



Coping with Technological Changes: Regional and National Preparedness in Face of Technical Change

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I INTRODUCTION

Countries around the world face the dual challenge presented by economic pressure and technological change. Our home country, Finland, can be seen as a canary in the coalmine for the need to meet new dynamics of increasingly volatile, complex, and ambiguous (VUCA, [1]) conditions. Finland was hit particularly hard by the Great Recession, and in 2009 alone Finland lost 8.5% of its GDP [2]. The workforce employed in industrial manufacturing was reduced by about 25% from 2007 to 2016, losing about 90,000 jobs during this period [3]. However, while certain national, economic, and geopolitical conditions exacerbated the direness of Finland's situation, the challenge of coping with technological changes is

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© The Author(s) 2020
M. Collan, K.-E. Michelsen (eds.), *Technical, Economic and Societal
Effects of Manufacturing 4.0*,
https://doi.org/10.1007/978-3-030-46103-4_12

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a global one. How do we measure, and how do we ensure regional and national preparedness in the face of the technical changes provided by the Fourth Industrial Revolution and Industry 4.0?

It should come as no surprise that not all nations or regions are equally prepared for this challenge. In terms of preparedness for Industry 4.0, evidence from patent data on advanced manufacturing processes and systems showed that many of Europe's capabilities in the field were based on a small group of nations [4]. In many regions, and indeed in entire Member States, such capabilities appeared outright absent.

Given the enthusiasm with which policymakers and key business and civil society representatives joined into 'surf the Industry 4.0 wave' during the latest years, surprisingly little empirical literature exists on the links between Manufacturing 4.0 and national specialization [5]. While a number of firm-level Industry 4.0 maturity models and readiness analyses have been developed [6, 7], models are still only emerging for societal levels of analysis. Lobo^{va} et al. [8] assesses levels of countries' formation of Industry 4.0 by measuring (1) the level of society's digitization, (2) mentions of Industry 4.0 in normative and legal governments of the state, and (3) total volume of financing of scientific research in the sphere of Industry 4.0. Sung [9] ranks *competitiveness for the fourth industrial revolution* by averaging three global competitiveness analyses.

This chapter argues that neither of these concepts fully capture regional and national abilities to cope with relevant technological changes. Instead, measurements of preparedness must consist of several elements including both technology push-factors (supply) and technology pull-factors (demand). As elaborated during this chapter, the supply side represents the existing industrial strengths of spatial entities, as well as the ongoing technological innovation. The demand side represents changes in future markets, fundamental changes to business models, and elements of technology foresight. To put it in simple terms, countries succeeding in the future industrial landscape will be those able—also in the future—to match their own competences with national and international demands.

In Fig. 1 we have presented supply (push) and demand-side (pull) challenges of Industry 4.0 strategy. In the field of technology innovation management, there is always a strategic need to analyze both supply and demand aspects of technological innovation. Successful technological innovation requires that both sides of market interaction (supply and demand) are managed successfully and simultaneously (see Fig. 1).

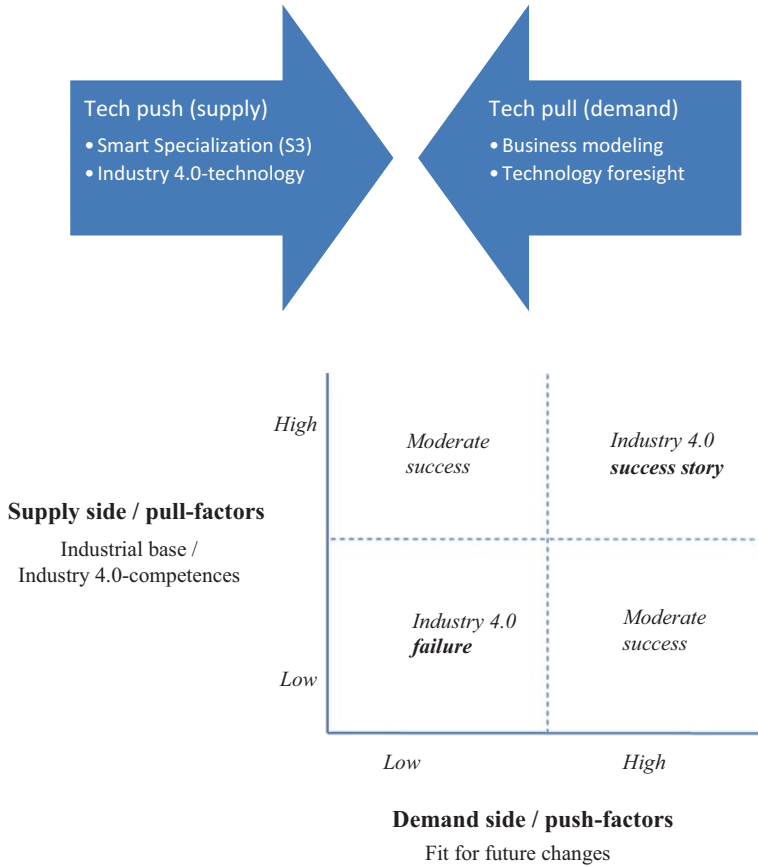


Fig. 1 Supply (push) and demand-side (pull) factors in the Industry 4.0 strategy

Our approach builds on a modified version of the concept of Smart Specialization in which we integrate a stronger futures focused perspective supplementing the evolution and refinement this theoretical concept has witnessed over the last decade. Smart Specialization Strategies (S3) is a knowledge-driven growth strategy, which remains the dominant answer of the European Union for the regional transformation challenges faced. In 2016 European Commissioner for Regional and Urban Policy Corina

Cretu termed smart specialization a ‘*key instrument for place-based development*’ and ‘*the most comprehensive policy experience of implementing innovation-driven progress in Europe*’ [10]. S3 presupposes that choices of technological domains should originate in prior analyses of a region’s economic, technological, and research specializations in order to be aimed at those with the greatest potential [11].

This chapter is structured by the four elements in Fig. 1 above. First, S3 is explained in more detail, since this is the primary building-block of current policymaking on this topic, as well as one of the dominant academic paradigms in the field. In order to succeed in the new conditions, proper attention must also be given to assessing and developing technical competences in the field of Industry 4.0. Since other chapters of this book focus more on Industry 4.0-technologies, this chapter will intentionally keep this topic short. On the pull/demand-side, the two core elements of the model relate to new modes of business modeling and the need for technology foresight. New business models and new markets are paramount to keeping a region competitive. The final part of the chapter demonstrates the benefits of foresight and applications of futures research methods. Throughout the chapter, we will use examples and cases based in Finland, but the concepts and ideas are transferable and easily applicable in other countries.

Smart Specialization (S3)

As mentioned, Smart Specialization has become the main adaptational mantra of the European Union. Smart Specialization, or S3 for Smart Specialization Strategy, ensures the capacity of an economic system (a region for example) to generate new specialties through the discovery of new domains of opportunity and the local concentration and agglomeration of resources and competencies in these domains [12]. Smart Specialization, more so than traditional industrial policy, places great emphasis on geographical contexts including the existing social, cultural, and institutional characteristics [13]. In S3 as a sector-specific innovation policy, governments (national, regional) are reframed with the task of developing capabilities connected with its territory, without accusations of merely ‘picking the winners’ in selecting fashionable or desirable sectors in a manner disjointed from existing specializations [14]. There are various reasons why S3 strategies are different in different European countries:

- The location and importance of industrial, export and import activities are different in different regions of national economies.
- The key elements of the S3 approach, industrial comparative advantages, regional resilience levels, and innovation activities are different in different regions.
- The industrial scale and scope factors are different in different regions.
- The nature of regional collaboration and actor-network network patterns are different in different regions inside national economies.
- Both private- and public sector decision-makers need a tailored regional knowledge base and information assets for investment decisions.
- The Entrepreneurial Discovery Process (EDP) and start-up ecosystems are different in different locations and regions. The nature of start-up ecosystems is having regional special characters.
- In general, pre-conditions of Industry 4.0/Manufacturing 4.0 strategy concerning Industry 1.0–3.0 developments, are different inside national economies, in regions.

Smart Specialization Strategy (S3) is an excellent example of a theoretical concept translated into policy. In S3, the recommendation is that resources should be concentrated on a limited number of well-defined priorities. The S3 approach thus requires tough choices on the basis of own strengths and international specialization [15]. The aim is not to create more specialized—and thereby less diversified—economies, but to capitalize on and leverage existing strengths in a region in order to build a competitive advantage in high-value activities [16]. S3 thus defines ‘the virtuous process of diversification’ [17] through local concentration of resources and capabilities within a select number of domains particularly likely to generate new activities aiming at transforming the existing structures, it forms capabilities by building micro-systems of innovation and drives structural local changes. The selected S3 priorities should be based on a shared vision built during a wide consultation process, which should be socially inclusive. It should include a wide range of entrepreneurs, researchers, social partners, etc. Priority setting should rely on the logic of the entrepreneurial discovery process (EDP) of likely market opportunities [18].

The place-based tenets of S3 are primarily aimed at underpinning regional development at a level more fine-grained than the national levels. The bottom-up approach reflects a popular turn from national to regional

innovation systems over the latest decades [5]. Part of this reason is the empirically verified benefits from the size and critical mass in R&D combined with the positive knowledge spillovers gained from proximity to sufficiently large R&D sectors within a given sector [12]. Since the spillover varies with geographical proximity, there is a tendency to aim at innovation ecosystems sufficiently large to create size, but not larger than that.

There are tendencies that fundamental changes to the manufacturing business model might underpin the regional spillover even further. As the line between manufacturing and services is blurred, emergent literature on servitization suggests, “Territorial Servitization” can contribute to local competitiveness and employment. This happens through a virtuous cycle generated when a local manufacturing base attracts or stimulates the creation of complementary knowledge-intensive service businesses, which in turn may facilitate the creation of new manufactures in the region [19, 20].

Smart Specialisation potentials across Finnish regions have been extensively evaluated in cooperation with the Manufacturing 4.0-project in Haukioja et al. [21] and Karppinen et al. [22]. In the context of preparedness for impacts of technical changes, we must understand the socio-economic historical background of regions. Some regions are more ready for technological changes and Industry 4.0 transformations. Key variables like demographic structure and education level of the population have impacts on preparedness for impacts of technological changes.

Like with any concept gaining rapid importance, many competing descriptions of Smart Specialization-elements exists. This chapter focuses on four main elements needed for a Smart Specialization-theory (visualized in Fig 2).

We want to underline that in the S3 approach the entrepreneurial discovery processes (EDPs) always link to the development of spatial start-up ecosystems. Entrepreneurial discovery always encourages experimentation and risk-taking. Some of the new economic activities identified as priorities are likely to fail. Otherwise, one could hardly speak of experimentation. This aspect is also relevant for innovative technological entrepreneurship and Industry4.0 / Manufacturing 4.0 developments.

Below we will expand further on the four main constitutive elements of Smart Specialization. We can claim that these four constitutive elements of Smart Specialisation Strategy (S3) promote the creation of Industry 3 and Industry 4.0-type manufacturing patterns in regions. These must be some comparative advantages of industrial activities in order to reach the Industry 4.0 level in different industrial sectors. In the European Union,

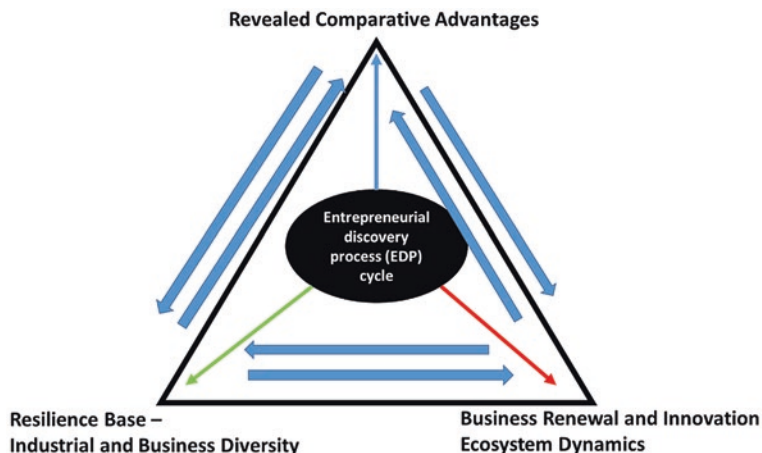


Fig. 2 S3 triangle (comparative advantage, resilience, and business renewal innovation ecosystem dynamics) with entrepreneurial discovery process

the existence of a national strategy for Smart Specialisation Strategy (S3) has been an ex-ante conditionality for the use of the European Union Structural Funds from 2014–2020 [23]. This means that if private and public stakeholders want to link Industry 4.0 development and investments to the use of structural funds of the EU, they should have a very good knowledge base of S3 smart industrial development in regions.

Revealed Comparative Advantages

A new systemic approach to Smart Specialisation Strategy has been developed in the publications of the S3-research group [24, 21]. The revealed comparative advantage (RCA) is a key concept in S3 strategy, as regions seek to upgrade along with their existing advantages and specializations. Typically, the revealed comparative advantage is defined to be an index used in international economics for calculating the relative advantage or disadvantage of a certain country/region in a certain class of goods or services as evidenced by trade flows or industrial activity (see [25]) It is based on the classical Ricardian comparative advantage concept.

Balassa-Hoover Index (BHI) is the key index when we want to analyze revealed comparative advantages in a spatial setting. The formula of BHI is the following:

$$\text{BHI}_{si} = \frac{\frac{x_{si}}{X_i}}{\frac{x_s}{X}}$$

where x_{si} is the number of employed people in region s and in industry i , (X_{si}/X_i) is the corresponding share for all sub-regions. If $\text{BHI}_{si} \geq 1$, there is a revealed comparative advantage in relation to all regions. In this way, we can understand whether regions have some comparative advantages which can provide a fundamental economic base for progressive industrial development.

Another very useful index is the Region's Relative Specialization Index (RRSI). We use RRSI as a measure of comparative specialization of sub-regions. RRSI can be calculated in the following way:

$$(\text{RRSI})_s = \sqrt{(1 - \text{BHI}_{i1})^2 + (1 - \text{BHI}_{i2})^2 + \dots + (1 - \text{BHI}_{in})^2}$$

The higher the RRS index is the more specialized the structure of the manufacturing industry is in the region. If the structure of a region is homogenous, the RRSI obtains value zero. If the $\text{RRSI} \neq 0$, the industrial structure of a region differs from the country's average. The higher the RRSI value, the more a region is different from the whole country.

The idea is that the revealed comparative advantages provide 'objective' tools in which actual historical data for trade or employment reveals actual comparative advantages. If a region exports a given sectors' products in a quantity that outsizes both the market for those products and the general regional trade patterns, the region is presumed to have an advantage in this sector. Often in the S3 approach, micro-based qualitative indicators and a bottom-up approach help to make local tailoring possible by providing understandings of the specific characteristics of a given region. However, in order to compare regions and regions' relative differences for a given phenomenon of interest with 'objective' measuring tools, quantifiable macro-indicators are needed.

Two recent publications analyzing Smart Specialization in Finland show different methods of applying these quantifiable macro-indicators. Haukioja et al. [21] presents a Labour Intensity of Manufacturing Index (LIMI) measuring regions' manufacturing workforce's share of the total regional workforce in order to evaluate how dependent regions are on industrial manufacturing. Regions with a higher LIMI-share may have

comparative advantages in manufacturing, but may also be more susceptible to risks in the case of rapid technological changes to manufacturing. Karppinen et al. [22] present analyses of Regions' Relative Specialisation Index (RRSI), based on a Balassa-Hoover (see [25]) index for the industry. This thorough analysis of Finland identifies no less than 432 relative advantage-subdivisions in the industrial sector alone [22]. This hints of many subnational comparative advantages around which the regions in question might build their Smart Specialization Strategy around.

For the long-term benefits of the comparative advantages, distinctions between various types of technologies and exports might be useful. Technologies and local business ecosystems that are simple to copy and easy to move to tend to be of reduced value and thus not a source of long-run rents [16]. More complex and difficult to imitate technologies are more sticky in space and holds greater promises for the regions and firms in which they are created. An alternative to revealed comparative advantages, that is to empirical evidence of actual trade-flows or employment patterns, are overall rankings of competitiveness. Global competitiveness rankings have been used to analyze countries' perspectives on Industry 4.0 [9]. In order for industrial manufacturing companies in a given country to thrive on open international markets, these are indeed relevant data. Fortunately, a wealth of global and refined data already exists in this regard. Competitiveness has been at the forefront of national economic policies around the world since the groundbreaking work of Michael Porter more than 25 years ago, and it has long forked from its firm-level origins into additional discussions of national competitiveness [26]. An important indicator of national competitiveness is the Global Competitiveness Reports of the World Economic Forum. Currently, these reports include five unique analytical domains: (1) Enabling environment, (2) human capital, (3) markets and (4) innovation ecosystem. As the reader might note, this has certain overlaps with other elements of our model, i.e. they might be considered a reflection of the S3-triangle as a whole.

Resilience Base: Industrial and Business Diversity

Regional specialization strongly depends on the industrial structure actually present in a region, and as a result shows clear traits of embeddedness and path dependencies [11]. In many studies of economic resilience, much effort is attributed to the development of factors and measures representing economic and related resilience. In our S3 approach, we have

focused on industrial and business diversity analysis. Resilience analyses are relevant and important because they help regions to adjust themselves to withstand and adjust to economic shocks. If the resilience level is very weak, even advanced industrial sectors can collapse and ruin all efforts to develop Industry 4.0 competences and capacities. We apply the Herfindahl-Hirschman Index (HHI) to the Finnish sub-region data. Our data includes 71 sub-regions and 24 industrial sectors [24, 21]. Our HHI analyses help decision-makers in the private and public sectors to identify resilience levels of the regions. The HHI formula is the following:

$$\text{HHI}_s = \sum_{i=1}^n \left(\frac{x_i}{x} \right)^2$$

where x_i is the number of employed people in the industrial sector (i) and x is a total number of people employed in all industrial sectors in region (s) and n is a number of industrial sectors (n). HHI-index is calculated as the sum of squared industry shares for each sub-region.

This kind of basic resilience analysis informs decision-makers about industrial resilience levels which vary much in different regions and spatial communities. Resilience analyses help decision-makers to identify risks of industrial policy and understand strategic trade-offs between comparative advantage analyses and resilience analyses. Both “sides” of industrial policy are relevant for Industry 4.0 strategy in the national level.

Business Renewal, Innovation Ecosystem Dynamics

The fourth critical analysis tool of S3 is focused on the business renewal and innovation ecosystem. In general, business demographics size matters in Industry 4.0. Current Industry 4.0 research reveals that small- and medium-sized enterprises (SMEs) often have more challenges to adapt to Industry 4.0 approach [27, 28]. This is a good reason to pay more attention to spatial variation in entrepreneurship and business demographics.

The smart region is an innovative region that is flexible in adapting to economic shocks. Adaptability is measured by the CDI index. The CDI index is calculated for the whole regional enterprise stock:

$$\text{CDI}_s = \left[\frac{EN_e + EN_e}{T_e} \right]_s$$

where EN_c = number of start-ups in the area, EX_c = number of deaths in the area and T_c is the number of enterprises in the area. The higher the CDI, the better the ability of the region to renew its business and industrial activity.

Entrepreneurial Discovery Process (EDP)

In Smart Specializations Strategies, it is presupposed that choices of technological domains reflect regions’ economic, technological, and research specialization [11]. The principle of ‘entrepreneurial discovery processes’ (EDP) then ensures that the choice of specialization hinges on capabilities already existing in the region. There are very close links between this idea of EDP and spatial innovation ecosystems.

Innovation ecosystem is, therefore, a key component of the Smart Specialization Strategy. In Fig. 3, we report Big Data analysis of the global start-up ecosystem of manufacturing. This study aims to identify digital trends across industries and to map emerging sectors by using co-word and social network analysis. As the industrial landscape has become complex and dynamic due to the rapid pace of technological change and digital transformation, identifying industry trends and emerging business

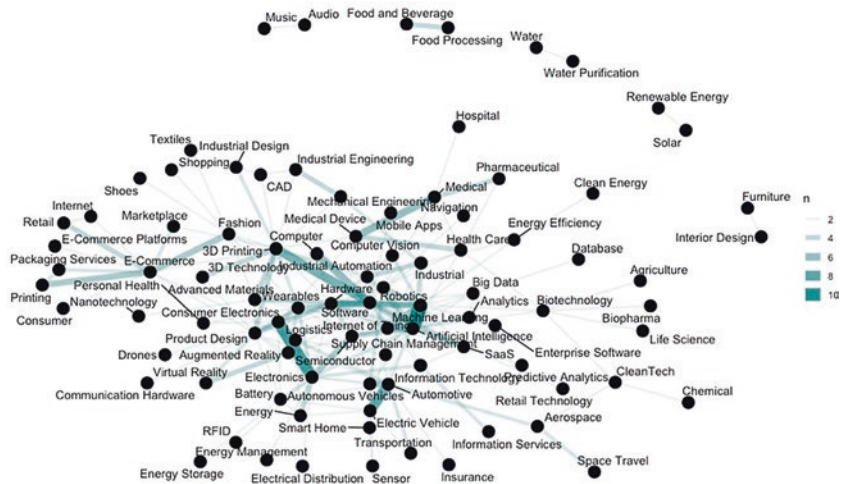


Fig. 3 Global start-up ecosystem of the Manufacturing cluster: A Big Data analysis [29]

areas can be critical for strategic planning and investment policy. This study examines industry and technology profiles of top start-ups across sectors and studies in which areas early-stage companies specialize. We have applied co-word analysis to reveal co-occurrences of keywords or key phrases related to technology and industry profiles of early-stage companies and then use social network analysis to visualize industry structure and to identify trends from word co-occurrence. The results obtained from the analysis show in which sub-industries digital technologies are penetrating and what new sectors are emerging [29].

We can see from the results (visible in Fig. 3) that

- The global start-up ecosystem of the manufacturing cluster is very diversified
- There strong links between robotics and machine learning, electronics and semiconductor (which is expected)
- There is a strong link between information tech, vehicles, and electric vehicles
- Industrial cluster centers are e-commerce, 3D printing, and energy utilities business
- Many elements of the global start-up ecosystem are isolated and not very networked.

The start-up ecosystem of Finland has been visualized and analyzed in a similar manner and the analysis shows not only results for Finland, but that it is possible to do both global analyses and analyses of smaller spatial entities, such as regions or countries. Among the 427 included start-ups in Finland, the role of manufacturing companies is very minor, with less than 3 percent of the total population situated in this sector. However, most start-ups are in sectors relevant for Industry 4.0, such as Information Technology (89 companies), Software (72 companies), Internet (45 Companies), Artificial Intelligence (43 companies). The largest sector outside this field is Health Care with 36 companies. We can note that Finnish start-up ecosystems need collaboration with the global start ecosystem to gain a competitive edge in the future. This kind of analysis can help decision-makers plan national Industry 4.0 strategy roadmaps. Similar analyses can be made for all countries with Big Data analytics. Again, we can note that many elements of the start-up ecosystem are quite isolated.

2 TECHNOLOGY INNOVATION, MARKETS AND BUSINESS MODELING

Nations have the opportunity to pursue innovation and increase their technological competencies as the main method of supply-side preparation for potential technological shifts. It is possible to analyze preparedness based on this step through several different approaches. Common approaches are for example patent and trademark analyses [30] or bibliometric analyses. In the context of preparedness for increased automation, indicators of digital readiness may, however, be a useful tool allowing also for the comparison between different entities. With some modifications we can turn the European Union's Digital Economy and Society Index (DESI) [31] into a new Manufacturing 4.0-index in which the main dimensions are based on the characterization of the four main features of Industry 4.0: Interconnectivity, Data, Integration, and Innovation [32, 33]. In addition, we add the important fifth dimension of the availability of necessary human resources with the required digital skills.

This operationalization can be seen below in Table 1 which also reports the results for Finland and its ranking against the other EU27, Iceland, Norway, Montenegro, North Macedonia, Serbia, Turkey, and Bosnia and Herzegovina.

The analysis shows that Finland has one of the most conducive foundations for digital advancement in Europe, as it consistently ranks at or near the top across the five dimensions of digital Manufacturing 4.0-readiness.

For a region to succeed in a competitive international environment, it is not enough to have the right competences and enabling conditions. The industrial firms of the region must also function with business models fitting their respective markets. Filtering and prioritizing futureproof markets and business models are therefore key elements of the 'demand'-side of coping with technological changes. Two new and key methods of analyzing market change preparedness are the analysis of Long-Term Business Opportunities and Business Model-Based Filtering Analysis.

The analysis of Long-Term Business Opportunities is a means to explore baseline projections of the long-term business of e.g. manufacturing industries in a given country [modified from [34]]. The baseline projections combine long-term projections of GDP growth for various countries [35], manufacturing outputs based on the World Input-Output Database (WIOD; [36]), national data on employment by manufacturing sectors, and calculations of Revealed Comparative Advantages. This

Table 1 Digital skills in Finland: Key results

	<i>Variable</i>	<i>Variable</i>	<i>Result</i>	<i>Rank</i>
Interconnectivity	Enterprises provide more than 20% of the employed persons with a portable device that allows a mobile connection to the Internet for business use	E_EMPMD2_ GT2020 2018	62%	2
	Share of turnover from web sales, business-to-business and business-to-government	ISOC_EC_ EVALN2	4%	8
Data	Using cloud computing services	ISOC_ CICCE_USE 2018	65%	1
Integration	Enterprise analyzing big data from any data source	ISOC_EB_BD 2018	19%	5
	Share of enterprises with ERP systems to share information internally	IE_ERP1 2017	39%	9
Innovation	Share of enterprises using CRM-systems	ISOC_ BDE15DEC 2011	39%	7
	Use 3D printing	ISOC_EB_ P3D 2018	7%	1
	Use robots	ISOC_EB_ P3D 2018	10%	2
Digital skills	Cumulated Horizon 2020-funding for ICT-related projects	Data from DG Connect		7
	Employed ICT specialists as share of total employment	ISOC_SKS_ ITSPT 2018	7.2%	1
	Percentage of individuals with basic or above basic overall digital skills	ISOC_SK_ DSKL_I 2017	76%	6
Sum	STEM graduates at Master's or equivalent level per thousand inhabitants	EDUC_UOE_ GRAD04 2017	7.7%	4
	Finland—Average ranking in Europe			4.4

framework provides a simple *ceteris paribus* analysis of whether existing trade patterns trend upwards or downwards. An analysis of the data for Finland shows that certain industrial sectors projects to increase their share of the Finnish economy (e.g. manufacture of machinery and equipment,

and manufacture of paper and paper products), while growth potentials in other sectors lack behind (e.g., manufacture of food products, and manufacture of textiles).

Since the World Input-Output Database is so detailed, the information can also be used to forecast shifts in individual export markets. Below is an example again based on the latest available information for Finland (Table 2), which does not quite show radical shifts, but still hints of ongoing changes. China, perhaps not so surprisingly, looks to become a bigger and more important market for Finland than e.g. the United Kingdom and Russia, due to the projected larger growth in GDP. Similar tables can be made for all countries included in the WIOD-database and the OECD GDP projections. It is also possible to break the numbers down to subnational levels in order to analyze which regions, again *ceteris paribus*, which are better positioned for long-term business opportunities.

Table 2 Top 10 manufacturing sectors and markets (excluding Finland and the rest of the world)

	<i>2012–2014</i>	<i>2035</i>
1	Market: Germany <i>Paper and paper products</i>	Market: Germany <i>Paper and paper products</i>
2	Market: Sweden <i>Coke and refined petroleum</i>	Market: Sweden <i>Coke and refined petroleum</i>
3	Market: USA <i>Paper and paper products</i>	Market: USA <i>Paper and paper products</i>
4	Market: Germany <i>Basic metals</i>	Market: Sweden <i>Chemicals and chemical products</i>
5	Market: Sweden <i>Chemicals and chemical products</i>	Market: Germany <i>Basic metals</i>
6	Market: Germany <i>Printing and reproduction of recorded media</i>	Market: China <i>Paper and paper products</i>
7	Market: United Kingdom <i>Paper and paper products</i>	Market: Germany <i>Printing and reproduction of recorded media</i>
8	Market: Sweden <i>Basic metals</i>	Market: Sweden <i>Basic metals</i>
9	Market: USA <i>Printing and reproduction of recorded media</i>	Market: United Kingdom <i>Paper and paper products</i>
10	Market: Russia <i>Chemicals and chemical products</i>	Market: China <i>Machinery and equipment</i>

During the latest decades, much of business research has focused on Business Model Innovation [37]. In recent years, this has also led to an academic focus on business model innovation through Industry 4.0 (e.g. [38]). Beyond the Industry 4.0-literature, there are new and inspiring approaches to business modelling like “happiness based business models” [39], business models based on “platform thinking” [40] or “sustainable socially responsible and ethically oriented” business models [41]. It is good to remember that firms can select different approaches to their business model. In Table 3 we present key alternatives for export-oriented business models (Table 3).

Business models can also be simplified according to the main market targeted. Modern companies typically work in Business-to-Business (B2B) markets, Business-to-Consumer (B2C) markets, or Business-to-Government (B2G) markets. In the future, business models will also increasingly include Business-to-Digital Networks (B2DN) markets, as buying and selling will be done on account of algorithms in digital networks. Future B2DN-models can be related to all three other types of models today, as the digital models exceedingly spread.

Global markets can be filtered to give ideas about which business model that is most promising for given markets, as well as which markets

Table 3 Typical business models [42]

<i>Business model</i>	<i>Definition</i>
Direct Sales	The company itself sells directly to foreign end customers either in Finland or locally.
Resale	The company sells to resellers who sell directly or through intermediaries to the end customer.
Licensing	The technology (or equivalent) is made available to another company to package it into a product or service to be sold for a license fee.
Franchising	Foreign, local operator operates in accordance with the business concept developed in Finland.
Associated Company	A foreign owned company with minority share sells a product or service locally to foreign customers.
Joint Venture	Equally owned (50/50) foreign company that sells in the local market.
Subsidiary	Wholly owned (or majority owned). The parent company has a majority of the shares, participations or other voting rights in the subsidiary company. The parent company is required to prepare consolidated financial statement, which records the profit or loss generated by the foreign affiliate.

are most promising for a given business model. We can call this a Business Model-Based Filtering Analysis. In general, the filtering model is based on three main market criteria: The absolute size of the market, the size of the sectors per capita, and the sectors' share of the overall economy (data from the IMF [43]).

As we know, three strategic arenas of innovation are technological innovation, business model innovation and social innovation [44, 30]. Business model innovation has traditionally based on the identification of consumers and end-users in national and global markets. For Industry 4.0 strategy not only supply-side analyses (technology push) are relevant, but there is a need to think demand-side analyses (technology pull). Then business model innovation plays an important role. The scaling and scoping of Industry 4.0 technology innovations require new business model innovations, which are based on professional export and import strategies with data lake filtering, Big Data analytics and knowledge management. It is good to understand that there is not a linear path to the big success of Industry 4.0 strategy. Often even very successful companies are not always winning in foreign markers, but they can learn from international markets and their own business failures. It is good to remember that both technology push and technology pull factors of Industry 4.0/Manufacturing 4.0 strategy need professional attention.

3 TECHNOLOGY FORESIGHT

Technology foresight is closely linked to national innovation policy, technology policy, science policy, and education policy work. Between these policies, there are various strategic trade-offs and national planning needs. The typical argument of technology foresight has linked to supply-side (technology push) analyses, but not so much to the demand-side (technology pull). There are six key frameworks of foresight (cf. Table 4): (1) predictive frame, (2) planning frame, (3) scenaric frame, (4) visionary frame, (5) critical frame, and (6) transformative frame [45]. There can be both explorative and normative analyses in the field of technology foresight. The level of perceived unpredictability has impacts on a selected frame of technology foresight. There are many social and economic benefits of technology foresight.

These kinds of technology foresight aspects are relevant also in the Industry 4.0 strategy discussion, because many current Industry 4.0 analyses are more linked to supply-side (technology push) analyses. In the best

Table 4 Frameworks of foresight and benefits and inputs for Industry 4.0 and Manufacturing 4.0

<i>Frameworks of foresight</i>	<i>Benefits and inputs for Industry 4.0/Manufacturing 4.0 strategy</i>
Predictive frame	Trend predictions and baseline scenarios of Industry 4.0/Manufacturing 4.0 developments
Planning frame	Industrial planning of IND4.0/MFG4.0
Scenario frame	Alternative development strategies of IND4.0/MFG4.0, Risk analyses of IND4.0/MFG4.0
Visionary frame	Long-run visions of IND4.0/MFG4.0 developments
Critical frame	Risk (forecasting what if? -scenarios) and uncertainty (backcasting scenarios) analyses of IND4.0/MFG4.0 development
Transformative frame	Roadmaps of IND4.0/MFG4.0 development

case, technology foresight helps decision-makers to build strategic roadmaps and assess alternative technology choices. Typical foresight processes include (1) the use of foresight methods, (2) network and stakeholder analyses and (3) decision-support for decision-makers and the pragmatic use of decision models [46]. These three pillars of foresight are needed to provide “fully-fledged foresight” with diagnosis, prognosis and prescription phase of technology foresight. In this way, technology foresight must be linked to actual processes of networking and decision-making.

In the field of technology foresight, one relevant framework is Gartner Hype Curve analysis, which focuses on digital technologies. Gartner Hype Cycle methodology gives us a view of how a technology or application will evolve over time, providing a sound source of insight to manage its deployment within the context of various business fields. The Gartner Hype Cycle approach is providing an important perspective to technological transformation in the VUCA environment [1], which SMEs and corporations face in the global economy.

An Example of Global Technology Foresight: Technology Power Index Analysis of Digital ICT Technologies

Digital and disruptive technologies create the most economic growth and productivity. Here we analyze longitudinal data of the 2008–2017 Gartner Hype Cycles and key digital ICT technologies in the world. Gartner Hype Cycle analyses have a strong influence on large companies’ technology

strategies and investment decisions. In this sub-section, we present the key results of Technology Power Index Analysis, TPIA [47]. The TPIA is based on the ranking positions of technologies and the power index of each technology (151 technologies) in the yearly Gartner evaluations from the year 2008 to 2017 [48]. The technologies ranked first to receive the highest power index numbers, and the technologies which are ranked lowest in the Gartner Hype Cycle have the smallest index numbers. Based on these TPIA calculations, all technologies receive a TPIA sum of technology power numbers. The larger the sum each technology gets, the more powerful the analyzed technology is. According to our analyses, the top 10 most powerful technologies are Surface Computers, Consumer Telematics, Mobile OTA Payment, Location Intelligence, Enterprise 3D Printing, Consumerization, Biometric Authentication Methods, Text Analytics, People-Literate Technology, Neurometric Hardware and In-Memory Analytics.

The lowest TPIA index technologies are held by new technologies in the “Technology Trigger Phase” of the Gartner Hype Curve. None of these low TPIA index-value technologies and innovations are fully ready to be used. It will take from five to ten years for them to become more powerful. The most recent Gartner reports for 2018–2020 provide some new insight into global technology foresight. New technology challenges are Augmented analytics, Quantum computing and Autonomous Things and Artificial Intelligence (AI). *Augmented analytics* reflects a third major wave for data and analytics capabilities. Data scientists are able to use automated algorithms to explore more hypotheses [49]. *Quantum computing* is based on the quantum state of subatomic particles. Quantum computers are an exponentially scalable and highly parallel computing model [49]. Autonomous things mean Robotics, Vehicles, Drones, Appliances and Agents. They can operate in four environments: sea, land, air and digital. Autonomous things use Artificial Intelligence (AI) to perform tasks traditionally done by humans [49].

The analysis of the Gartner Hype Curve helps leaders to understand the dynamics of on-going technological disruption, which is extremely important for SMEs and corporate leaders in being able to foresight the future of digital ICT technologies. Technological transformation, in particular, is changing many basic assumptions of business management and strategic planning. The digital transformation process can be estimated from the yearly results of Gartner’s Hype Curve analysis. This technology foresight study reveals that companies have to take significant risks when making

technological choices. It can be argued that technology risks can be managed, but not completely eliminated by technology foresight. By using futures studies and technology foresight methods it is possible to engage relevant stakeholders in the region in ideations on how these technologies might affect business in the region, as well as how the region could move forward in order to generate opportunities based on the emerging technologies.

4 CONCLUSIONS

This chapter highlights that in the discussions about Industry 4.0 and Manufacturing 4.0 development demand and technology pull factors are often forgotten and the technology push approach dominates discussions. We should understand also the demand side of the Industry 4.0 orchestration in a connection with consideration of the development of Industry 4.0 know-how and competences. The analytical thinking behind the Industry 4.0 approach is not just a question of supply-side and the production modernization and fast digitization of super-connected ubiquitous production. Supply chain management is an elementary part of Industry 4.0 expertise and development. In practice, this means that the supply and demand side (eCommerce and consumption on the domestic and international markets) analyses must be linked together. This means also a new kind of orchestration challenge throughout the whole supply chain and a new kind of innovative business model development.

In this chapter, we have addressed the general challenges of anticipation and the development of Industry 4.0 and Manufacturing 4.0 strategy. Foresight analyses can provide an overview of how the transition from Industry 3.0 to Industry 4.0 is taking place. Generally speaking, the transition from Stage 1.0 and Stage 2.0 to Industry 4.0 is extremely challenging for any operator or company. Conversely, the transition from Industry 3.0 is, of course, one step easier, as the industrial companies that have reached this Industry 3.0 stage, already have proven capabilities and intellectual capital to support the transition to Industry 4.0 level. Generally speaking, we can say that the proven abilities in international competition are helping companies move into Industry 4.0 level. Digital learning and learning, in general, is an important part of the transition to Industry 4.0. Manufacturing 4.0 and Industry 4.0 target is already challenging because of the need to combine cognitive ergonomics with physical ergonomics. This requires in-house testing, innovation and experimentation, for which

smaller companies, in particular, have fewer resources than large corporations. It is evident that larger companies act as drivers of change in many modern industries, shaping their industry cultures and practices through their own policies and standards. In particular, this affects the operational supply-side logistics and supply chains. On the other hand, small businesses firms tend to be innovative and agile, and through their own start-up ecosystem, they can develop into major players in the Industry 4.0, too.

Industry 4.0 is a challenge for both small and large companies, and often local ecosystems of innovation play a major role in regional industrial changes and transformations. As a key result, in this chapter, we have presented the European approach of the Smart Specialization Strategy (S3). We argue that achieving Industry 4.0 level in the industry will be easier if and when decision-makers have knowledge of the state of smart specialization regionally. Of course, factors such as population, employment and migration are important background factors, but the revealed comparative advantages, resilience levels, renewal and creativity processes, and entrepreneurial culture are the fundamental pillars on which the transition to Industry 4.0 is built regionally. When reliable information is available about these strategic key factors, making future investments is also easier.

Technology Foresight offers its own perspectives on Industry 4.0 know-how and development. Foresight can provide six different perspectives on Industry 4.0 development: (1) Predictive frame, (2) Planning frame, (3) Scenaric frame, (4) Visionary frame, Critical frame, and (6) Transformative frame. The Predictive frame can be used to produce statistical forecasting analyses of socio-economic and technical forecasts and baseline scenario development for Industry 4.0 developments. The Planning frame can be used to generate operational and strategic plans for the development of Industry 4.0 supply chains. The Scenaric frame can be used to generate forecasting and backcasting scenarios for Industry 4.0 and Manufacturing 4.0 developments. Through the Visionary frame, visions of Industry 4.0 developments can be created and produced. Through the Transformative frame, it is possible to produce technology roadmaps for Industry 4.0 development. There are many possibilities to apply foresight tools and methods to develop Industry 4.0 and Manufacturing 4.0 know-how and competences.

The Garner Hype Curve Technology Foresight presented in this article is a good example of a foresight tool that can be used to evaluate the evolution of very large ICT and digital technologies over time. Through our

TPIA technology foresight analysis, we can create a better understanding of digital technology development, helping companies to evaluate their own technology choices and the risks involved in technology choices.

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