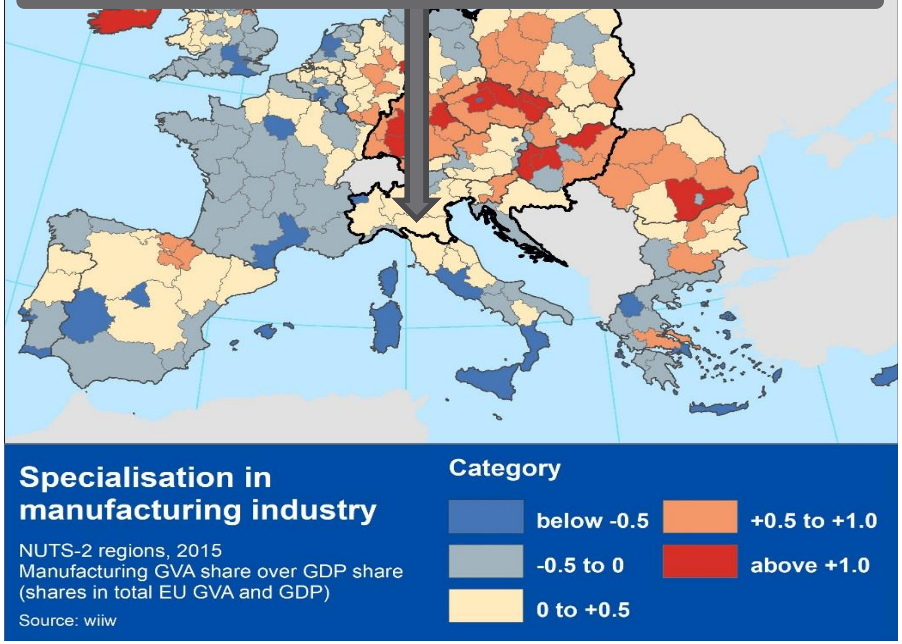
Contrasting regional pathways

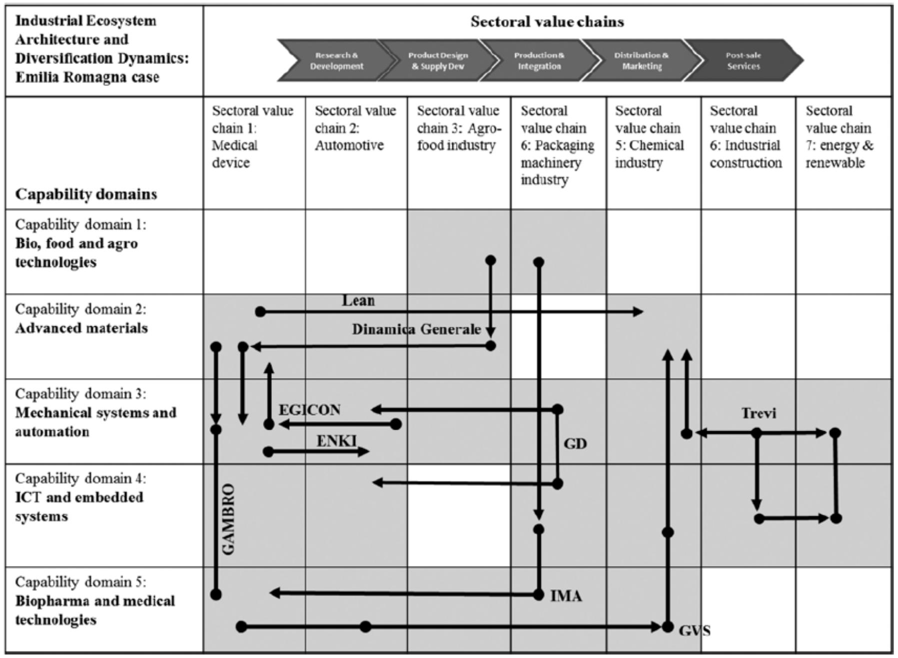
	Emilia Romagna	Piedmont
Population	4.4 million	4.4 million
GDP (2014)	144.14 B€	122.94 B€
GDP variation (2005-2014)	+13.2%	+2.4%
Unemployment (2015)	7.7%	9.2%
Unemployment (2006)	3.4%	4.1%
Firms (2014)	370,259	336,338
Employees	1,518,243	1,331,000
NACE C Firms (2014)	38,742	33,454
Employees	453,089	415,161

Table 2. *Firm population and employment by sectors and firm size in 2015 for the ER region*

Firm size	0–9 units		10–49 units		50–249 units		>250 units		Total	
Industry	Firms	Employees	Firms	Employees	Firms	Employees	Firms	Employees	Firms	employees
Food and beverage	4,094	14,214	794	14,426	118	12,793	22	15,920	5,028	57,353
Textile and apparel	4,562	13,342	782	13,930	78	7,964	13	7,617	5,435	42,853
Wood and paper	2,992	8,418	550	10,155	49	5,191	5	2,079	3,596	25,843
Petroleum	3	13	4	73	2	171	0	0	9	257
Chemicals	272	981	127	2,876	47	4,647	5	2,762	451	11,266
Pharmaceuticals	8	9	10	261	6	628	4	2,810	28	3,708
Rubber and plastics	1,703	5,654	691	14,144	141	14,731	34	19,089	2,569	53,618
Metal	5,425	17,834	1,694	31,595	173	15,422	8	3,204	7,300	68,055
Electronics	487	1,461	171	3,874	35	3,706	6	3,581	699	12,622
Electrical	705	2,265	279	5,507	53	5,505	8	3,623	1,045	16,900
Machinery	2,813	10,221	1,447	28,696	266	28,129	55	35,389	4,581	102,435
Transport equipment	335	1,022	172	3,817	41	4,019	17	11,336	565	20,194
Other	6,678	14,894	689	12,334	61	5,880	8	4,877	7,436	37,985
Total	30,077	90,328	7,410	141,688	1,070	108,786	185	112,287	38,742	453,089

Source: Own elaboration based on official data from ISTAT (2015).





Production Space: A structured space of opportunities and constraints

Industrial Ecosystem Architecture	Sectoral value chains: Research & Development → Product Design & Supply Dev → Production & Integration → Distribution & Marketing → Post-sale Services				
Capability domains	Sectoral value chain 1	Sectoral value chain 2	Sectoral value chain 3	Sectoral value chain …	Sectoral value chain n
Capability domain 1					
Capability domain 2					
Capability domain 3					
Capability domain 4					
Capability domain ...					
Capability domain n					

Architecture and Dynamics of Industrial Ecosystems

- Diversification dynamics, within and across sectoral value chains, in the structured production space of an industrial ecosystem, follow three main patterns:
- (i) **diversification triggered by *similarities***;
- (ii) **diversification triggered by *complementarities***;
- (iii) **diversification triggered by *recombination/integration* across capability domains.**
- **Diversification may lead to innovative industrial renewal dynamics** in mature industrial economies both in the form of the ‘emergence’ of new sectoral value chains, or the ‘transformation’ of the existing ones, for example when firms upgrade towards higher-value product segments.
- The **‘decline’** of an industrial ecosystem can be understood as a “transformation failure”, thus, the incapacity to govern the transition towards new innovative diversification trajectories.

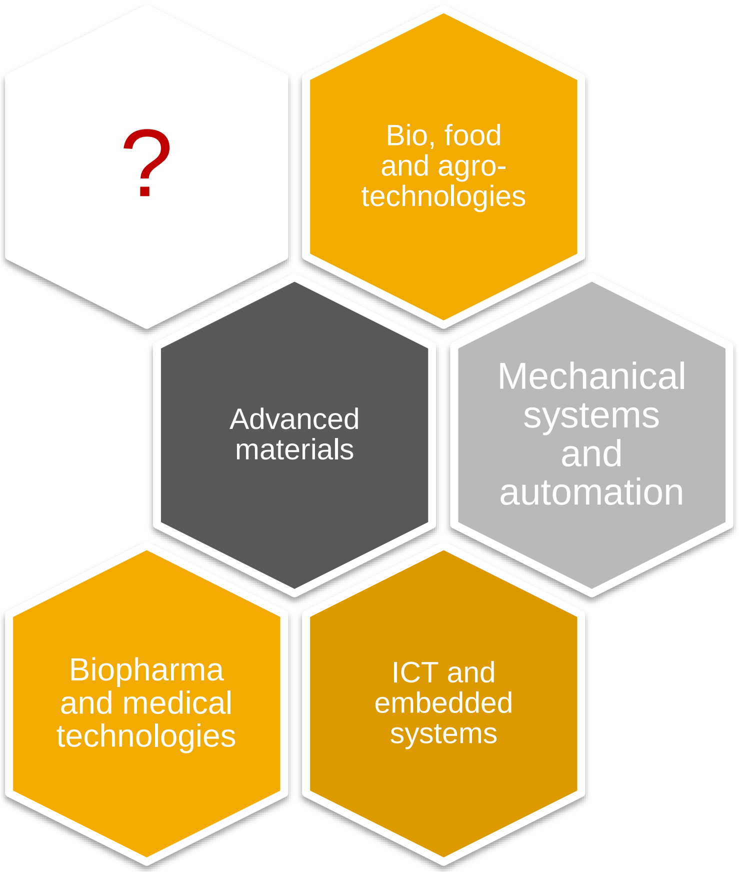
Industrial ecosystem Architecture: Types of Diversification	**Sectoral value chains**				
Capability domains	Sectoral value chain 1	Sectoral value chain 2	Sectoral value chain 3	Sectoral value chain …	Sectoral value chain n
Capability domain 1		Complementarity			
Capability domain 2					Integration recombination
Capability domain 3	Integration recombination	Similarity	Complementarity		
Capability domain 4					
Capability domain ...					
Capability domain n				Similarity	

Table 1. *The capability domains of the ER industrial ecosystem*

Capability domains	Distinctive clusters of resources and capabilities	Cross-sectoral value chains applications
Bio, food and agro-technologies	• Characterisation and selection of new raw materials, their quality and safety • Design and validation of equipment and plants for food processing and packaging • Agro-food process and product optimisation • Agro-food biological resource improvement and valorisation • Mechanic and functional augmented food • Improvement of the nutritional characteristics of food • Agro-food-specialised industrial equipment and mechanical plants • Food packaging, including innovative materials for packaging, quality and hygiene, environmental impact of packaging • Advanced plants and technique for food and drug packaging, including active packaging • Molecular traceability and traceability systems • Agro-food-relevant microorganism • Food quality, safety and health, including use of non-destructive analysis methods • Valorisation of typical productions • Assisted improvement platform for the seed industry • Agro food industry by-products and rejects value recovery • Dedicated energy crops and residual biomass in agriculture • Biomass evaluation mapping and modelling for energy uses • Energy conversion systems	• Food and beverage industries • Suppliers of raw materials and semi-finished products • Producers of sensors and packaging materials • Seed industries • Mills • Ingredients and semimanufactures • Fruit and vegetable consortia • Phytosanitary product manufacturer • Packaging • Chemical industry • Rubber and plastic • Pharmaceutical industry • Machines and plants for the food industry • Waste treatment and disposal
Advanced materials	• Material sciences (all material application) • Development and characterisation of new materials • Design, processes, synthesis and characterisation on organic and inorganic and hybrid materials • Advanced materials, design and photonic applications • Advanced functional materials • Structured and/or composite materials for advanced applications • Surface treatments	• Advanced manufacturing • Automatic machinery • Agricultural machinery • Automotive and transport • Electronics • ICT industry • Hydraulics • Industrial mechanics • Mechatronics for industrial and civil use • Machine tools • Packaging • Mechanical components
	• Polymers and injection moulding technologies • Metallurgy, corrosion and polymeric materials for the environment • Ceramics • High performance, functionally augmented and low-recycling-cost ceramic materials • Recycled materials technology	• Energy and environment
Mechanical systems and automation	• Industrial design for mechanics • Precision engineering • Mechanical design, prototyping and e-testing • NVH (noise, vibration, harshness) • x-tronics, automation, mathematical models • x-tronics, automation, logic models • x-tronics, actuators, control electronics, power electronics • x-tronics, hydraulic actuators • x-tronics, sensors • Automation, robotics and mechatronics: actuators and sensors • Virtual prototyping and experimental modelling of mechanic systems • Tracking and tracing of products and processes • Augmented and virtual reality • Collaborative design validation, digital mock up, virtual prototyping exploration and real-time simulation for the design of new products • Mechanical properties, in particular tribological (fiction and wear), surface and multiscale coatings • Coating engineering for mechanics • Coating engineering at the macro–micro scale • Processing and nanofabrication • Configuration and management of integrated production systems • Industrial applications of materials and innovative technological processes • Machining technologies for the automotive and aeronautical sector • Fluid dynamics • Thermo – fluid dynamic, engines, car and vehicles • Thermo – fluid dynamic, machines and energy conversion systems	• Advanced manufacturing • Automatic machinery • Agricultural machinery • Automotive and transport • Electronics • ICT industry • Hydraulics • Industrial mechanics • Mechatronics for industrial and civil use • Machine tools • Packaging • Mechanical components • Food industry • Civil construction • Industrial construction • Chemical industry • Pharmaceutical industry • Biomedical industry • Logistics and transport • Safety • Defence

Capability domains	Distinctive clusters of resources and capabilities	Cross-sectoral value chains applications
ICT and embedded systems	• Electronic components • Embedded systems • Software engineering and software architecture • Interoperability, protocols and standards • Automation and control • Algorithms, data and signal processing • Mechatronic systems and applications • Robotics • Integration in components and systems • Men-machine interfaces • Computer vision and pattern recognition • Sensor and monitoring/control systems • Information and communication systems and network infrastructure • Knowledge management and semantic-based systems • Cloud computing, mobile and pervasive computing • Internet of things • Bioinformatics	• Advanced manufacturing • Automatic machinery • Agricultural machinery • Automotive and transport • Electronics • ICT industry • Hydraulics • Industrial mechanics • Mechatronics for industrial and civil use • Machine tools • Packaging • Mechanical components • Food industry • Civil construction • Industrial construction • Chemical industry • Pharmaceutical industry • Biomedical industry • Logistics and transport • Multimedia • Pubic Administrations • Safety • Defence
Biopharma and medical technologies	• Biosensors • Medical devices • Drug delivery and quality by design • Drug discovery • E-care • OMICs and bioinformatics for 'OMICs' • Pre-clinic trials • Diagnosis technologies • Development and pre-clinic validation of biological therapeutic agents (antibody drugs) • Personal health technologies • Therapy technology • Advanced therapies • 2D and 3D scaffolds • Regenerative medicine and tissue engineering in orthopaedics • Pharmaceutical innovation • Translational medicine, especially for innovative diagnosis and treatment of degenerative disease of the nervous and cardiopulmonary systems • Industrial applications of genomic and mitochondrial medicine • Biocompatibility, technological innovation and advanced therapies • Computational bioengineering • Nanobiotechnologies • Clinic bioinformatics	• Health services • Pharmaceutical-biotechnological • Biomedical and biomaterials • Nanotechnological • ICT • Cosmetics • Food industry

Source: Own elaboration based on several sources including ASTER sectoral and technology studies, High Technology Network data, and personal interviews with ASTER and companies in the ER ecosystem.



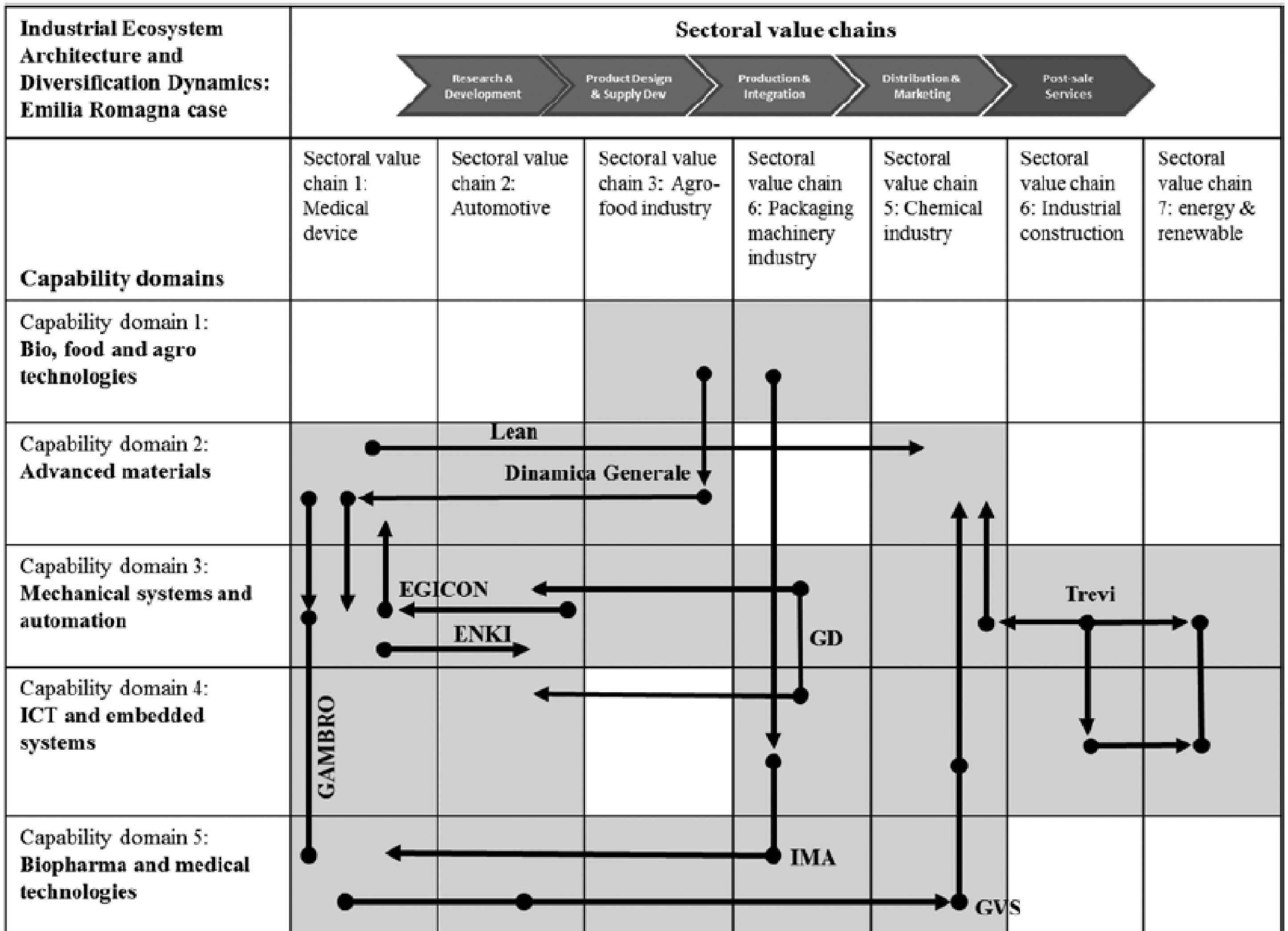


Fig. 4. *The ER production space matrix and diversification dynamics: illustrative company cases*
Source: Author

The population/diversification of the industrial ecosystem

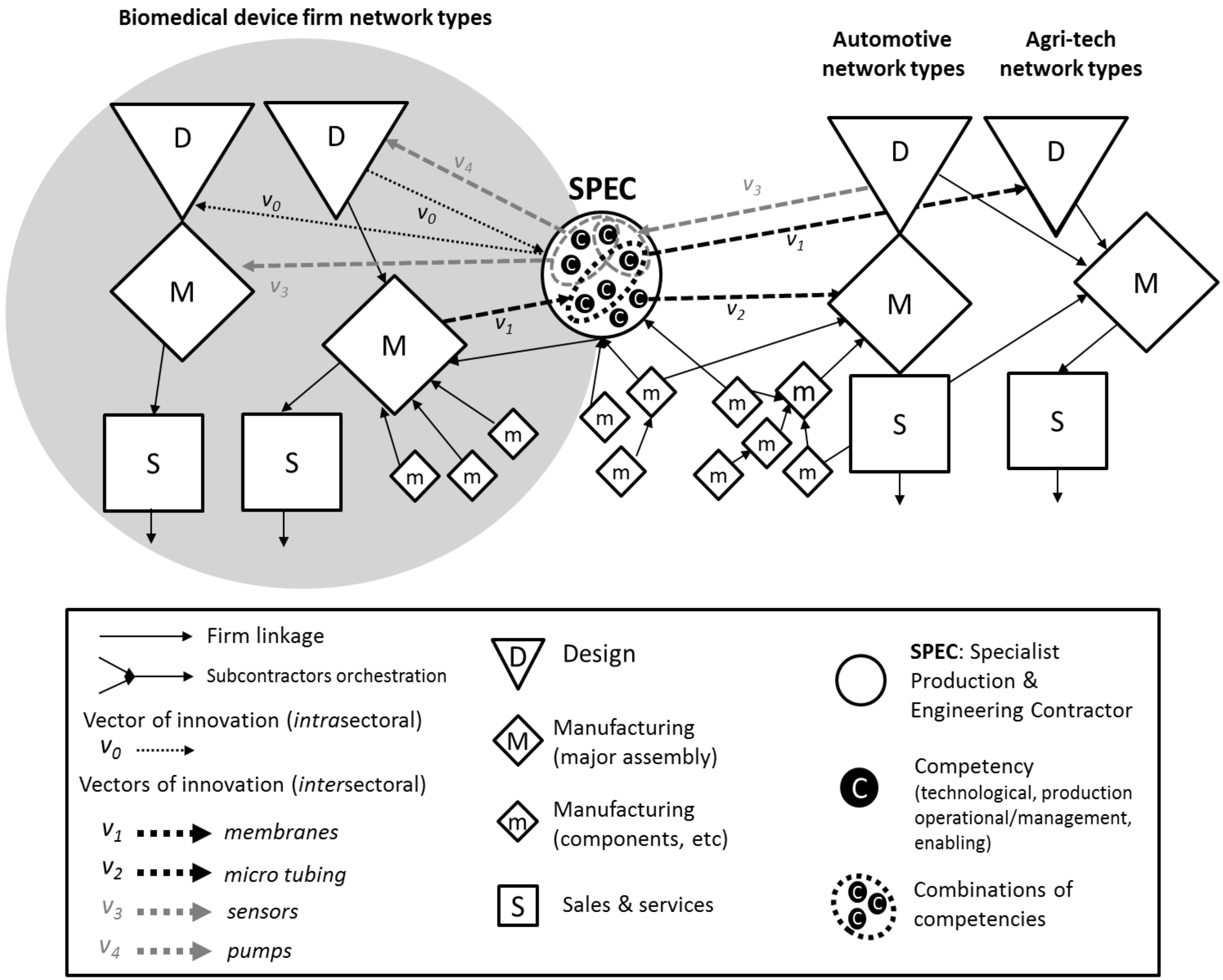
- variety of focal firms operating as system integrators, but also complementors, suppliers and specialist contractors (including knowledge-intensive business services [KIBS]) ‘joining up’ and ‘pollinating’ the industrial ecosystem

- Variety of diversification patters along similarity, complementarity and recombination (also 4IR technology fusion)

- International companies strategies for nurturing the ecosystem:

  - promoting the spin-off and development of specialist contractors

  - Corporate governance restructuring/M&E, long term contracts etc.


Biomedical device firm network types
Automotive network types
Agri-tech network types
SPEC
D
M
S
m
v_0
v_1
v_2
v_3
v_4
Firm linkage
Subcontractors orchestration
Vector of innovation (*intra*sectoral)
v_0
Vectors of innovation (*inter*sectoral)
v_1 *membranes*
v_2 *micro tubing*
v_3 *sensors*
v_4 *pumps*
Design
Manufacturing (major assembly)
Manufacturing (components, etc)
Sales & services
SPEC: Specialist Production & Engineering Contractor
Competency (technological, production operational/management, enabling)
Combinations of competencies

Policy challenges in mature industrial economies

- The policy challenge of **keeping the ecosystem along a trajectory of diversification and innovative industrial renewal** is paramount.
- There are multiple factors which can lead to a **“transformation failure”** in the industrial ecosystem and result in its decline.
- **Decline might be determined by** the presence of structural holes in the production space; failures in developing closely complementary capabilities; failures in catching-up with emerging technologies; extractive governance models which do not support co-value creation processes.
- **New tools for designing diversification strategies which take into account the complex architecture of the industrial ecosystem are needed**

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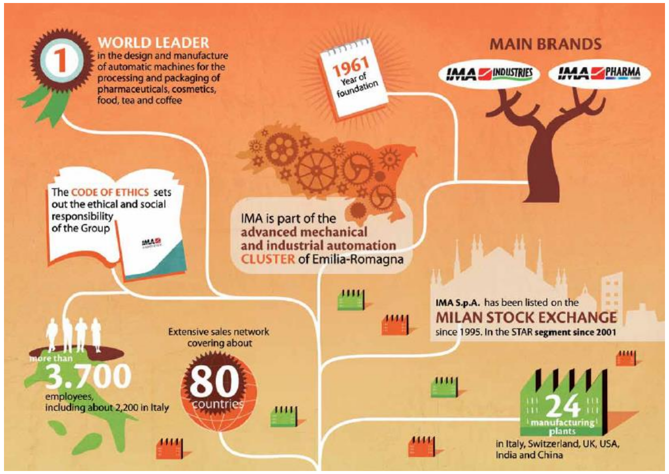
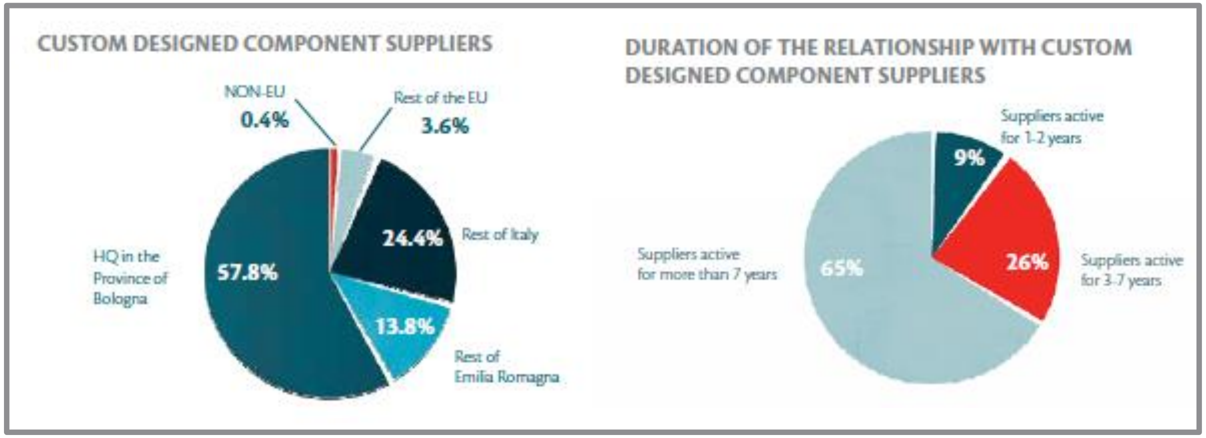
Industry case 1, ER: Packaging machinery (**diversification in higher value product-segments)**

- The world packaging machine industry accounts for a total turnover of over 33 billion dollars and is composed of **four main product segments**: Food, Beverage, Personal Care, and Pharmaceutical packaging.
- Over the past 15 years the industry has grown at a cumulative rate of 15%, with the Pharma value-product segment growing at over 20%. Together with Baden-Württemberg and Hessen in Germany, Emilia Romagna (ER) in Italy is **the regional industrial system with the highest concentration of firms producing automatic packaging machines**
- The **industrial ecosystem of the Emilian packaging valley** is mainly composed by SMEs operating as subcontractors, however four global leaders are also located in this area: IMA, GD, SACMI and Marchesini.

Among them, **IMA** has been the most successful in shifting towards the highest value-product segment of the packaging industry – i.e. Pharma.

The **IMA** case: from Food to Pharma





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24 plants
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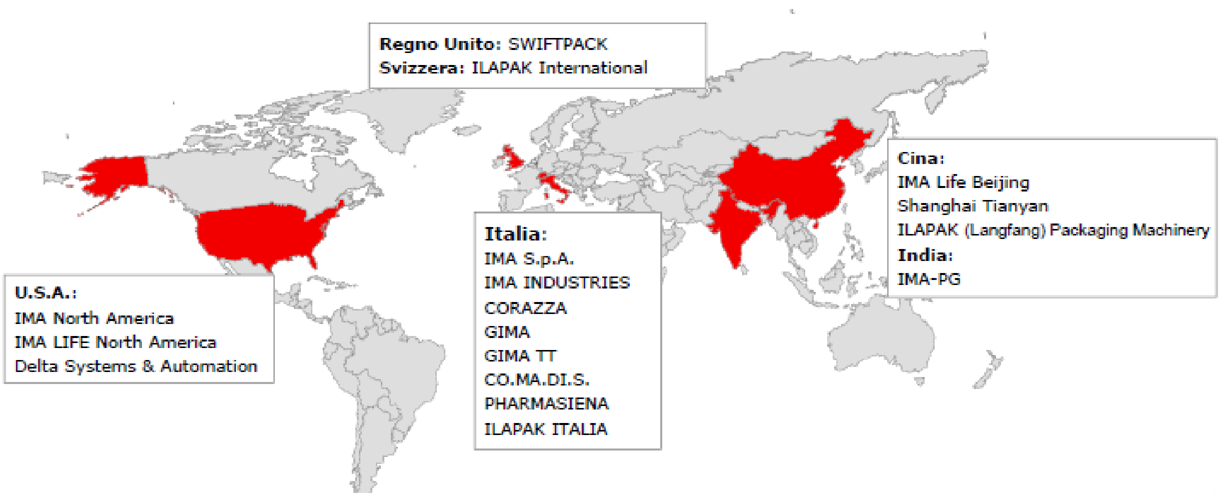

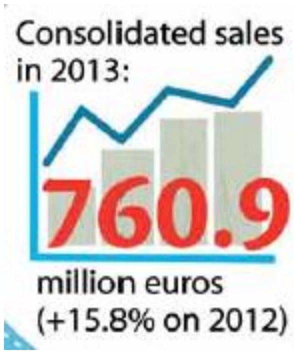

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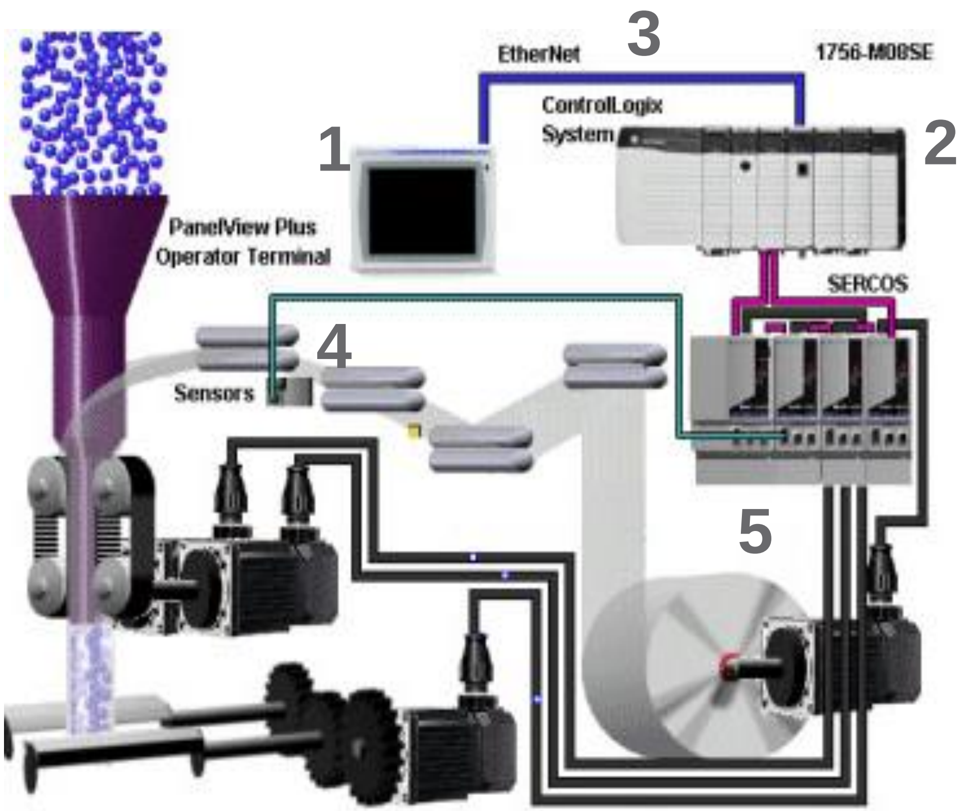
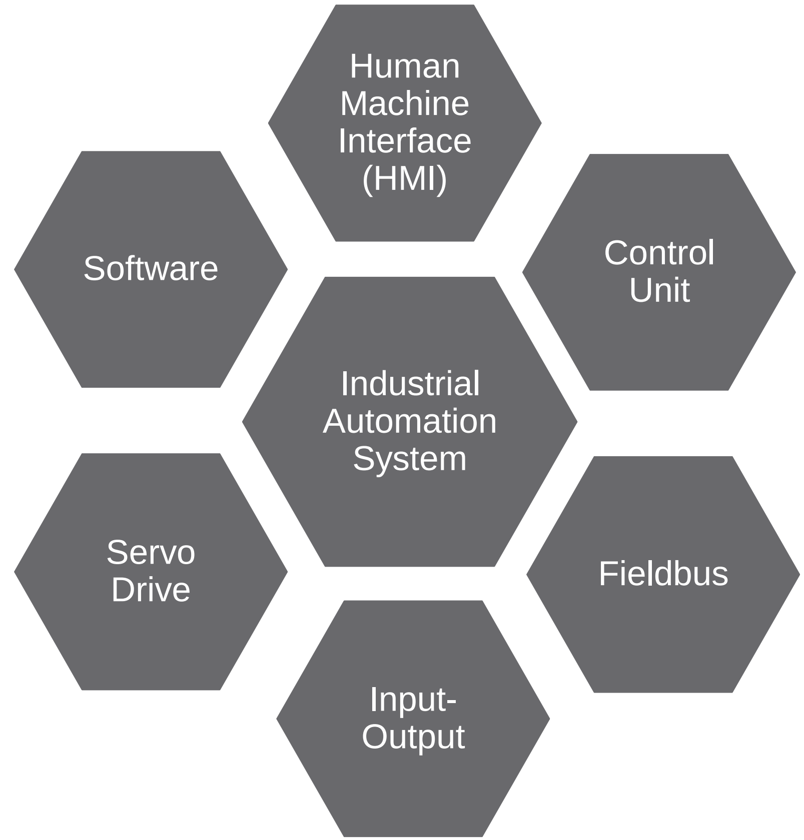
Industry case 1, ER: Packaging machinery (**diversification in higher value product-segments)**

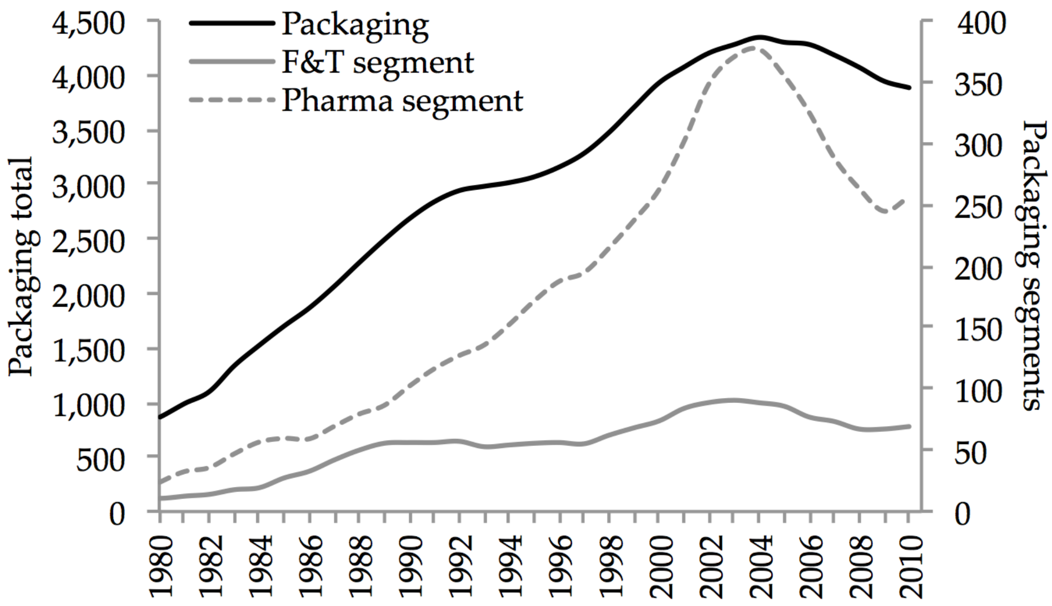




Packaging machines have evolved, over the past two decades, **from an architecture based on mechanical components**, ***into*** a combination of **mechanical transmissions, robotics, interfacing electronics, and control software**. This modularity prompting the need for new production capabilities, pave the way for a **totally integrated mechatronic platforms**.

Industry case 1, ER: Packaging machinery (**diversification in higher value product-segments): Tecnology cycle**

- strong technology dynamism reaching two peaks in 1992 and 2004

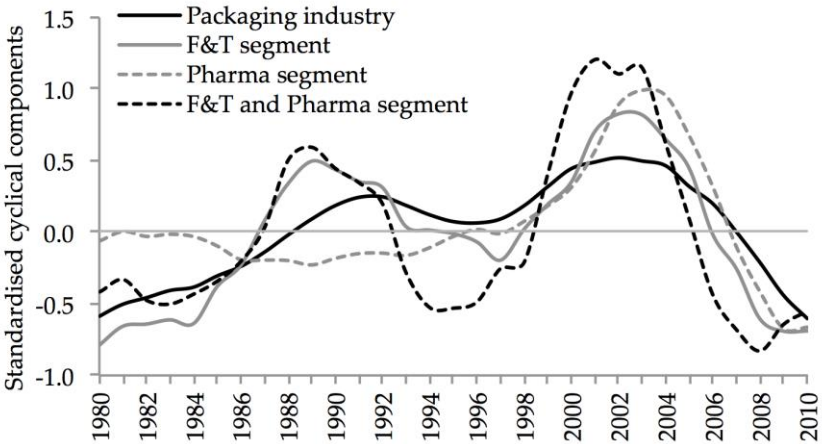


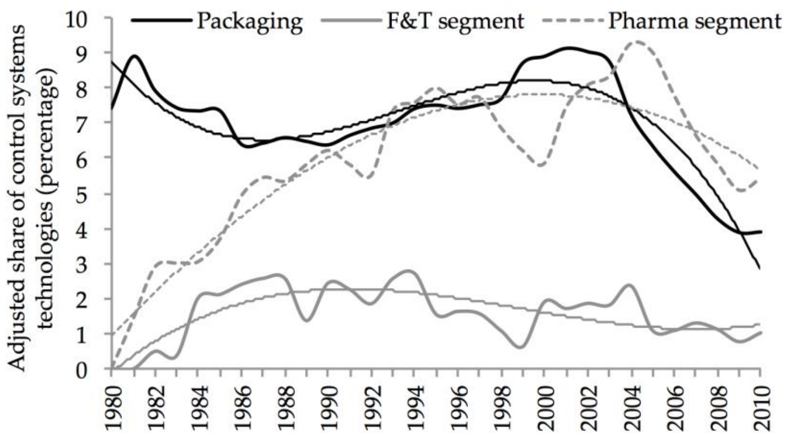
the F&T segment
- **reached a stage of technology maturity starting from the late 1980s**,
- its most substantial expansionary cycle (1998-2004) was correlated with the strong **technological acceleration in the Pharma segment** starting from 1998.

- at product segment level, we observe **two very different patterns for F&T and Pharma**. Technology applications in the F&T segment remain fundamentally stable over the entire period, with on average 60 patents applications per year. E

Industry case 1, ER: Packaging machinery (**diversification in higher value product-segments): technology transition**

- we can identify the **technology cycles for each product segments** (by extracting the standardised cyclical components of the patents applications patterns and removing the segment specific trends
- we track the transition **from mechanics to mechatronics** (adoption and integration in packaging machines of automatic control systems based on electronics, information and communication technologies): this **technology transition opened higher value-product segment opportunities** resulting from the increasing operational speed and configuration flexibility of the packaging machines, the full traceability of the packaged products and the possibility of integrating and standardising entire packaging production lines



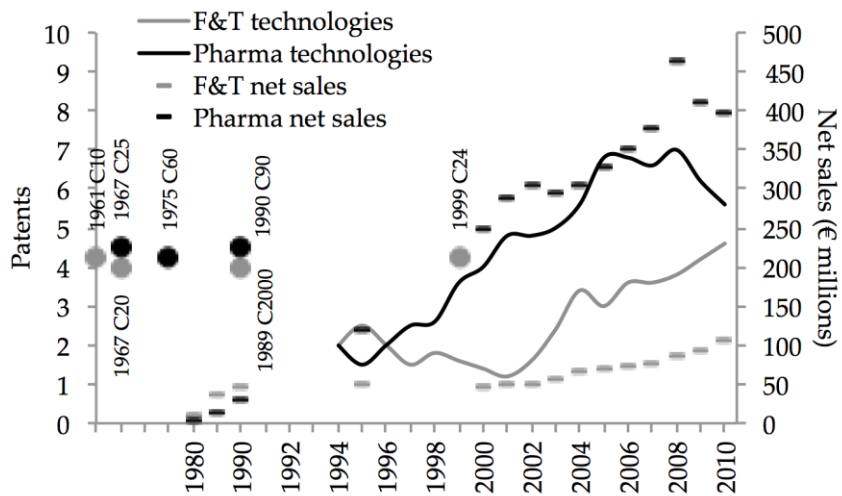


Industry case 1, ER: Packaging machinery (**diversification in higher value product-segments): Technology transition and organisational reconfiguration**

- What IMA did to diversify into higher-value product segments?

Technological transition

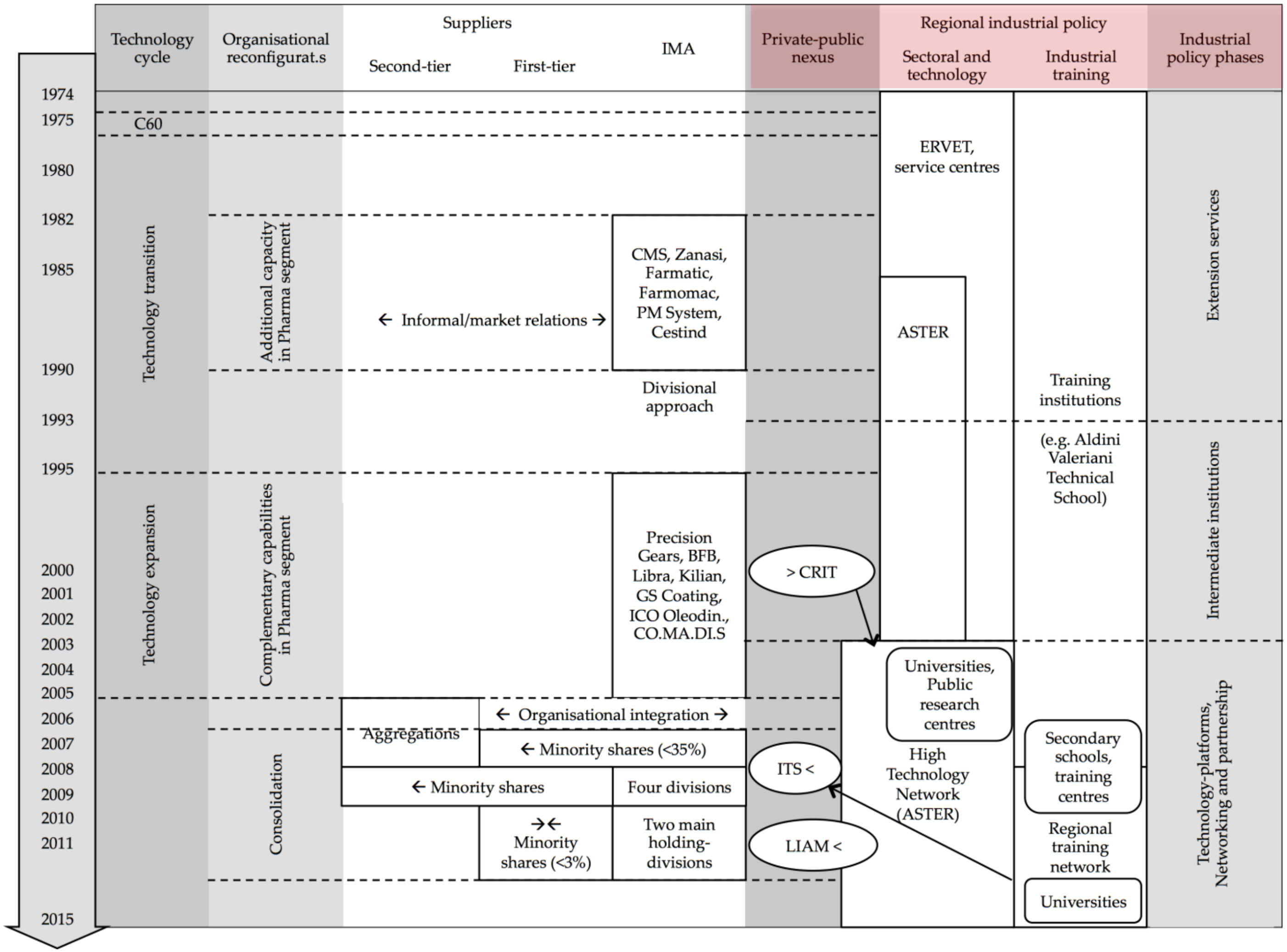
IMA is today's the world leader in the production of packaging machines and integrated packaging lines for the Pharma segment with a world market share of 16%



Organisational reconfiguration: internal structure and its strategic relationships with the ER regional production system

- Internationalisation, in two stages
- Acquisition of complementary capabilities
- Organisational integration and consolidation of local suppliers

Industry case 1, ER: Packaging machinery (**diversification in higher value product-segments)**



The role of the Public Sector:
-3 phases
-2 axes

Key lessons:

•Continuous policy/institutional re-alignment

•Multi-level interventions (IMA, first, second tier suppliers) **for industrial ecosystem development**

High Technology Network – ASTER
Technology platform based PTIs

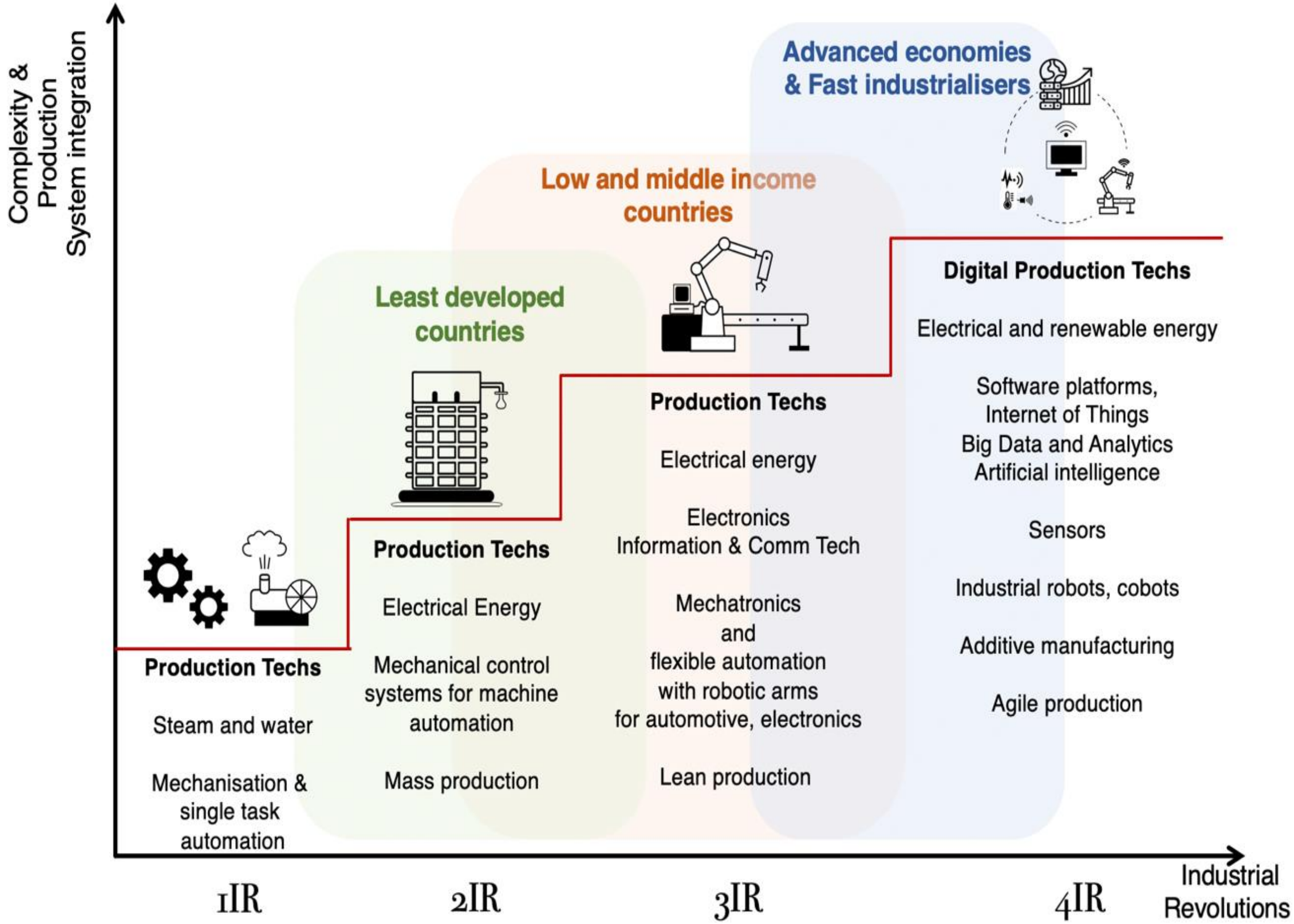
Outline

- Analytical frameworks matter to visualise opportunities and develop innovative industrial renewal pathways
- Opportunities for diversification and innovative industrial renewal are often nested in the productive structure of industrial ecosystems
- Innovative industrial renewal can follow different sectoral and cross-sectoral pathways (increasingly cross-sectoral given digitalisation)
- Industrial restructuring and industrial policy alignment is critical, especially when innovative industrial renewal requires technology fusion
- **Challenges of peripheral regions in the digitalisation era**

Source: Author, see IDR 2020

Digitalisation

Evolutionary transition or evolutionary disruption?



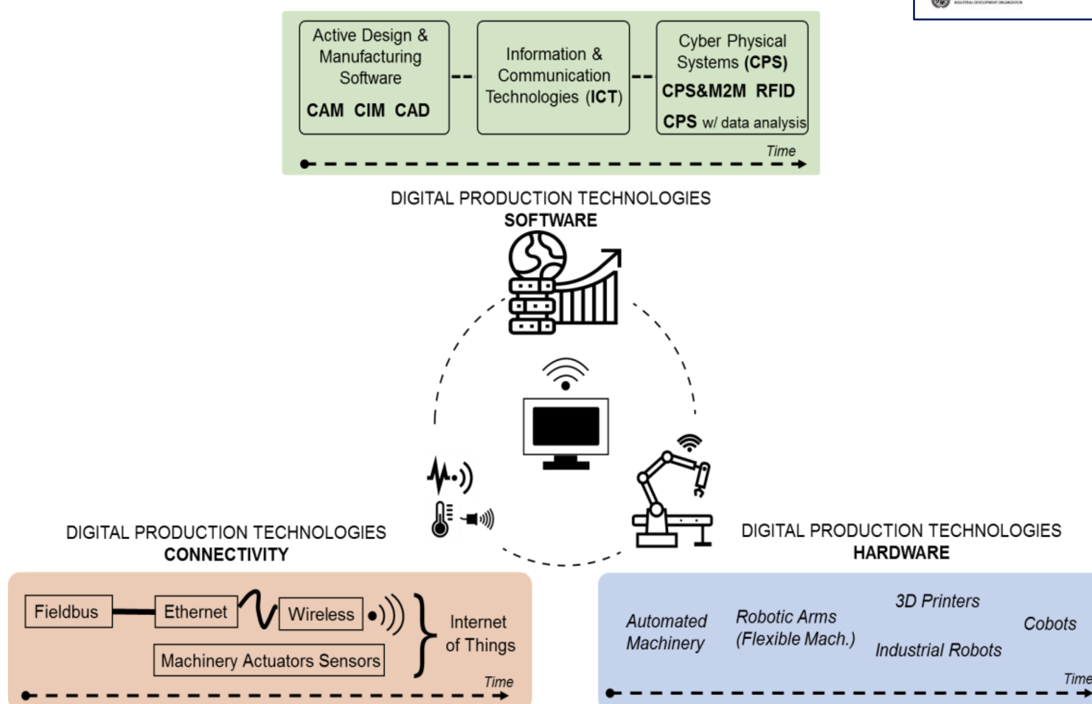
Source: Author, see IDR 2020

Digital production technologies

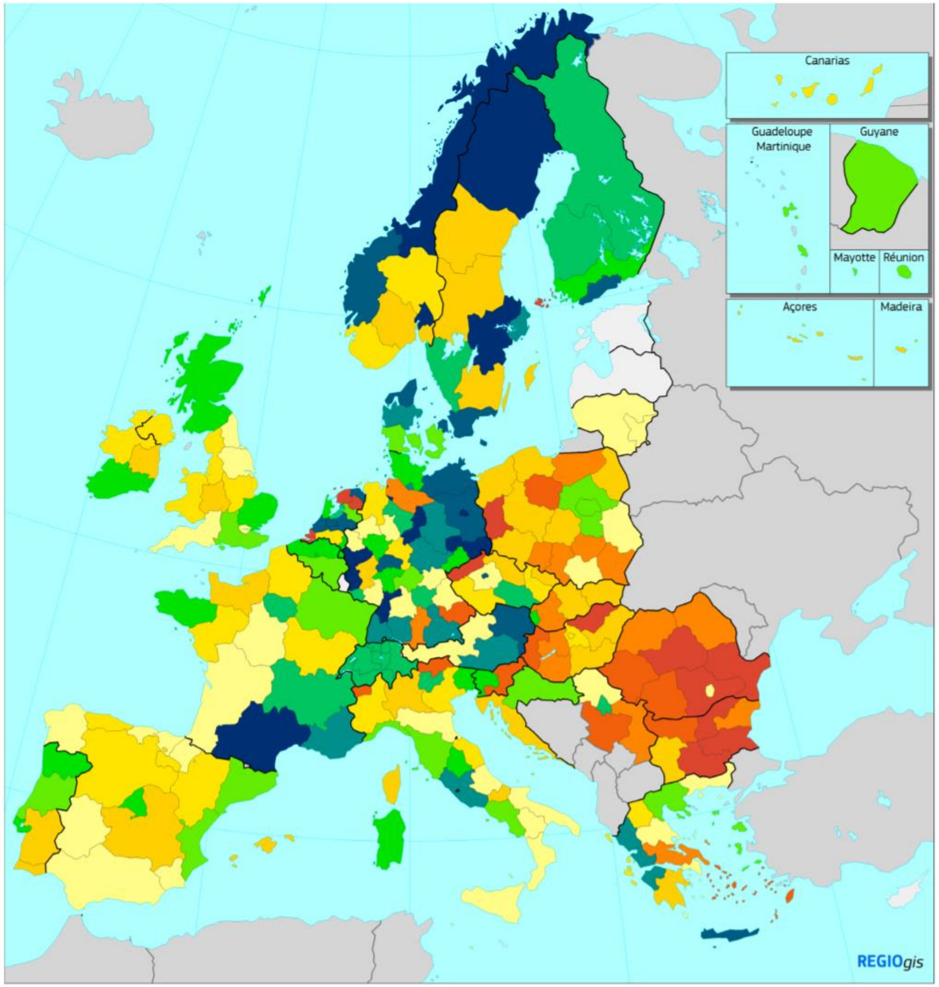
Evolutionary transition or evolutionary disruption?

Digital production technologies: backbone of productivity and sustainability

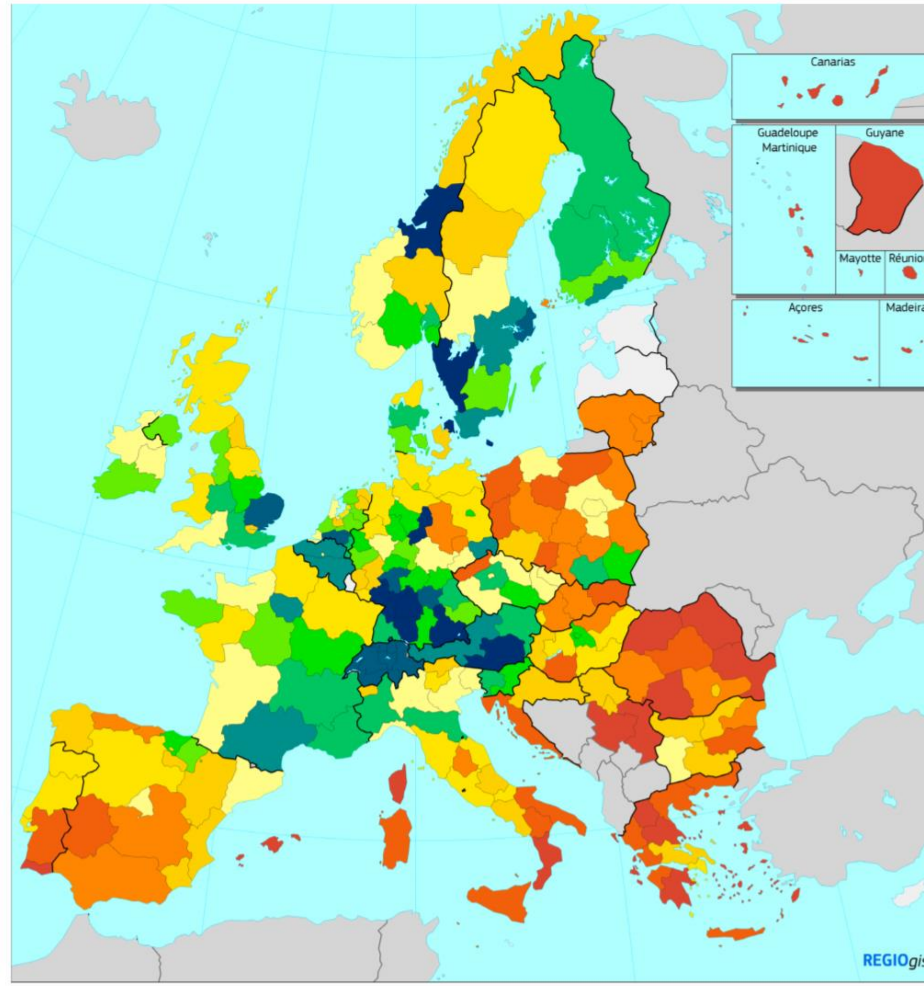
- result from incremental changes in the ***hardware*** of these machines, as well as their ***software*** – thus, their functionalities and data use in a cyber-physical space – and their ***connectivity*** – thus, their integration with other production technologies (and products).



SOAS University of London



R&D expenditure in the public sector as percentage of GDP



R&D expenditure in the business sector as percentage of GDP

- Bottom one-third low performers
- Middle one-third low performers
- Top one-third low performers
- Bottom one-third moderate performers
- Middle one-third moderate performers
- Top one-third moderate performers
- Bottom one-third strong performers
- Middle one-third strong performers
- Top one-third strong performers
- Bottom one-third high performers
- Middle one-third high performers
- Top one-third high performers

Challenges in digitalisation

- Technology absorption, effective deployment and 'capability threshold'
- Production system retrofitting and integration
- Basic and digital infrastructure
- Technology diffusion, 4IR islands and the digital capability gap
- Endogenous asymmetries in technology access and affordability

Summing up

- Analytical frameworks matter: Industrial ecosystem
- Opportunities for diversification and innovative industrial renewal
- Innovative industrial renewal: sectoral and cross-sectoral pathways
- Industrial restructuring and industrial policy alignment
- Challenges of peripheral regions in the digitalisation era