

Van de Velde, Els et al.

Research Report

Towards better monitoring of innovation strengths, regional specialisation and industrial modernisation in the EU. Report

Provided in Cooperation with:

ZEW - Leibniz Centre for European Economic Research

Suggested Citation: Van de Velde, Els et al. (2019) : Towards better monitoring of innovation strengths, regional specialisation and industrial modernisation in the EU. Report, ISBN 978-92-76-09179-0, Publications Office of the European Union, Luxembourg, <https://doi.org/10.2873/667836>

This Version is available at:

<https://hdl.handle.net/10419/222368>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.



European
Commission



Towards better monitoring of innovation strengths, regional specialisation and industrial modernisation in the EU

Innovation

EUROPEAN COMMISSION

Executive Agency for Small and Medium-sized Enterprises (EASME)

Department A - COSME, H2020 SME and EMFF

Unit A.1 – COSME

E-mail: EASME-COSME-ENQUIRIES@ec.europa.eu

European Commission

B-1049 Brussels

Towards better monitoring of innovation strengths, regional specialisation and industrial modernisation in the EU

Report

Project number: EASME/COSME/2016/014

By

Els Van de Velde, Jean-François Romainville; IDEA Consult

Henning Kroll, Sven Wydra; Fraunhofer ISI

Christian Rammer; ZEW

Kincső Izsak, Paresa Markianidou, Carolina Spaini; Technopolis Group

Antonio Collado, Inga Sabanova; CARSA

July 2019

The information and views set out in this report are those of the author(s) and do not necessarily reflect the official opinion of EASME or of the Commission. Neither EASME, nor the Commission can guarantee the accuracy of the data included in this study. Neither EASME, nor the Commission or any person acting on their behalf may be held responsible for the use which may be made of the information contained therein.

***Europe Direct is a service to help you find answers
to your questions about the European Union.***

**Freephone number (*):
00 800 6 7 8 9 10 11**

(*) The information given is free, as are most calls (though some operators, phone boxes or hotels may charge you).

LEGAL NOTICE

This document has been prepared for the European Commission however it reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

More information on the European Union is available on the Internet (<http://www.europa.eu>).

Luxembourg: Publications Office of the European Union, 2019

ISBN 978-92-76-09179-0

doi: 10.2873/667836

Catalogue ET-01-19-646-EN-N

© European Union, 2019

Contents

1/ EXECUTIVE SUMMARY	7
2/ Introduction	9
2.1 Overall context and objectives of the study	9
2.2 Structure of the final study report	10
3/ Conceptual framework for monitoring industrial modernisation	12
3.1 Definitions	12
3.2 Conceptual background	13
3.3 Building blocks and dimensions	14
3.4 Differentiation and international comparison	17
4/ Indicators on industrial modernisation from existing sources	19
4.1 Sources for indicators	19
4.2 Selection of indicators	20
5/ Existing indicator gaps and proposals for filling the gaps	31
5.1 Identifying gaps in existing scoreboards and observatories	31
5.2 Proposed indicators to fill gaps in coverage by existing scoreboards and observatories	32
5.3 Remaining gaps	41
5.4 Combined broad list of indicators	42
6/ A final list of priority indicators for monitoring industrial modernisation	45
7/ Recommendations	47
7.1 Recommendations by Building Block	47
7.2 Actions to advance future monitoring systems	49
8/ Annexes	51
8.1 Annex 1: Final list of 33 priority indicators for monitoring industrial modernisation	51
8.2 Annex 2: Definition of indicators and data sources	57
8.3 Annex 3: Summary of the case studies	64

LIST OF TABLES

Table 1: Indicators on industrial modernisation available from existing scoreboards, observatories, monitoring systems22

Table 2: Proposed sector breakdown for indicators for which a NACE breakdown is available..... 29

Table 3: Gaps in indicator coverage by existing scoreboards and observatories 31

Table 4: Proposed indicators on industrial modernisation to fill gaps in existing scoreboards and observatories ..35

Table 5: Proposed indicators for monitoring industrial modernisation42

Table 6: Final list of priority indicators for monitoring industrial modernisation 45

Table 7: List of 33 priority indicators on industrial modernisation with descriptive information..... 51

Table 8: Indicators for monitoring industrial modernisation: definition and data sources..... 57

LIST OF FIGURES

Figure 1: Approach for developing an indicator system to monitor industrial modernisation 10

Figure 2: Conceptual Framework for Industrial Modernisation 13

Figure 3: Conceptual structure for a final list of indicators..... 14

1/ EXECUTIVE SUMMARY

This study on the *monitoring of innovation strengths, regional specialisation and industrial modernisation in the European Union* has two main aims. The first is to verify whether the **existing indicators and data sources provide a sufficient basis** for monitoring relevant aspects of industrial modernisation in the European Union, while the second is to propose a grounded **system of indicators to measure industrial modernisation**.

The future monitoring of industrial modernisation will need to cover different aspects. The monitoring system proposed in this report focuses on **industrial modernisation as a transformative process that aims at improving the competitiveness of European manufacturing** in an increasingly competitive global environment. Industrial modernisation has to address the upcoming challenges facing manufacturing in Europe as well as to respond to new opportunities of production, including the changes resulting from digitalisation and other new technologies.

Five **case studies** were conducted to explore the available indicators in more depth in a number of specific domains, and to demonstrate the political utility of combining the available information into new aggregated data compilations.

Five key areas were explored through in-depth case studies:

1. Provision and uptake of advanced manufacturing technologies

This case study explores new, better and more industry-oriented ways for the generation of comprehensive datasets on the provision and uptake of advanced manufacturing technologies. It integrates a traditional technological development-oriented perspective with the uptake of technologies in the industrial production process. It identifies and classifies technologies related to the digitalisation of production to discover that the technological competitiveness differs highly compared to existing KETs. It also compiles references on existing approaches to collect data on the uptake and use of advanced manufacturing technologies in and across different Member States. Data availability remains a key issue for the uptake of advanced manufacturing technologies, because there are currently no high-quality datasets publicly available.

2. Region- and industry specific framework conditions to support industrial modernisation

The aim of this case study is to construct an indicator framework that captures regional framework conditions relevant for industrial modernisation. The approach is piloted for two sectors (textiles and automotive) and focuses on digitisation as a relevant pillar of industrial modernisation. The main outcome of this case study is that it is possible to use partially existing indicators, but also the indicator design that exists in the current major EU monitoring platforms/ EU initiatives to recalculate a good number of indicators at sectoral level for regions. New indicators are however needed considering especially the new methods to mine and organise data available on the web and other unstructured databases.

3. Capturing cross-regional cooperation patterns and potential synergies for industrial modernisation

This case study investigates cross-regional cooperation linked to industrial development in the European Union and aspires to shed more light on potential synergies and cooperation patterns across EU regions. The case study has created an indicator framework for capturing cross-regional flows according to specific dimensions and investigated how the results can be used by and linked to the ongoing Thematic Smart Specialisation Platforms and to the conducted value chain analysis and mapping. This case study combined indicators that capture flows and linkages extracted from various EU level monitors and observatories and its added value is that this combination is assessed against the existing qualitative studies. The research identified the geographical collaboration patterns according to various indicators that can help policy-makers to better understand to which other regions the local innovation system actors are connected to.

4. Analysis of business environment and public support to improve SME participation in industrial modernisation

This case study explores a novel way of analysing the business environment specific to SME development, sustainability and growth, with a particular focus on internationalisation. The case study identifies four dimensions of business environment specific to SME development and growth, especially within the EU: (1) regulations, (2) access to finance, (3) digital infrastructure and (4) human capital and knowledge diffusion. The case study demonstrates that human capital and digital infrastructure affect the national performance and competitiveness of EU Member states and confirms the link between business environment and internationalisation performance.

5. Identification and better monitoring of business investments enabling and supporting industrial modernisation

This case study sheds light on the role of business sector investment for advancing industrial modernisation and on the extent to which sufficient information is available on the relevant types of investment. The key motivation for the case study is that investment in capital goods, which has for

a long time been a major indirect driver for modernisation, is changing its nature in times of digitisation and upcoming new (generic) key enabling technologies. It investigates combinations of different types of investments in tangible assets (machinery, equipment, buildings) and intangible assets (software and databases, other intellectual property, firm-specific human capital, firm-specific organisational capital, and firm-specific marketing capital). The case study highlights a lack of structural collection of information on intangible assets, especially at regional level.

In conjunction with the results of the case studies, this report proposes a **system for monitoring industrial modernisation** that is structured around **four main building blocks** which include an output level (on performance) and three groups of drivers of industrial modernisation (innovation strengths, regional specialisation, and business trends and environment). In assessing industrial modernisation performance, a distinction is made between the **outcomes and impacts** of industrial modernisation (i.e. its contribution to policy objectives) and the actual **process** of industrial modernisation (i.e. the uptake of new production technologies or the introduction of new business models). From the analysis, a number of pertinent, high quality indicators on outcome and impact can be made available using existing data sources. There is no need for additional data collection, but rather a need to combine and present the existing data in a suitable format. This can be largely done by accessing available information from public statistics and process it accordingly.

Innovation and investment encompass all capabilities and capacities required for advancing manufacturing. Previous projects have collected a substantial amount of high-quality indicators with good coverage. In general, it seems viable and useful to **complement available indicators** from studies like the KETs Observatory with pertinent information from official statistical sources. To that end, the study recommends an intensified dialogue with Eurostat and those in charge of existing innovation monitors. As there is a **lack of targeted data sources** on the actual process of industrial modernisation, i.e. the diffusion of new technologies and business models, the study recommends engaging in a dialogue with relevant experts to explore if firm-level surveys could be conducted for all EU Member States and to assess how much time and resources this would require.

The study also recommends **using available indicators** where these are suitable and then to combine these with a set of **sectoral and regional indicators** to characterise specific situations. A number of sectoral indicators from existing monitoring platforms for regional level comparisons are estimated. The study further recommends defining composite indicators for both regional and sectoral framework conditions and presents the components which could later be used for this purpose.

This results in a concrete and viable **outline for a future indicator system on industrial modernisation**. It is structured along the four main conceptual building blocks identified in the study. The indicators have been selected based on conceptual quality, with a key focus on availability. The **final list of 33 key indicators** has been established according to both conceptual criteria and relative availability, and is **intended to provide a broad cross-sectional monitoring** of industrial modernisation. Finally, as the area of industrial modernisation is often characterised by traditional indicators that are too partial or cover aspects that are not readily amenable to quantitative measurement, this area could benefit from novel methods such as web scraping or big data analysis.

2/ Introduction

2.1 Overall context and objectives of the study

This study aims to verify whether existing indicators and data sources provide a sufficient basis for monitoring relevant aspects of industrial modernisation in the European Union, and to propose a conceptually grounded system of indicators to measure industrial modernisation.

The future monitoring of industrial modernisation needs to cover many different aspects. The monitoring system proposed in this report focuses on industrial modernisation as a transformative process that aims at maintaining or upgrading the competitiveness of European manufacturing in an increasingly competitive global environment. Industrial modernisation has to address the upcoming challenges facing manufacturing in Europe and respond to new opportunities of production, including the changes resulting from digitalisation and other new technologies.

Accordingly, a number of case studies were conducted to explore the available indicators in more depth in specific, conceptually relevant domains - and to demonstrate the political utility of combining the available information into new aggregated data compilations.

In detail, five key areas were explored through in-depth case studies

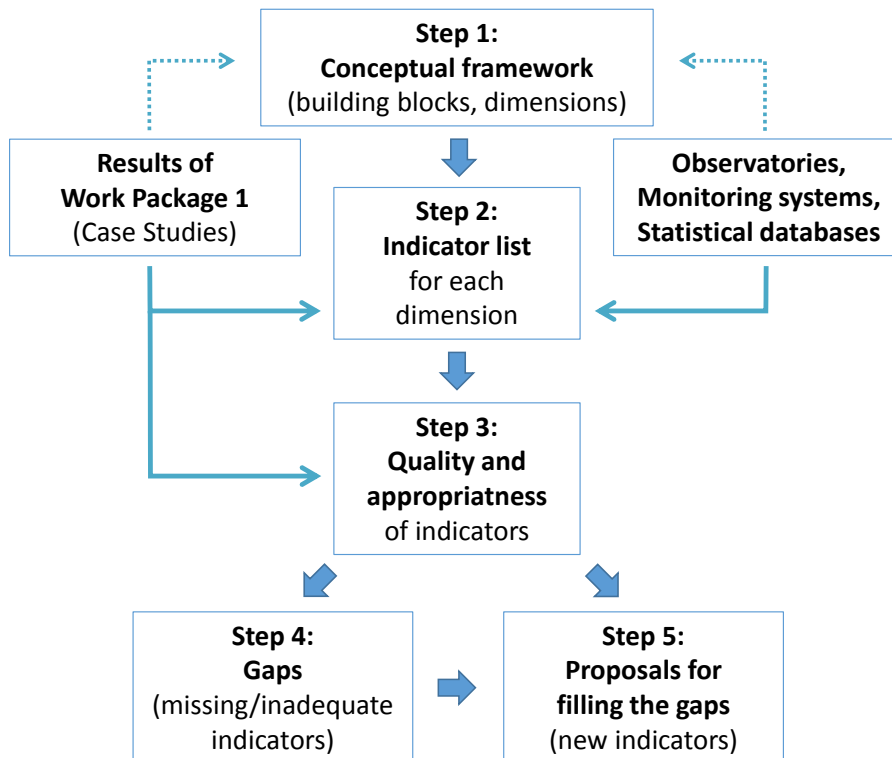
1. *Provision and uptake of advanced manufacturing technologies*
This case study outlines the need for data collection regarding the provision and uptake of advanced manufacturing technologies, including but not limited to the Key Enabling Technologies (KETs).
2. *Region- and industry specific framework conditions to support industrial modernisation*
This case study selects two sectors (textiles and automotive) and focuses on digitisation as a relevant pillar of industrial modernisation.
3. *Capturing cross-regional cooperation patterns and potential synergies for industrial modernisation*
This case study investigates cross-regional cooperation linked to industrial development in the European Union and aspires to shed more light on potential synergies and cooperation patterns across EU regions.
4. *Analysis of Business environment and public support to improve SME participation in industrial modernisation*
This case study explores a novel way of analysing the business environment specific to SME development, sustainability and growth, with a particular focus on internationalisation.
5. *Identification and better monitoring of business investments enabling and supporting industrial modernisation*
This case study sheds light on the role of business sector investment for advancing industrial modernisation and on the extent to which sufficient information is available on the relevant types of investment.

During these case studies, the project partners conducted in-depth reviews of existing scoreboards, observatories, and monitoring systems as well as Eurostat databases and reports that propose so far proprietary but potentially suitable approaches to monitoring. Detailed summaries of these case studies are provided in report's Annex.

Subsequently, the information collected, and the lessons learnt over the course of these thematic case studies were aggregated to develop a conceptually informed, politically relevant and empirically viable system for monitoring industrial modernisation in Europe. To that end, the following steps were conducted (Figure 1):

- First, a conceptual framework of industrial modernisation was proposed based on earlier studies and important sub-dimensions of measurement (building blocks) were then derived from it;
- Second, tentative lists of relevant indicators were proposed for each building block;
- Third, the proposed indicators were examined in terms of data quality and appropriateness for the specific purpose of monitoring industrial modernisation;
- Fourth, remaining gaps were identified, i.e. with respect to indicators that are either unavailable or not available in sufficient granularity (by region, sector or firm size);
- Fifth, initial proposals were made for how such gaps could be filled by additional indicators or by using additional data sources.

Figure 1: Approach for developing an indicator system to monitor industrial modernisation



Source: authors, based on conceptual work in the project

In more detail, an initial list of 61 possible indicators was compiled as a starting point to develop a final indicator system for industrial modernisation. Furthermore, the project partners drew up a first overview of obvious "gap areas", for which the current availability of pertinent indicators is either low or zero - even though it would be highly desirable to cover them.

Building on this, the project partners then organised further in-depth consultations on the lessons learnt with a view to the utility and pertinence of particular indicators that resulted in the exclusion of some initially proposed indicators, the inclusion of others based on additional research as well as the more concrete specification of gaps not only in terms of "areas" but also in terms of concrete indicators. Ultimately, this work resulted in a proposal for a final shortlist of indicators that are currently available or to be collected as well as recommendations on how to further develop this system to monitor industrial modernisation in the future.

2.2 Structure of the final study report

This final report summarises the conceptual and practical insights from the project, including those from the different case studies as well as the subsequent in-depth review of possible indicators. Its primary purpose is to present the project's findings, conclusions and recommendations. It reports the work performed during the different stages to the extent needed for this purpose. Overall, it pursues a twofold objective. First, it presents this project's overarching structure for a system of indicators based on "main building blocks" (sub dimensions of measurement). Second, it outlines a shortlist of the currently best available indicators for each of these building blocks.

This report focuses on proposing a pragmatically viable system of indicators that are already available to a varying degree. There will be concrete opportunities to take up the results of this project in a related project recently launched by the European Commission¹. Furthermore, it will take a long-term perspective in proposing additional indicators, whose inclusion would be desirable from a political and conceptual standpoint. These

¹ The project "Monitoring Digital Transformation and Key Enabling Technologies" (EASME/COSME/20174/043)

include both so far unavailable and currently substandard indicators. Based on lessons learnt during work in the project, moreover, the report suggests concrete steps towards improving the breadth and depth of coverage in the proposed monitoring system - as well as concrete suggestions on how the European Commission could work towards making them available in the future.

The report starts by presenting and justifying a structure for a monitoring system, followed by a detailed illustration of the different sub-dimensions of measurement ("building blocks") derived from it. Subsequently, it provides a summary of the project's findings on the availability and accessibility of pertinent indicators for these building blocks, followed by the shortlist of indicators. Finally, it presents recommendations for action to further develop the monitoring system. For the interested reader, there are summaries from the case studies in the Annex to this report.

3/ Conceptual framework for monitoring industrial modernisation

3.1 Definitions

A monitoring system on industrial modernisation has to rest on sound conceptual understanding of 'industrial modernisation'. In this project, **industrial modernisation** is used to describe the **transformation and upgrading process that aims at maintaining or increasing the competitiveness of European manufacturing in an increasingly competitive global environment**. Industrial modernisation both has to address upcoming challenges for manufacturing in Europe and respond to new opportunities of production, including the changes resulting from digitalisation and other new technologies.

Factors that affect the **ability for industrial modernisation** include:

- ▶ **Innovation capacity** to develop new and improve existing products (goods and services) and processes, including the generation of new knowledge (e.g. R&D), the adoption and usage of advanced technologies, in particular digital and key enabling technologies, and investment in new equipment, infrastructures and intangible assets;
- ▶ **Managerial and organisational capabilities** to master new challenges, including the disruptive transformation of industries (e.g. through the emergence of digital-based platforms), servitisation, changes in markets and customer demands, such capabilities include reactivity and anticipation, flexibility, and fast decision-making;
- ▶ **Skills development** in order to prepare the workforce for new requirements and new models of production and collaboration, ranging from education to vocational training and on-the-job learning and including human resource management practices such as improving workplace environments;
- ▶ **Openness** and the capacity to cooperate, build and develop clusters and networks along value chains, and to engage in joint activities with academia and the wider research and innovation community both on a regional and global scale;
- ▶ Industrial **sustainability**, including energy saving, resource-efficient and environmental friendly production processes and eco-innovative solutions.

Within the concept of industrial modernisation, the term '**industry**' refers to activities related to the manufacture of goods. Manufacturing sectors are hence the key target group of industrial modernisation efforts. However, the nature of manufacturing has changed, and increasing interaction between goods production² and services has blurred the border between manufacturing and other sectors. Today, the competitiveness of manufacturing depends on its ability to develop and market solution-oriented approaches, enter into new forms of collaboration with suppliers and clients, and complement goods with services. Industrial activities are integrated in more complex value chains. As a consequence, industry cannot be understood as the manufacturing sector only, but needs to be regarded as a much broader set of mutually dependent activities. Considering this broader scope of manufacturing is a key element in the conceptual framework. When using the term 'manufacturing' in the following, the term does not refer to the narrow concept of manufacturing industries as used in classifications of economic activities (e.g. NACE rev. 2 sectors 10 to 33) but to a more comprehensive understanding which includes other activities related to the production of goods through value chains and manufacturing clusters and networks.

Successful industrial modernisation will be reflected in a manufacturing sector that is highly competitive. Competitiveness includes the ability to sell products on global markets (export performance), which is closely linked to the ability to produce efficiently and to reach a high level of productivity. But competitiveness is not only related to short-term market results, but also to longer term performance, which is reflected in the growth of the manufacturing sector, including service activities that are closely related to manufacturing, and the sustainability of production activities in manufacturing.

² The terms 'production' and 'product' are used here in the way they are used in national accounts. Production hence refers to any economic activity that creates value added. The output of this process can be physical goods, digital goods ('knowledge products') or services. Accordingly, the term 'product' encompasses all three types of outputs.

3.2 Conceptual background

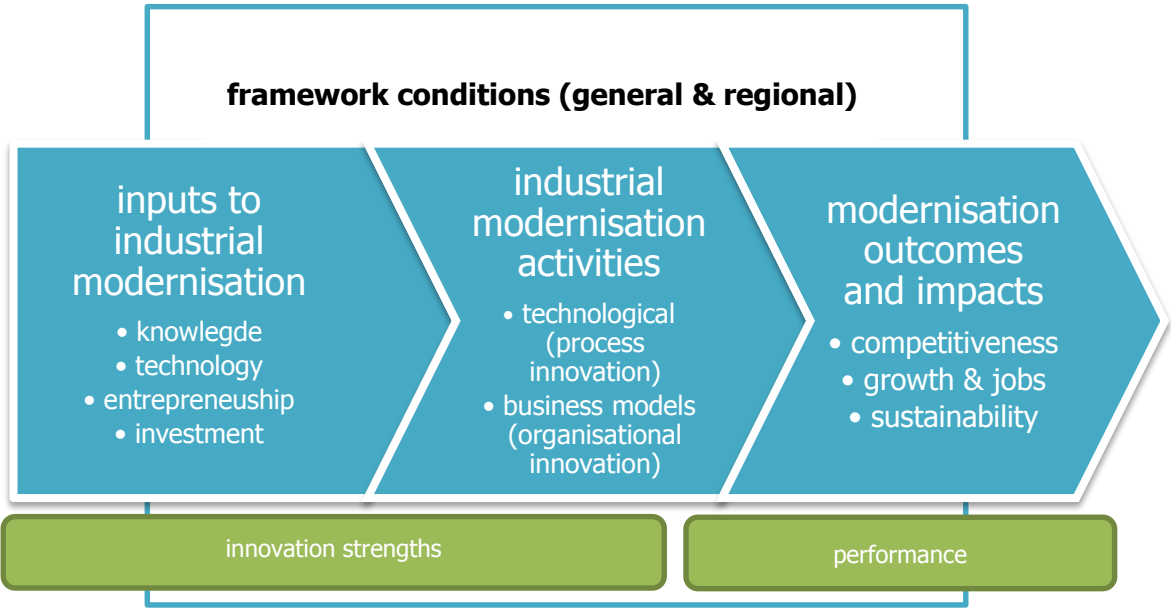
This study's final proposal for a comprehensive approach to monitoring is based on a basic understanding of industrial modernisation as a process of process and organisational innovation which is fuelled by targeted inputs, enabling framework conditions that will eventually result in a variety of desirable outcomes and impacts. In the proposed structure for monitoring, these four main areas will be given equal - or at least comparable - weight to arrive at a robust and encompassing assessment of strengths, weaknesses and bottlenecks.

In principle, this project considered industrial modernisation as a significant introduction of processes or organisation and management models at least new to the firm. Often, such modernisation is at the same time accompanied (and measurable) by the introduction of new products. However, industrial modernisation goes beyond the generation of new products and technologies - it describes a change in firms' mode of operation'. At the level of definition, it is therefore instrumental for this report to understand industrial modernisation as a bundle of process and organisational innovations, triggered by new technologies and advances in management - resulting in new products, services and combined solutions and, eventually, desirable outcomes in the context of the European Unions 2020 targets.

Figure 2 illustrates the conceptual relations between central categories of measurement as follows:

On the right, indicators related to the outcomes and impact of industrial modernisation reflect central target categories ('**performance indicators**'). They indicate to what extent industrial modernisation has served its multiple purposes of enhancing competitiveness, safeguarding growth and jobs as well as ensuring the transition towards a more sustainable production system, Towards the left, two areas capture **innovation strengths**:
 In the middle, a set of indicators refers to industrial modernisation proper, i.e. the introduction and diffusion of production processes and business models that are at least new to the firm,
 On the left, a set of indicators reflects targeted inputs to industrial modernisation. Industrial modernisation rests on these activities as indispensable preconditions.
 In the background, a final subgroup of indicators covers enabling framework conditions at different levels. Some of those relate to **regional specialisation**, others to **business trends and environment**. In the following, both areas will be considered in separation, as was foreseen in the design of the case studies.

Figure 2: Conceptual Framework for Industrial Modernisation

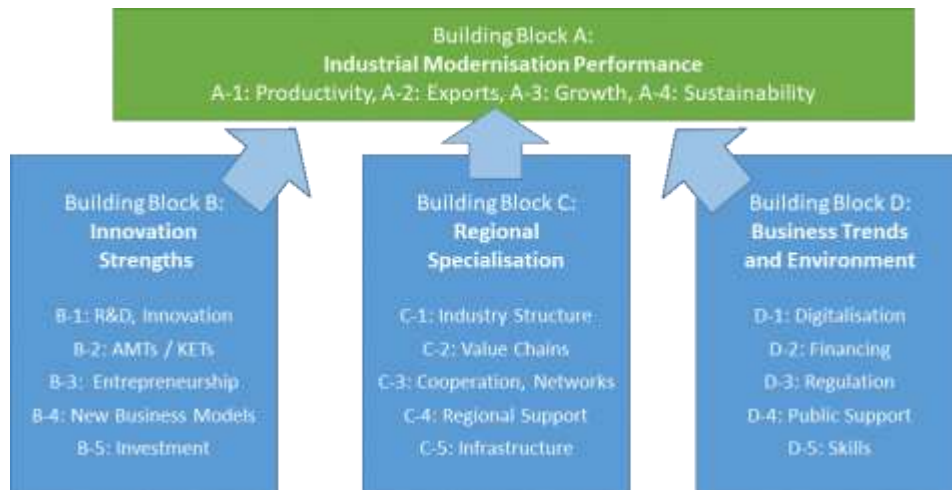


Source: authors, based on conceptual work in the project

Below, Figure 3 illustrates the structure for a to be proposed monitoring system that this project has adopted from the outset. It defines the abovementioned range of performance indicators as an overarching target dimension under which it subsumes three main "building blocks" of relevant measurement dimensions.

- Innovation strengths,
- Regional specialisation,
- Business trends and environment.

Figure 3: Conceptual structure for a final list of indicators



Source: authors, based on conceptual work in the project

By disentangling the building blocks from a strictly conceptual framing, this approach provides higher degrees of freedom in collecting what is currently available - as it allows to adapt the selection criteria slightly between the building blocks. For regional specialisation, for example, availability in regional disaggregation will evidently be essential, while for other dimensions, it is not necessarily an absolute requirement.

With a view to all dimensions, the final selection of indicators must reflect that industrial modernisation is a multifaceted process, regarding not only its scope and speed but also the very nature and primary objective of the different activities subsumed under it. For example, various earlier studies unambiguously showed that the introduction of different technologies and business models not only requires different means, but also serves different purposes (e.g. improving productivity vs. improving sustainability). Thus, different industrial modernisation efforts commonly produce equally different, in part even contrary outcomes.

The above structure also anticipates a central point to be repeated later. At the level of industrial modernisation performance, the proposed indicators yield themselves readily to the definition of target values by nature and purpose. While this of course limits the message, many performance indicators can in principle be used 'on aggregate' without further differentiating by sectors, regions or other relevant dimensions.

The ways in which industrial modernisation is facilitated or caused, in contrast, are manifold, part recursive and overlapping. Against this background, the definition of simple target values in the three foundational dimensions would be contrary to both common sense and scientifically established findings. Instead, such indicators should be used as a tool of guidance to inform policy on specific pathways of causation for specific sub targets of industrial modernisation (e.g. competitiveness and productivity, growth and jobs, sustainability), tracing those back to specific modernisation activities and, ultimately, required inputs and framework conditions. Against this background, they should to the extent possible be thematically, sectorally and regionally specific. With a view to the three foundational dimension it is therefore next to indispensable that relevant data can be disaggregated by relevant dimensions be those sectoral or regional.

3.3 Building blocks and dimensions

The conceptual framework of industrial modernisation used in this project consists of four main building blocks which include an output level and three groups of drivers of industrial modernisation (see Figure 3):

At the **output level**, industrial modernisation refers to the performance of the manufacturing sector. Four dimensions of performance are considered to be particularly important:

- ▶ **Productivity (A-1)** relates outputs and inputs of the production process. Productivity in physical terms (e.g. number of units produced per unit of input) is a measure of the efficiency of a given production process. Productivity in monetary terms (e.g. value added per unit of input) includes a valorisation of the physical output by the market, as it weights the physical output by its market price. Inputs include all types of capital used in the production process (human capital, fixed assets such as machinery and equipment, intangible assets such as software, intellectual property, organisational capital, and reputation). The production process is not limited to the manufacture of a good but includes all economic activities of a producing unit (e.g. also logistics, marketing, administration).
- ▶ **Exports (A-2)** refer to the sale of products to clients located outside the home market. Home markets are usually equivalent to national economies but may also refer to other geographic delineations of markets. The ability to export products shows that manufacturing in a given region can compete with manufacturing in the export market. As exporter usually face additional hurdles as compared to domestic producers (e.g. higher transaction costs, lack of reputation), exporting often indicates a superior competitiveness.
- ▶ **Growth (A-3)** indicates the ability of manufacturing to increase its activities over time. Growth may be related to total output (sales), to value added, to employment or to the amount of capital employed in production. As a dimension of industrial modernisation, growth should be considered in a longer term rather than in short term (year to year changes) as the latter may be affected by various business cycle effects. Related to growth, is the share of manufacturing in an economies total output as this share informs about the development of manufacturing vis-à-vis other parts of the economy.
- ▶ **Sustainability (A-4)** describes the ability of manufacturing to produce in a way that limits negative externalities on the environment (e.g. air, water, noise emissions) and increases the re-use of materials (circular economy). Given the increasing global challenges of climate change and resource scarcity, a sustainable production of goods is becoming ever more important for industrial modernisation.

Innovation strengths summarise all capabilities and capacities required for advancing manufacturing and for meeting the upcoming challenges:

- ▶ **R&D (B-1)** covers all activities for generating new knowledge relevant to product or process innovation. Own R&D activities in manufacturing are not only the base for upgrading production by own efforts, they are often also the basis for absorbing external knowledge and integrating others' technologies. **Innovation** captures the introduction of new or improved products or processes. Innovation can either rest on own R&D efforts or be based on using or adopting others' knowledge.
- ▶ **Advanced manufacturing technologies (AMTs) (B-2)** are critical enablers for many modernisation efforts in industry. AMTs are related to key enabling technologies (KETs) which include biotechnology, nanotechnology, microelectronics, photonics and new materials often provide the technology base for product innovation in manufacturing. Another increasingly important enabling technology is related to software technologies such as artificial intelligence and other big data analytics, block chain technologies, and supercomputing. AMTs typically represent a smart combination of different KETs (often characterised by high performance manufacturing technologies plus ICT-enabled technologies plus sustainable manufacturing technologies) with the aim to improve production processes in terms of precision, speed, flexibility, cost-effectiveness, capacity etc.
- ▶ **Entrepreneurship (B-3)** refers to the start-up of new manufacturing activities by establishing new firms and by scaling up young firms to an economically efficient size. In addition, entrepreneurship is also linked to the development and implementation of new forms of manufacturing by exploring and exploiting new opportunities in production process, linking of value chains, marketing and customer integration, cooperation and business models.
- ▶ **New business models (B-4)** describe novel approaches in manufacturing to manage production and market products, usually involving new forms of interaction with suppliers, clients and other business partners. While new business models have been critical for industrial modernisation ever since, digitalisation has changed the opportunities for new business models drastically.

- ▶ **Investment (B-5)** covers all activities to enlarge or update the stock of fixed and intangible assets required for manufacturing activities. Investment can take place by purchasing or in-house production of capital goods, but also includes other forms of enlarging the amount of assets that can be used in production (e.g. leasing). Mergers and acquisitions of existing firms or parts of firms is not considered investment in the context of industrial modernisation. When investing in additional assets, the newly added assets usually represent the most updated (modern) version of assets available (e.g. the newest generation of a machine or a software version). For that reason, investment is closely linked to industrial modernisation.

Regional specialisation takes into account the specific role of openness, collaboration, value chains and clusters for a successful transformation of the manufacturing sector. In this context, regional specialisation does not only refer to the relative importance of manufacturing activities within a region, but also to the entire ecosystem of a region that is relevant for goods production activities, including regional support (e.g. intermediaries) and the infrastructure available to industry:

- ▶ **Industry structure (C-1)** informs about the relative importance of different manufacturing activities and related activities within a certain region. Industry structure can be used to determine the significance of manufacturing activities and the regional distribution of specific industries. If a certain industry has a high relative importance for a region, this often goes along with the development of a specialised infrastructure and a particular attention of regional policy actors for this industry.
- ▶ **Value chains (C-2)** are a key component of any manufacturing activity. Manufacturing strongly builds upon a sophisticated division of labour among material and technology suppliers, service providers, producers and customers, including logistics and data flows among the actors at different stages of the value chain. Value chains hence not only refer to flows of goods (as represented in input-output tables), but also to the exchange of information and the organisation of the entire process. Changes in value chains, e.g. through outsourcing and insourcing, can have huge impacts on industrial modernisation. Value chains can have a regional focus, but they can also involve actors from around the globe. The geographic scope of value chains is a major determinant of input prices and terms of trade.
- ▶ **Cooperation and networks (C-3)** represent ways of interaction among manufacturing firms and between manufacturing and other relevant actors in order to perform manufacturing activities. Other actors may include actors along the value chain, knowledge producing and disseminating actors (e.g. universities, research institutes) and public actors (governments, agencies). If cooperation and networks are regionally focussed and take place within a certain industrial value chain, often the term cluster is used to describe this dense and focussed interaction network.
- ▶ **Regional support (C-4)** comprises all forms of activities in a region that are intended to facilitate manufacturing activities directly or indirectly. Such support may include consultancy, financing, infrastructure supply. Regional support is often targeted at SMEs and at strengthening cooperation, networks and clusters in a region.
- ▶ **Infrastructure (C-5)** refers to all long-lasting tangible assets outside the manufacturing sector but needed to perform manufacturing activities efficiently and effectively. This physical infrastructure includes transport and communication networks, supply of energy and water, and waste removal and recycling. As any physical infrastructure is localised, it provides an important regional input to any manufacturing activity. Other types of infrastructure (e.g. financial and social infrastructure) are discussed below under business trends and environment.

Business trends and environment cover a variety of framework conditions and changes in the business world that can act either as drivers or obstacles to industrial modernisation efforts:

- ▶ **Digitalisation (D-1)** is currently the single most important business trend for industrial modernisation. There are many signs that digitalisation shapes manufacturing fundamentally and enters into a new era of industry ('Industry 4.0'). As a driver for industrial modernisation, digitalisation impacts many of the dimensions discussed above, notably AMTs, new business models and the way R&D is performed, value chains, cooperation and physical infrastructures.
- ▶ **Financing (D-2)** relates to the provision of financial services and the supply of financial capital (credit, equity) to the manufacturing sector. The financing system includes private banks, insurances and other financial intermediaries as well as public actors (e.g. public venture capital funds, government banks and guarantee schemes).
- ▶ **Regulation (D-3)** comprises all legislative government activities that affect manufacturing activities directly or indirectly, including among others taxation, product law, IP law, industrial plant regulation, labour law, standardisation, data protection law, environmental regulation, and trade regulation.

- ▶ **Public support (D-4)** refers to a wide variety of government activities with a view to facilitate manufacturing activities and advance industrial modernisation. In addition to direct public support like subsidies or loans for performing certain modernisation activities, public support also relates to the provision of social infrastructure and an effective juridical system.
- ▶ **Skills (D-5)** are listed last but are among the most important framework conditions for industrial modernisation today. The changes taking place in industry as a result of digitalisation, new technologies, new forms of interaction, changes in demand and in value chains, new international competitors and many more require constant adaptations and innovations. The skills of the workforce employed in industry, as well as the skills available on the labour market, are critical for adequately responding to these changes. As a business environment factor, skills refer both to the formal qualification of people learned in education institutions (from primary to tertiary) and learning in the job through continuing education, advanced training and on-the-job learning.

One should emphasise that the important **role of services** for industrial manufacturing is captured through various dimensions in the conceptual model. First, the dimension of R&D & innovation also includes innovations of manufacturing firms in the field of services, e.g. new value-added services and new product-related services. Secondly, entrepreneurship covers start-ups in service areas and service sectors. Thirdly, new business models are very often related to new product-service combinations offered by manufacturing firms. Fourthly, the investment dimension includes investment in intangibles such as software and databases, and non-R&D innovation expenditure in the area of design which cover service-related activities. Fifthly, value chains cover the links between manufacturing and services, e.g. the purchase of service inputs. Sixthly, regional support includes support services provided to manufacturing firms that facilitate modernisation efforts. Seventhly, digital services are an important component of the digitalisation dimension. Finally, the skills dimension also captures skills related to service activities, particularly related to digital skills.

3.4 Differentiation and international comparison

While it is largely undisputed that all the dimensions listed above are relevant for industrial modernisation, their actual relative importance is impossible to determine, particularly as the relevance of each dimension varies by the specific manufacturing activity concerned, by size and other characteristics of manufacturing firms, and by location. For monitoring industrial modernisation efforts, it is hence essential to take into account the specific situation of industry.

- ▶ A key dimension in this respect is certainly the **industrial sector**. The way manufacturing operates differs substantially by the type of goods production, including the relevance of different technologies (key enabling technologies, types of advanced manufacturing technology), the way competition in the market takes place, the role of regional factors and openness, and the relevance of various business trends. It is therefore essential to differentiate an industrial modernisation monitoring system by individual manufacturing sectors as much as possible.
- ▶ A second important dimension of differentiation is the **regional** one. As manufacturing activities are dependent upon the regional environment, the same manufacturing sector may respond to the same challenge very differently in different regions.
- ▶ Finally, **size** of firms also plays a key role. Small and medium-sized enterprises (SMEs) are usually much restricted in their ability to respond to industrial modernisation challenges as compared to large enterprises.

Another layer of differentiation that is essential for a monitoring system of industrial modernisation is the role of creating new approaches to industrial modernisation versus the diffusion of already existing approaches to advance manufacturing and framework conditions that provide the right environment for industrial modernisation:

- ▶ **Creation** refers to the generation of technologies, tools, methods or other types of knowledge needed for industrial modernisation. Creative activities include, but are not limited to R&D. Creative abilities are not only required for generating new knowledge, but are also a main determinant of absorptive capacities and learning abilities which can significantly help for adopting and using external knowledge.
- ▶ **Diffusion** covers the process of adopting existing knowledge to be used to modernise industrial activities. Diffusion can take a variety of forms. One way is to purchase technology, equipment, intangible assets (such as software, IP) or other external knowledge (e.g. by contracting out R&D). Another way is through mobility of workers (e.g. hiring workers with special skills). A third one is by observing and learning from others using various channels (from trade fairs to patent files). Diffusion of knowledge and technology can take place over long distances or may be bounded to a local environment.

- ▶ **Framework conditions** include the wider setting within which industrial modernisation takes place. This setting can provide incentives for investing in modernisation, but may also impede modernisation efforts by unfavourable business environments.

For monitoring industrial modernisation, it is paramount to take the **international** (global) perspective into account. For many industrial activities, internationalisation is essential both in sourcing of inputs and in marketing of products. Internationalisation of manufacturing has taken place from the very beginning of goods production, since most goods can be traded easily while economies of scale and scope have always provided incentives for a division of labour, i.e. to concentrate a certain production activity on a few products which are produced in large quantities to serve markets far beyond the local vicinity. For this reason, almost all manufacturing activities directly or indirectly are subject to international competition, which is global competition today. Monitoring industrial modernisation in the EU has also to monitor developments taking place in other parts of the world.

4/ Indicators on industrial modernisation from existing sources

4.1 Sources for indicators

The conceptual framework presented in the previous chapter demonstrates the wide variety of factors influencing industrial modernisation. Setting up a monitoring system that covers all relevant dimensions by a comprehensive set of indicators would require a significant effort and would most likely result in a huge indicator system which will be challenging to maintain and to use for policy purposes.

In this project, the goal is to develop a monitoring system for industrial modernisation that builds upon existing initiatives rather than to develop new indicators. For this purpose, several existing scoreboards, observatories, monitoring systems and statistical databases were examined in terms of availability and quality of indicators as well as the possibilities and limitations for combining different sources (based on the case studies of this project).

We selected sources that meet the following criteria:

- ▶ **Coverage** of EU-28 (and preferable other COSME) countries;
- ▶ Use of **quantitative data** from reliable statistical sources;
- ▶ **Regular update** (i.e. one-time activities such as a single study or report were excluded).

Based on these criteria, the following EU initiatives in the area of scoreboards, observatories and monitoring systems were examined:

- ▶ KETs Observatory, including KETs Technology Infrastructures mapping
- ▶ European Cluster Observatory (ECO) / European Observatory for Clusters and Industrial Change (EOCIC), including the Regional Ecosystem Scoreboard (RES)
- ▶ Regional Innovation Monitor (RIM)
- ▶ Regional Competitiveness Index (RCI)
- ▶ European Innovation Scoreboard (EIS) and Regional Innovation Scoreboard (RIS)
- ▶ EU Industrial R&D Investment Scoreboard
- ▶ Digital Economy and Society Index (DESI)
- ▶ Digital Entrepreneurship Monitor (DEM) and Digital Transformation Scoreboard
- ▶ EU Eco-Innovation Scoreboard (Eco-IS)
- ▶ EU Resource Efficiency Scoreboard

In addition, primary sources of statistical data were examined too, including the databases provided by:

- ▶ Eurostat;
- ▶ European Patent Office (Patstat database);
- ▶ EU KLEMS (Kapital, Labour, Energy, Material, Services) database and WIOD (World Input-Output Database);
- ▶ UN organisations (particularly with respect to trade data);
- ▶ World Bank (e.g. doing business);
- ▶ OECD (particularly with respect to complementing Eurostat data for non-EU countries)

as well as data collection activities by research institutes and private organisations, such as the European Manufacturing Survey or venture capital data from Invest Europe.

4.2 Selection of indicators

For selecting indicators, the following criteria were applied:

- ▶ **Relevance:** The indicator should have a direct link to one of the dimensions of industrial modernisation that have been identified in the conceptual framework.
- ▶ **Absence of overlap:** The indicator should measure a unique aspect not measured by other indicators.
- ▶ **Directedness:** A higher indicator value should indicate a better performance in terms of industrial modernisation.
- ▶ **Coverage:** The indicator should be available for all EU-28 countries and other COSME countries.
- ▶ **Reliability:** The indicator should build upon high quality data, i.e. the data should be representative, the data should not be biased towards certain activities, firms, sectors or regions; and the data should be comparable across countries and time.
- ▶ **Timeliness:** The data should be up-to-date and updated frequently.
- ▶ **Differentiation:** The indicator should allow a breakdown by the three dimensions region, sector and firm size.
- ▶ **International comparability:** The indicator should be available for non-European countries, particularly for other countries with a strong manufacturing sector.

In the following, we provide some background information on the selection process for each building block and dimension of the conceptual model. We consider indicators in existing scoreboards, observatories and monitoring systems, but also discuss sources for potential additional indicators based on existing statistical databases.

Building Block A: Industrial modernisation performance

There are few indicators on the output dimension of industrial performance in scoreboards and observatories. However, some relevant performance indicators can be taken from existing statistical databases, e.g. national accounts statistics, trade statistics and structural business statistics. In 2018, a background study commissioned by DG Grow as part of the Single Market Integration and Competitiveness Report dealt with measuring of competitiveness,³ which is closely related to measuring the performance of industrial modernisation. From this report, indicators on productivity and exports are taken. Growth indicators can be calculated based on the same data sources. Sustainability indicators are available from scoreboards related to environmental issues.

- ▶ **Productivity (A-1):** There are no productivity indicators in existing sources. But both national account statistics and structural business statistics provide data for calculating standard indicators on productivity (labour productivity, growth of total factor productivity). Country coverage and international comparison is very good, as are breakdowns by sector. Structural business statistics also allows a breakdown by size and region.
- ▶ **Exports (A-2):** The EIS contains a relevant export-related indicator. More indicators can be calculated using trade statistics which offer a wealth of information on export performance. Linking trade data to industry data is challenging, however, due to different classification and reporting standards. This limits the reliability of some indicators.
- ▶ **Growth (A-3):** There are no growth indicators related to manufacturing in existing sources. However, national account statistics and structural business statistics provide excellent data for calculating growth indicators.
- ▶ **Sustainability (A-4):** Indicators on sustainability are available from the Eco-Innovation Scoreboard. The EU Resource Efficiency Scoreboard also offers some indicators, though these are not specific to manufacturing.

Building Block B: Innovation strengths

- ▶ **R&D, innovation (B-1):** There are several well-established indicators on R&D and innovation that can be taken from the EIS. The regional version of the scoreboard also allows for a regional breakdown. For a breakdown by sector or size, own calculations based on the underlying original statistics would be required.

³ See Peneder, M., C. Rammer (eds.) (2018), *Measuring Competitiveness*, Vienna and Mannheim: Austrian Institute of Economic Research, Centre for European Economic Research (<https://ec.europa.eu/docsroom/documents/28181>).

- ▶ **AMTs (B-2):** The KETs Observatory offers a number of indicators which are basically capturing the creation side of industrial modernisation. In order to complement the diffusion side, data from firm surveys are useful. In this respect, the European Manufacturing Survey is an appropriate source, though it covers only a limited set of countries.
- ▶ **Entrepreneurship (B-3):** Entrepreneurship is not well covered by existing scoreboards and observatories, though the European Cluster Observatory and the Regional Ecosystem Scoreboard provide some indicators. Additional indicators can be derived from business demography statistics and are offered by other international organisations and initiatives (OECD, GEM).
- ▶ **New business models (B-4):** No indicator could be found in existing sources. There are also no other statistical data sources for establishing an indicator that would meet the selection criteria.
- ▶ **Investment (B-5):** While the EIS includes one investment indicator, many more relevant indicators can be constructed using structural business statistics (SBS). The EU KLEMS database also provides reliable data on investment by sector. SBS data also allow a breakdown by size, but not by region.

Building Block C: Regional specialisation

- ▶ **Industry structure (C-1):** The ECO and the RES, based on structural business statistics, provide indicators on industry structure.
- ▶ **Value chains (C-2):** There are few relevant indicators in existing sources. The trade in value added statistics provide a number of indicators to characterise international value chains in manufacturing. More indicators can be derived from input-output tables, including WIOD for international comparisons.
- ▶ **Cooperation and networks (C-3):** The ECO and the RES contain several indicators on this dimension, including cluster-related indicators. Other scoreboards such as the EIS also offer indicators on this dimension.
- ▶ **Regional support (C-4):** The ECO and the RES provide one indicator on this dimension.
- ▶ **Infrastructure (C-5):** The ECO and the RES provide indicators. More indicators may be obtained from Eurostat's transport statistics.

Building Block D: Business trends and environment

- ▶ **Digitalisation (D-1):** The Digital Economy and Society Index (DESI) as well as the Digital Transformation Scoreboard as part of the DEM contain a wealth of indicators related to digitalisation. Only few indicators are available for manufacturing, however, while most indicators refer to the entire economy or society.
- ▶ **Financing (D-2):** The EIS as well as the RES contain some relevant indicators. More can be found in the OECD scoreboard on financing SMEs and entrepreneurship. Country coverage of this scoreboard is limited, however, and no indicators are specific to the manufacturing industry.
- ▶ **Regulation (D-3):** General indicators on the regulatory framework for businesses are available from the World Bank's Doing Business publication and are used in the ECO and the RES. These indicators are not specific to the manufacturing industry, however.
- ▶ **Public support (D-4):** The ECO and the RES offer one indicator on this dimension. In addition, the OECD scoreboard on financing SMEs and entrepreneurship contains some indicators on public financial support to SMEs, but cannot be narrowed down to manufacturing. Eurostat's Community Innovation Survey collects information on public support related to innovation.
- ▶ **Skills (D-5):** The EIS and the DESI include several skill-related indicators relevant to industrial modernisation.

The proposed indicators that can be taken from existing scoreboards and observatories are presented in Table 1. For each indicator, the table provides a definition, the source of the original data to calculate the indicator and the scoreboard, observatory or monitoring system that provides the indicator. In addition, separate columns inform about a possible breakdown by sector (NACE division), region (NUTS 2) and firm size (small, medium-sized and large firms) as well as on quality criteria (frequency of data updates, timeliness of data, country coverage, international comparability, assessment of data reliability). A final column summarises the rationale for selecting the indicator as a measure of industrial modernisation.

In total, 32 indicators have been selected on the basis of the criteria described above. Additional indicators to fill gaps and provide more detailed information are presented in section 5.

Table 1: Indicators on industrial modernisation available from existing scoreboards, observatories, monitoring systems

Dimension	Indicator	Definition	Data source	Scoreboard, Observatory	Type	Sector breakdown	Regional breakdown	Size breakdown	Frequency	Timeliness	Country coverage	International comparability	Data reliability	Rationale and caveats
Exports (A-2)	Medium/high-tech exports	Share of exports of medium and high-tech goods in total goods exports	Eurostat	EIS, RIS	Performance	no	country	no	annual	2017	EU-28, IS, IL, MK, NO, RS, CH, TR, UA	yes, for almost all countries (based on UN Comtrade data)	very high	A high share of medium and high-tech products in total exports.
Sustainability (A-4)	Material efficiency	Domestic material consumption (DMC) per capita	Eurostat	Resource Efficiency Scoreboard, Eco-IS	Performance	no	country	no	annual	2015	EU-28	no	high	Provides an indication of the total amount of resource consumption in an economy, but including non-manufacturing activities and resource consumption based on imported resources.
Sustainability (A-4)	Environmental process innovation	Share of enterprises that introduced an innovation with environmental benefits obtained within the enterprise	Eurostat	Eco-IS	Creation	NACE divisions (partly aggregated)	country (NUTS 2 based on special calculation)	SEs, MEs, LEs	irregular	2014	EU-28	no	high	A high share of process eco-innovators shows that firms are prepared to reduce the environmental impacts of their production activities.
Sustainability (A-4)	Environmental management	Number of ISO 14001 registered organisations per population	ISO	Eco-IS	Diffusion	no	country	no	annual	2017	EU-28, IS, IL, MK, NO, RS, CH, TR, UA	yes	very high	A high share of firms using environmental management systems indicates an awareness towards sustainability issues.

R&D, innovation (B-1)	Business R&D expenditure	Share of internal business R&D expenditure in value added	Eurostat	EIS	Creation	NACE divisions (partly aggregated)	country, NUTS 2	SEs, MEs, LEs	annual	2016	EU-28, IS, IL, MK, NO, RS, CH, TR, UA	all OECD	very high	R&D expenditure represent the efforts of firms to create new knowledge relevant for product or process innovation.
R&D, innovation (B-1)	SMEs with innovations	Share of SMEs who introduced at least one product or process innovation within the previous three years	Eurostat	EIS, RIS	Diffusion	NACE divisions (partly aggregated)	country, NUTS 2	SEs, MEs, LEs	biennial	2014 (update for 2016 soon)	EU-28, IS, IL, MK, NO, RS, CH, TR, UA	most OECD	high	The introduction of product or process innovation indicates that firms update their product portfolio and/or production technologies and methods.
R&D, innovation (B-1)	Sales of new products	Share of sales of product innovations in total sales	Eurostat	EIS, RIS	Diffusion	NACE divisions (partly aggregated)	country, NUTS 2	SEs, MEs, LEs	biennial	2014 (update for 2016 soon)	EU-28, IS, IL, MK, NO, RS, CH, TR, UA	most OECD	high	A high share of new product sales indicates that the product portfolio has been updated and modernised.
R&D, innovation (B-1)	Design applications	Number of industrial design applications per value added	EUIPO	EIS, RIS	Creation	no	country, NUTS 2	no	annual	2017	EU-28, IS, IL, MK, NO, RS, CH, TR, UA	no	very high	A high number of industrial designs indicates that firms renew products by using novel design approaches, which are likely to respond to changing user demands.
AMTs (B-2)	KET generation in production	Share of KETs in total production	Eurostat (special calculation required)	KETs Observatory	Creation	no	country	no	annual	2013 (update will follow soon)	most EU-28 countries	yes, but with significant additional assumptions	high (but difficult to extend to whole AMT field)	This indicator reflects the production activity of a country in KETs. Hence, it reflects the capability of manufacturing in this fields. Moreover, production capability and know-how are often a key source prerequisite for further innovation in Advanced Manufacturing Technologies.

AMTs (B-2)	KET and AMT patents	KETs/AMTs patent applications per value added	PAT-STAT (country level) REGPAT (Patents, regional level)	KETs Observatory	Creation	no	country, NUTS 2	no	annual	2011 (update will follow soon)	complete	almost all countries globally	high	KETs/AMT patenting indicates technological competitiveness of a country. It is often an important asset for commercialisation of innovation related to industrial modernisation.
Entrepreneurship (B-3)	Opportunity driven start-ups	Ratio between the share of persons involved in improvement-driven entrepreneurship and the share of persons involved in necessity-driven entrepreneurship	GEM	EIS	Creation	no	country	no	annual	2017	EU-28, IS, IL, MK, NO, CH, TR	yes	high	A strong orientation of entrepreneurial attitudes towards the utilisation of opportunities will help to produce more start-ups oriented at scaling-up and making a larger impact on the existing structure of manufacturing. The indicator is not specific to manufacturing, however.
Entrepreneurship (B-3)	Gazelles	Share of gazelles in all start-ups	Eurostat	EOCIC	Creation	NACE divisions	country	no	annual	2016	EU-28	no	high	A high share of gazelles indicates that industry is modernised through fast growing start-ups; the fast growth indicating that the start-ups' business models serve demand.
Investment (B-5)	Non-R&D innovation expenditure	Sum of total innovation expenditure of enterprises excluding R&D expenditures	Eurostat	EIS, RIS	Diffusion	NACE divisions (partly aggregated)	country, NUTS 2	SEs, MEs, LEs	biennial	2014 (update for 2016 soon)	EU-28, MK, NO, RS, CH, TR, UA	no	medium	Non-R&D innovation expenditure complement the indicator on R&D expenditure by covering other investment in innovative assets.
Industry structure (C-1)	Specialisation in clusters of emerging industries	Share of emerging industries in total economic activity	Orbis	ECO, RES	Creation	no	country, NUTS 2	no	annual	2017	EU-28	yes	high	Specialisation in clusters of emerging industries can reflect about the industrial dynamics ongoing in the region in terms of moving to higher-value added activities in the value chain.

Cooperation, networks (C-3)	International co-publications	International co-publications in themes relevant for industrial modernisation per population	Scopus	RES	Creation	no	country, NUTS 2	no	annual	2017	EU-28	yes	high	Co-publications indicate cooperation with other knowledge actors, particularly in science.
Cooperation, networks (C-3)	International co-inventions	International co-inventions in themes relevant for industrial modernisation per population	EPO	RES	Creation	no	country, NUTS 2	no	annual	2017	EU-28	yes	high	Co-inventions indicate cooperation with other knowledge actors, particularly in industry.
Cooperation, networks (C-3)	Innovation cooperation	Share of SMEs cooperating with others on innovation	Eurostat	EIS, RIS	Creation	NACE divisions (partly aggregated)	country, NUTS 2	SEs, MEs, LEs	biennial	2014 (update for 2016 soon)	EU-28	no	high	A high share of cooperating SMEs indicates that SMEs are prepared to take up external knowledge for modernising their activities.
Regional support (C-4)	Support services	Availability of support services to enterprises through cluster organisations		ECO, RES	Framework	no	country, NUTS 2	no	irregular	2014	EU-28	no	medium	Regional support infrastructure can help SMEs to adopt new technologies. The indicator is not specific to manufacturing, however, and may include activities of cluster organisations not related to SMEs.
Infrastructure (C-5)	Transport infrastructure	Average of motorway and railway potential accessibility	Own calculations based on Eurostat, national statistics	RES, RCI	Framework	no	country, NUTS 2	no	irregular, but slowly changing over time	2014	EU-28	no	high	Access to good infrastructure is a basis for efficient goods production by easing exchange of goods (both for inputs and sales).

Infra-structure (C-5)	4G coverage	Share of households with 4G coverage	IHS and Point Topic	DESI	Frame work	no	country	no	irre-regular	2016	EU-28	no	high	A high 4G coverage indicates that new digital infrastructure is taken up quickly, which can help industrial modernisation that rests on access to new digital infrastructure.
Digitali-sation (D-1)	Broad-band penetra-tion	Number of enterprises with a maximum contracted download speed of the fastest fixed internet connection of at least 100 Mb/s	Eurostat	EIS	Diffu-sion	NACE divisions (partly aggre-gated)	country	SEs, MEs, LEs	annual	2017	EU-28, MK, NO, RS, TR, UA	yes, but from other data sources	high	The use of broadband with high download speed is a precondition for many digitalisation applications relevant to Industry 4.0.
Digitali-sation (D-1)	eCom-merce	Share of sales from eCommerce in total turnover of SMEs	Eurostat	DESI	Diffu-sion	NACE divisions (partly aggre-gated)	country	SEs, MEs, LEs	annual	2017	EU-28, MK, NO, RS, TR, UA	no	high	A high share of sales from eCommerce in SMEs indicates that SMEs are using modern ways of commercialising products more intensively.
Digitali-sation (D-1)	Business Digi-tisation	Index of the adoption of 5 technologies: electronic information sharing, RFID, social media, eInvoices, cloud services	Eurostat	DESI	Diffu-sion	NACE divisions (partly aggre-gated)	country	SEs, MEs, LEs	annual	2017	EU-28, MK, NO, RS, TR, UA	no	high	A higher index shows that emerging digital technologies are used more broadly in the business sector, which can contribute to modernisation efforts.
Financing (D-2)	Venture capital	Private equity raised for early stage, expansion and replacement per value added	Invest Europe	EIS	Frame work	no	country	no	annual	2017	EU-28, IL, NO, RS, CH, UA	yes, but from other data sources	high	A high volume of venture capital eases the financing of innovative young firms and hence their contribution to modernising industry.

Financing (D-2)	Country Credit Rating	Index based on an assessment by the Institutional Investor Magazine Ranking	IMD	RES	Frame work	no	country	country	annual	2017	EU-28	most countries	medium	A high index shows that the access to credit is rather easy which should help firms to invest into modernisation activities.
Regulation (D-3)	Time to start business	Number of calendar days that are required for starting a business	World Bank	RES	Frame work	no	country	country	annual	2017	EU-28, IS, MK, NO, LI	all countries	high	A high indicator shows that new businesses can be established quickly, which should encourage potential entrepreneurs to start new ventures.
Regulation (D-3)	Protecting minority investors	Index based on six sub-indices (disclosure, director liability, shareholder suits, shareholder rights, ownership and control, corporate transparency)	World Bank	RES	Frame work	no	country	no	annual	2017	EU-28, IS, MK, NO, LI	all countries	high	Protecting minority investors can spur the inflow of investment from abroad, which will equip domestic firms with additional capital that can be used to upgrade production activities.
Regulation (D-3)	Strength of legal rights	Index ranging from 0 to 12	World Bank	RES	Frame work	no	country	no	annual	2017	EU-28, IS, MK, NO, LI	all countries	high	Strong legal rights can encourage investors from abroad to invest in the local economy, providing additional impulses for upgrading of industry.
Public support (D-4)	Financial support to innovation	Share of innovation active firms receiving public financial support for innovation	Eurostat	RES (discontinued)	Creation	NACE divisions (partly aggregated)	country, NUTS-2	SEs, MEs, LEs	biennial	2014 (update for 2016 soon)	EU-28	no	high	A high share of innovating firms receiving public funding shows that the public support system is addressing innovation issues broadly and hence provides support to increasing innovation strength of firms.

Skills (D-5)	Lifelong learning	Share of 25 to 64 years old persons with training	Eurostat	EIS, RIS	Frame work	no	country, NUTS-2	no	annual	2017	EU-28, IS, MK, NO, RS, CH, TR	no	high	A high participation rate in continuous learning of adults indicates that the knowledge base of the workforce is updated regularly.
Skills (D-5)	Firms with ICT training	Share of enterprises that provided any type of training to develop ICT-related skills of their personnel	Eurostat	EIS	Diffu-sion	NACE divisions (partly aggregated)	country	SEs, MEs, LEs	annual	2017	EU-28, IS, MK, NO, RS	no	high	A high share indicates that training on ICT skills is widespread will be beneficial to modernisation efforts which increasingly rest on the use of digitalisation.
Skills (D-5)	ICT Specialist Skills	Share of persons with ICT skills in total employment	Eurostat	DESI	Frame work	NACE divisions (partly aggregated)	country	no	annual	2017	EU-28	no	high	A high share of persons with ICT skills will allow firms to more easily find workers with the skills needed for industrial modernisation.

Source: authors, based on conceptual work in the project

The 32 indicators are taken from the following existing observatories and scoreboards:

- ▶ 12 from the European Innovation Scoreboard
- ▶ 8 from the Regional Ecosystem Scoreboard
- ▶ 4 from the Digital Economy and Society Index
- ▶ 3 from the European Cluster Observatory and the European Observatory for Clusters and Industrial Change
- ▶ 3 from the EU Eco-Innovation Scoreboard
- ▶ 2 from the KETs Observatory

A main challenge for setting up an indicator system to monitor industrial modernisation based on existing scoreboards, observatories and monitoring systems is to curtail the indicators to manufacturing and to break indicators down by manufacturing sector. While many indicators would principally allow for a differentiation by NACE sector, the existing sources do not provide this breakdown. Consequently, one would need to calculate the indicators for individual manufacturing sectors based on the data from the original data sources. For producing indicators for individual manufacturing sectors, we proposed the following sector breakdown (Table 2).

Table 2: Proposed sector breakdown for indicators for which a NACE breakdown is available

Short name	NACE rev. 2	NACE rev. 1.1
Total Manufacturing	C	D
Food, beverages, tobacco	10-12	15-16
Textiles, clothing, leather products	13-15	17-19
Wood and paper products, printing	16-18	20-22 ^{a)}
Chemicals, pharmaceuticals, petroleum	19-21	23-24
Plastics, rubber, non-metallic mineral products	22-23	25-26
Metals and metal products	24-25	27-28
Electronics, electrical equipment, instruments	26-27	30-33 ^{b)}
Machinery and equipment	28	29
Vehicles	29-30	34-35
Furniture, other products, repair and installation	31-33	36-37 ^{c)}

a) Includes publishing (not part of manufacturing in NACE rev. 2)

b) Includes medical products (part of section 32 in NACE rev. 2)

c) Includes recycling (not part of manufacturing in NACE rev. 2), excludes repair and installation

A similar situation occurs when it comes to break down indicators by size class. Some sources offer indicators specific to SMEs, usually applying a 250 employees' threshold as the upper limit, but different thresholds for excluding micro enterprises. For all proposed indicators, no differentiation between small enterprises and medium-sized enterprises is available. For many indicators, the underlying statistical data do not allow for any size class breakdown.

For those indicators for which a breakdown by size class is possible, we propose to use the following four classes:

- ▶ micro enterprises: 0 to 9 employed persons
- ▶ small enterprises (SEs): 10 to 49 employed persons
- ▶ medium-sized enterprises (MEs): 50 to 249 employed persons
- ▶ large enterprises (LEs): 250 or more employed persons

The situation is somewhat better with regard to a regional breakdown since the Regional Innovation Scoreboard and the Regional Ecosystem Scoreboard already offer indicators at the NUTS 2 level. For most other indicators, however, no such breakdown exists, and for most of them, a breakdown by NUTS 2 is not possible due to lack of regional data in the original data sources.

5/ Existing indicator gaps and proposals for filling the gaps

5.1 Identifying gaps in existing scoreboards and observatories

The list of indicators shown in Table 1 is the starting point for identifying gaps in coverage by existing observatories and scoreboards. There can be different types of gaps:

- ▶ On a **conceptual level**, gaps appear if dimensions of industrial modernisation are not covered adequately. On the one hand, this includes missing indicators for important dimensions of industrial modernisation. On the other hand, existing indicators may be too unfocused on industrial modernisation, but mainly capturing phenomena not related to the manufacturing sector. In addition, existing indicators may focus on creation or diffusion only.
- ▶ Lack of **data quality** (reliability, comparability, timeliness) can be another source of gaps.
- ▶ Gaps can also refer to a lack of **data differentiation**, i.e. if existing indicators cannot be differentiated by sector, region or firm size.
- ▶ Another gap relates to a lack of **country coverage** when existing indicators do not cover the EU-28 plus other COSME countries, or international comparison is not possible.

Gaps are identified by examining Table 1. For likely conceptual gaps, the indicators listed in Table 1 are compared with the conceptual discussion of each dimension of industrial modernisation in chapter 3.3.

Table 3 summarises the findings of the gap analysis. Four dimensions are not covered at all by existing indicators (productivity, growth, new business models, and value chains). Other dimensions are covered by just one indicator or by indicators that capture very specific topics and not all relevant aspects of a dimension. In addition, for some dimensions the existing indicators show gaps in terms of breakdowns and country coverage. Data quality gaps are not an issue, reflecting that the indicators used in existing scoreboards and observatories have been selected with a view on high data quality. For three dimensions, no gaps have been found (sustainability, R&D/innovation, cooperation/networks) implying that these dimensions are well-covered by indicators from existing sources.

For each dimension for which gaps have been identified, we looked for appropriate sources to fill the gaps. The rightmost column in Table 3 summarises the findings of this effort. Only in a few cases, no appropriate sources could be found. These remaining gaps and potential approaches to close the gaps in future are discussed in the next section.

The following section briefly discusses the additional indicators that are proposed for completing the monitoring system on industrial modernisation.

Table 3: Gaps in indicator coverage by existing scoreboards and observatories

Dimension	Conceptual gaps	Data quality gaps	Data differentiation gaps	Coverage gaps	Potential sources to fill gaps
Productivity (A-1)	No indicators				Structural business statistics, national accounts statistics, EU KLEMS
Exports (A-2)	No SME-related indicators No indicators on export intensity/performance		No sector and size breakdown		Trade statistics
Growth (A-3)	No indicators				Structural business statistics, national accounts statistics
Sustainability (A-4)					
R&D, innovation (B-1)					
AMTs (B-2)	No diffusion indicators on the use of AMT		No sector and size breakdown		European Manufacturing Survey*
Entrepreneurship (B-3)	No indicators on contribution of start-ups to total economic activity (employment, sales etc.)		No regional breakdown		Business demography statistics,
New business	No indicators				No appropriate sources

models (B-4)					found
Investment (B-5)	No indicators on most categories of tangible and intangible investment			No international comparison	Structural business statistics, national accounts statistics, EU KLEMS
Industry structure (C-1)	No indicators on the relative importance of manufacturing			No international comparison	Structural business statistics, national accounts statistics, EU KLEMS
Value chains (C-2)	No indicators				Trade in value added statistics (OECD), input-output statistics (WIOD)
Cooperation, networks (C-3)					
Regional support (C-4)	No indicators on financial support, no indicators on demonstration or competence centre		No sector and size breakdown	No international comparison	No appropriate sources found
Infrastructure (C-5)	No indicators on energy supply, difficult to calculate and update indicator on transport infrastructure		No sector and size breakdown		Transport statistics
Digitalisation (D-1)	No indicators related to Industry 4.0		No regional breakdown		Private data providers
Financing (D-2)	No indicators on financing obstacles for SMEs		No regional, sector and size breakdown		OECD Scoreboard Financing SMEs and Entrepreneurs
Regulation (D-3)	No indicators on manufacturing-specific regulations		No regional, sector and size breakdown		No appropriate sources found
Public support (D-4)	No indicators on public support outside innovation			No international comparison	OECD Scoreboard Financing SMEs and Entrepreneurs
Skills (D-5)				No international comparison	No appropriate sources found

* The European Manufacturing Survey (EMS) is a private initiative and currently carried out in 10 EU member states on a triennial base. Filling the data gap for the diffusion of AMT would require an extension of the EMS to all member states and an agreement with the data producers on how to access the data needed for calculating the proposed indicators.

Source: authors, based on conceptual work in the project

5.2 Proposed indicators to fill gaps in coverage by existing scoreboards and observatories

In order to close these gaps, we examined existing original data sources (statistics) as well as scoreboards provided by other organisations and initiatives. Table 4 shows the additional indicators which we propose for filling the gaps. For each indicator, the same details are provided as in Table 1. In total, we propose 25 additional indicators:

- ▶ 2 indicators cover the performance dimension '**productivity**'. The indicator 'labour productivity' is a standard indicator for measuring the productivity level. It can be calculated from official statistics (structural business statistics) and can be broken down by sector, region and size class. Using comparable data from OECD sources or from WIOD allows for an international comparison. A second indicator on total factor productivity growth rests on the EU KLEMS database. This indicator captures the dynamic dimension of productivity.
- ▶ 3 indicators are proposed for measuring **export** performance: Revealed comparative advantage is a standard indicator in trade analysis showing a relative export advantage of a country. Trade balance informs about the export orientation of manufacturing when controlling for the amount of imports. Both indicators are taken from Eurostat trade statistics. For international comparison, OECD data can be used. Both indicators can be broken down by sector, but not by region. Another indicator on the share of SMEs in total exports allows to analyse export performance by firm size and the role of SMEs for exporting. This indicator is available from Structural Business Statistics.

- ▶ 2 indicators represent the performance dimension '**growth**'. The change in the share of manufacturing in total value added (GDP) informs about the relative growth performance of industry as compared to a country's total economic growth. The real change in manufacturing value added shows whether manufacturing is growing in a country. Both indicators are taken from Structural Business Statistics or National Accounts Statistics and can be broken down by sector, region and size. Comparable OECD data allows for international comparison.
- ▶ 3 indicators complement the **AMTs** indicators from the KETs Observatory with a view on diffusion. While the KETs Observatory includes the dimension 'diffusion', the indicators used for this dimension refer to the production, export and demand of goods that are based on new KETs, but not on the use of advanced manufacturing process technology in manufacturing firms as a process technology. The latter is of critical importance for industrial modernising, however. Since official statistics do not provide such data, we propose to use, as a starting point, data from the European Manufacturing Survey (EMS). While this survey offers very good measures on the diffusion of AMTs, it only covers a limited set of countries and does not allow for international comparison beyond Europe. The two proposed indicators measure the current and the planned use of AMTs. EMS data allows for a sector and size breakdown. In addition, we propose to use data on the use of robots as a third indicator. Though robots are only one type of AMT, they represent an important technology in many manufacturing sectors. Data on robots are also available for countries outside the EU.
- ▶ 1 indicator on **entrepreneurship** measures the economic impact of start-ups (Share of employment in firms established in the past five years in total employment). The indicator uses Eurostat data (Business Demography Statistics). The indicator can be broken down by sector. International comparison can be made for some countries based on similar data from the OECD entrepreneurship data base.
- ▶ 3 indicators on **investment** cover important aspects of investment not represented by indicators from existing observatories and scoreboards: investment in machinery and equipment, investment in ICT hardware, and investment in software and databases. Data is available from Eurostat (Structural Business Statistics) or from EU KLEMS. The latter data base also provides data for an international comparison.
- ▶ 1 proposed indicator on the share of manufacturing in total economic activities complements the dimension '**industry structure**'. This indicator rests on Eurostat data (Structural Business Statistics) and can be broken down by region, sector and size class. OECD data allows for an international comparison.
- ▶ 4 indicators are proposed to measure the dimension '**value chains**'. A first indicator 'industrial services' captures the use of knowledge-intensive services (such as computer programming, other IT services, engineering, R&D) used by the manufacturing sector. This indicator can be calculated from input-output table and allows a break down by sector. Using the WIOD database would allow for international comparison. The second indicator 'value added in exports' measures the share of domestic value added in gross exports and indicates the role of domestic production for goods exports. A third indicator on domestic value added in final demand captures the role of the demand side for triggering manufacturing. The final indicator measures the share of inputs from outside the EU in total value added and provides an indication of the global integration of manufacturing value added chains. All three indicators can be taken from the Trade in Value Added Statistics provided by the OECD.
- ▶ We refrained from proposing further value-added indicators based on input-output tables (e.g. share of domestic inputs from other manufacturing sectors in manufacturing output) since it is not possible to establish an optimum level for such indicators that can be used to evaluate whether a country is doing well or not. Indicators from input-output statistics in general strongly represent the specific industry structure of a country, reflecting differences in specialisation patterns. From a theoretical point of view, there is no clear way to determine whether a certain specialisation pattern is superior over another. As a general rule, specialisation emerges from using comparative advantages of countries, and every country will follow that specialisation pattern that best utilises its specific resources.
- ▶ 2 additional indicators in the field of **infrastructure** are intended to measure missing aspects. One indicator on energy supply relies on price data for gas and electricity for non-household users which are provided by Eurostat (Energy Statistics). The other indicator measures the supply of transport infrastructure with respect to motorways and high-speed railways. Both indicators cannot be broken down by sector, size or region. There is also no international comparable data available.
- ▶ 2 additional indicators on **digitalisation** cover the use of machine-to-machine communication and the availability of data professionals. Both represent important aspects of industry 4.0 applications. This data is provided by a private source. A breakdown by sector, size or region is not possible while the data sources allow for international comparison.

- ▶ 1 additional indicator on **financing** covers the level of interest rates of loans for SMEs, using data provided by the OECD and published in the Scoreboard 'Financing SMEs and Entrepreneurs'.
- ▶ 1 additional indicator on **public support** covers public support for general investment activity, again using the OECD Scoreboard 'Financing SMEs and Entrepreneurs'.

Table 4: Proposed indicators on industrial modernisation to fill gaps in existing scoreboards and observatories

Dimension	Indicator	Definition	Data source	Scoreboard, Observatory	Type	Sector breakdown	Regional breakdown	Size breakdown	Frequency	Timeliness	Country coverage	International comparability	Data reliability	Rationale and caveats
Productivity (A-1)	Labour productivity (A-1-1)	Value added per hour worked	Eurostat	none	Performance	NACE divisions	country (NUTS 2 for value added per person employed)	SEs, MEs, LEs	annual	2016	EU-28, IS, IL, MK, NO, RS, CH, TR, UA	for OECD countries (based on STAN or WIOD)	very high	Output per labour input informs about the efficiency of the production process. The indicator is affected by capital intensity: if capital intensity (capital to labour ratio) is high, labour productivity will c.p. be higher.
Productivity (A-1)	Total factor productivity growth (A-1-2)	Change in value added minus change in labour input minus change in capital input	EU KLEMS	none	Performance	NACE divisions	country	no	annual	2015	EU-28	USA, other countries from WIOD data base	very high	Growth in total factor productivity informs about the progress made in increasing efficiency of the entire production process.
Exports (A-2)	Revealed comparative advantage (RCA) (A-2-2)	Share of a sector's exports in total exports in a given country divided by the respective share for all countries	Eurostat	none	Performance	NACE divisions	country	no	annual	2016	EU-28	yes, for almost all countries (based on UN Comtrade data)	very high	A higher RCA indicates that the respective sector in the country considered has a stronger position on export markets compared to the same sector in other countries.
Exports (A-2)	Trade balance (A-2-3)	Exports minus imports per value added	Eurostat	none	Performance	NACE divisions	country	no	annual	2016	EU-28	yes, but requires linking of UN Comtrade data and	high	A positive trade balance indicates that a sector in a country is able to sell its products abroad and at the same time compete. The indicator requires

												value added data (e.g. OECD STAN database)		linking trade statistics (exports, imports) and production statistics (value added).
Exports (A-2)	Export share of SMEs (A-2-4)	Share of exports in total sales of SMEs	Eurostat	none	Performance	NACE divisions	country	SEs, MEs, LEs	annual	2016	EU-28	no	high	A high export share of SMEs indicates that also smaller firms are able to produce on a competitive level.
Growth (A-3)	Change in manufacturing share (A-3-1)	Change in the share of manufacturing sectors in total value added	Eurostat	none	Performance	NACE divisions	country, NUTS 2	SEs, MEs, LEs	annual	2017	EU-28, IS, IL, MK, NO, RS, CH, TR, UA	for OECD countries	very high	An increase in the share of manufacturing in total value added shows that manufacturing is able to compete successfully over other economic activities in employing scarce resources.
Growth (A-3)	Change in real value added (A-3-2)	Growth rate of real value added in manufacturing	Eurostat	none	Performance	NACE divisions	country, NUTS 2	SEs, MEs, LEs	annual	2017	EU-28, IS, IL, MK, NO, RS, CH, TR, UA	for OECD countries	very high	A high growth of real value added is an indicator for competitiveness.
AMTs (B-2)	AMT use in production (B-2-3)	Share of firms that are using AMT in their production processes	European Manufacturing Survey	none	Diffusion	NACE sections and divisions, but depending on sample size by country	country	SEs, MEs, LEs	triennial	2015 (update for 2018 soon)	AT, HR, DK, DE, NL, PT, SR, SI, ES, CH (proprietary data)	no	generally high, in some countries sample size is limited	The indicator measures the use of AMT in manufacturing firms, i.e. the de facto state of play with a view to industrial modernisation.
AMTs (B-2)	Planned AMT use in production (B-	Share of firms that have concrete plans to	European Manufacturing	none	Diffusion	NACE sections and divisions, but	country	SEs, MEs, LEs	triennial	2015 (update for 2018)	AT, HR, DK, DE, NL, PT, SR, SI, ES, CH	no	generally high, in some	The indicator measures the dynamics of AMT adoption in manufacturing, i.e. it helps to assess whether

	2-4)	introduce AMT in their production processes	Survey			depending on sample size by country				soon)	(proprietary data)		countries sample size is limited	processes have been initiated while they are not yet fully completed.
AMTs (B-2)	Use of robots (B-2-5)	Number of industrial robots used in manufacturing per value added in manufacturing	International Federation of Robotics	none	Diffusion	for some aggregated NACE sectors	country	no	annual	2016	EU-28	yes	very high	A large number of robots used in manufacturing indicates a high level of sophistication in production. However, robots are more relevant for some sectors than for others.
Entrepreneurship (B-3)	Scale-up rate (B-3-3)	Share of employment in firms established in the past five years in total employment	Eurostat	none	Creation	NACE divisions (partly aggregated)	country, NUTS 2	SEs	annual	2016	EU-28, CH, NO, IS, MK, TR	no	high	A high share of employment in young firms indicates a renewal of the enterprise sector by newly established firms.
Investment (B-5)	Expenditure for machinery and equipment (B-5-2)	Expenditure for machinery and equipment as a percentage of value added	Eurostat	none	Diffusion	NACE divisions	country	SEs, MEs, LEs	annual	2015	EU-28, CH, NO, IS, MK, BA, LI, TR	for OECD countries	very high	A high level of expenditure for machinery and equipment indicates that firms modernise their stock of fixed assets that is used in the production process.
Investment (B-5)	Software expenditure (B-5-3)	Gross fixed capital formation in software and databases per value added	Eurostat, EU KLEMS	none	Diffusion	NACE divisions (partly aggregated)	country	no	annual	2015	EU-28	most OECD countries	high	A high level of expenditure for software and database indicates that firms modernise their stock of fixed assets that is used in the production process.
Investment (B-5)	Investment in ICT equip-	Gross fixed capital formation of computing	Eurostat, EU KLEMS	none	Diffusion	NACE divisions (partly aggregated)	country	no	annual	2016	EU-28, NO, BA	most OECD countries	high	A high level of investment in ICT equipment indicates that firms are modernising the production and

	ment (B-5-4)	and communication equipment per value added				gated)									organisational processes.
Industry structure (C-1)	Manufacturing share (C-1-2)	Share of manufacturing sectors in total value added	Eurostat	none	Performance	NACE divisions	country, NUTS 2	SEs, MEs, LEs	annual	2017	EU-28, IS, IL, MK, NO, RS, CH, TR, UA	for OECD countries	very high	A high share of manufacturing in total value added shows that the manufacturing sector is competitive vis-à-vis other sectors.	
Value chains (C-2)	Industrial services (C-2-1)	Share of knowledge-intensive industrial services per manufacturing output	Eurostat	none	Creation	NACE divisions	country, NUTS-2	no	annual	2016	EU-28	for OECD countries and other countries covered in WIOD	very high	A high share indicates that there is a large service sector providing specialised services for manufacturing firms.	
Value chains (C-2)	Value added in exports (C-2-2)	Share of domestic value added in gross exports	Eurostat	none	Diffusion	NACE divisions	country	no	annual	2016	EU-28	for OECD countries	very high	A high share indicates that the exports of goods rest on domestic production rather than purchase and selling-on of goods from other countries.	
Value chains (C-2)	Domestic value added in final demand (C-2-3)	Share of domestic value added in final domestic demand for manufacturing products	Eurostat	none	Diffusion	NACE divisions	country	no	annual	2016	EU-28	for OECD countries	high	The indicator shows to what extent domestic manufacturing is supplying domestic demand for manufacturing goods. A high share indicates a producer-user interaction within a country.	
Value chains (C-2)	RoW share in indirect value added (C-2-4)	Share of inputs from outside the EU in total value added	Eurostat	none	Diffusion	NACE divisions	country	no	annual	2016	EU-28	for OECD countries	high	A high share of global sourcing of inputs indicates that manufacturing is taking advantages of an international division of labour.	

Infra-structure (C-5)	Energy supply (C-5-3)	Average price for gas and electricity for medium and large non-household consumers	Eurostat	none	Frame-work	no	country	no	annual	2017	EU-28, IS, LI, NO, MN, MK, RS, TR, BA, KV, MD	no	very high	High cost for energy reduce price competitiveness of manufacturing. But high energy prices can provide incentives for more energy-efficient production methods.
Infra-structure (C-5)	Transport density (C-5-4)	Length of motorways and high-speed railway lines	Eurostat	none	Frame-work	no	country	no	annual	2016	EU-28, IS, NO, CH, MK, TR	for most countries from national sources	very high	A dense network of motorways and railways provides good transport opportunity both to ship goods, hence supporting exchange with other regions, specialisation and access to other markets.
Digitalisation (D-1)	Machine to Machine SIM card penetration (D-1-4)	Number of M2M SIM Cards per population	GSMA intelligence/IHS	none	Diffu-sion	no	country	no	annual	2017	EU-28	yes	high	A high indicator value shows that M2M communication is already widespread.
Digitalisation (D-1)	Data professionals (D-1-5)	Share of data professionals weighted by the number of ICT companies in total employment	IDC Europe	none	Frame-work	no	country	no	annual	2017	EU-28	no	high	This is a specific indicator that can capture digital skills related to industry 4.0. The indicator is not specific to manufacturing, however, as all data professionals are considered, regardless of the industry they are employed in.
Financing (D-2)	SME real interest rate (D-2-3)	Interest rate for loans to SMEs, minus inflation rate	OECD	OECD Score-board Financing SMEs and	Frame-work	no	country	no	annual	2016	21 EU countries, IL, RS	most OECD countries	high	A low real interest rate for SMEs provides an incentive to invest in new assets and hence modernise businesses.

				Entre-preneurs										
Public support (D-4)	Government loan guarantees for SMEs (D-4-2)	Amount of government loan guarantees for SMEs per GDP	OECD	OECD Scoreboard Financing SMEs and Entrepreneurs	Frame-work	no	country	no	annual	2016	14 EU countries , IL, RS	most OECD countries	high	A high amount of government loan guarantees for SMEs helps SMEs to invest in new assets.

Source: authors, based on conceptual work in the project

5.3 Remaining gaps

The efforts to complement data for filling existing gaps resulted in a quite comprehensive coverage of all elements of the conceptual model. At the same time, for almost all dimensions of the conceptual, there is at least one indicator that can be differentiated by sector, region or size class, and at least one indicator for which international comparison is possible. However, some gaps could not be closed:

- ▶ We did not find adequate indicators on **new business models** related to manufacturing. This gap is a serious one because modernising European industry will have to include new approaches of doing business and realigning ways of production, marketing and interaction with users. Collecting comparable data on new business models is very challenging, however, as a new business model cannot be readily observed in the market for at least three reasons:⁴ First, business models are mainly intangible, combining knowledge, practices and business methods into a coherent approach to generate and deliver solutions to customers in a way that provides value to the customer and generates profit for the firm. Secondly, establishing whether a firm's business model is new requires comparison to preceding business models of the same firm, for which detailed, and usually confidential information is needed. Thirdly, collecting data on new business models through surveys is complicated by the fact that business models are specific to markets and industries, and few conceptual statistical work has been undertaken yet to develop measures that can be applied across markets and industries. As long as these conceptual challenges are not responded to, it will remain very difficult to come up with reliable and useful indicators on new business models. For the time being, we propose not to cover this aspect of industrial modernisation within an indicator-based monitoring system. For qualitative information on new business models, existing observatories such as the Business Innovation Observatory can be used.
- ▶ To improve the situation, the Commission could consider the following steps:
 - ◆ Conduct analytical work based on existing or novel firm-level data to identify changes in business models. Among the existing data bases, the CIS micro data may provide a useful source (e.g. following Waldner et al. 2015). Among novel data bases, results from ongoing activities of using information from firm web pages and other publicly available firm-level data to identify innovation should be considered.
 - ◆ Promote conceptual work to develop a measurement approach on business model innovation to be implemented in firm surveys such as the ICT survey (particularly with respect to digital business models) and the CIS.
- ▶ For indicators on **regional support**, the role of **demonstration and competence centres** cannot be captured due to a lack of data on such centres across all regions in Europe, including an indication of the size and significance of these centres. This gap would constitute a main shortcoming of a monitoring system on industrial modernisation since such centres are important catalysts for transferring new production technologies and approaches in the SME sector within a region. There are basically three ways to generate reliable and representative data on the significance of demonstration and competence centres:
 - ◆ One way would be to search for such centres in all European regions using publicly accessible information sources (e.g. websites). This way can be implemented and updated regularly in a centralised way, e.g. by a service provider of the Commission. But it risks that some relevant centres may not be found.
 - ◆ A second approach is to contact all regions in Europe and ask them to deliver the required information. This approach requires cooperation of all regions and risks incomplete data if some regions do not deliver.
 - ◆ A third way would be to add a question on the use of regional demonstration and competence centres by firms in an existing enterprise survey, e.g. the CIS.

⁴ See also Waldner, F., Poetz, M.K., Grimpe, C., Eurich, M. (2015), Antecedents and Consequences of Business Model Innovation: The Role of Industry Structure, in C. Baden-Fuller, V. Mangematin (eds.), *Business Models and Modelling* (Advances in Strategic Management, Volume 33), Emerald Group Publishing Limited, 347-386.

- ◆ In addition, we were not able to find indicators on regional support that would allow for an international comparison. There is also a gap with respect to sector and size breakdown. The latter gap could be closed if firm-level data on the use of regional support would be used. Among the existing data sources, one could use a standard question from the CIS on firms receiving support for innovation from regional authorities. This data is already available, though a regional breakdown would require special calculations by the National Statistical Institutes that carry out the CIS.
- ▶ For **infrastructure**, there are no data that could be broken down by sector or size class, which is not necessarily a shortcoming since infrastructure is usually available to all sectors and to all firms of any size.
- ▶ For **skills**, we did not find appropriate indicators that are available for non-European countries.

5.4 Combined broad list of indicators

Combining the list of indicators on industrial modernisation from existing observatories and scoreboards with the list of proposed additional indicators to fill gaps gives a list of 61 indicators. Table 5 summarises the list of indicators. Of the total, 34 indicators can be broken down by manufacturing sectors (usually at an aggregated 2-digit level closely to the list of sectors shown in Table 2). 22 indicators allow a breakdown by firm size, usually distinguishing small, medium-sized and large enterprises. 23 indicators can be presented for NUTS-2 regions. Note that breakdowns of indicators from existing observatories and scoreboards sometimes require additional calculations based on the original statistical data since the existing sources do not include such a differentiation.

Table 5: Proposed indicators for monitoring industrial modernisation

Indicator number	Dimension	Indicator name	Source	Break down			Priority*
				Sector	Size	Region	
A-1-1	Productivity	Labour productivity	New	x	x	x	1
A-1-2	Productivity	Total factor productivity growth	New	x			1
A-2-1	Exports	Medium/high-tech exports	EIS			x	2
A-2-2	Exports	Revealed comparative advantage	New	x			1
A-2-3	Exports	Trade balance	New	x			1
A-2-4	Exports	Export share of SMEs	New	x	x		2
A-3-1	Growth	Change in manufacturing share	New	x	x	x	1
A-3-2	Growth	Change in real value added	New	x	x	x	1
A-3-3	Growth	Job growth	New	x		x	1
A-3-4	Growth	Growth of role of industrial services	New	x			1
A-3-5	Growth	Growth of value added in exports	New	x			1
A-4-1	Sustainability	Material efficiency	Eco-IS				1
A-4-2	Sustainability	Environmental process innovation	Eco-IS	x	x	x	2
A-4-3	Sustainability	Environmental management	Eco-IS				2
B-1-1	R&D, innovation	Business R&D expenditure	EIS	x	x	x	1
B-1-2	R&D, innovation	SMEs with innovations	EIS	x	x	x	1
B-1-3	R&D, innovation	Sales of new products	EIS	x	x	x	1

B-1-4	R&D, innovation	Design applications	EIS			x	2
B-2-1	AMTs	KET generation in production	KETsO	x	x	x	1
B-2-2	AMTs	KET and AMT patents	KETsO	x	x	x	1
B-2-3	AMTs	AMT use in production	New	x	x		2
B-2-4	AMTs	Planned AMT use in production	New	x	x		2
B-2-5	AMTs	Use of robots	New	(x)			1
B-3-1	Entrepreneurship	Opportunity driven start-ups	EIS				2
B-3-2	Entrepreneurship	Gazelles	EOCIC		x		1
B-3-3	Entrepreneurship	Scale-up rate	New	x			1
B-5-1	Investment	Non-R&D innovation expenditure	EIS	x	x	x	2
B-5-2	Investment	Expenditure for machinery & equipment	New	x	x		1
B-5-3	Investment	Software expenditure	New	x	x		1
B-5-4	Investment	Investment in ICT equipment	New	x			2
C-1-1	Industry structure	Specialisation in clusters of emerging ind.	ECO			x	1
C-1-2	Industry structure	Manufacturing share	New	x	x	x	1
C-2-1	Value chains	Industrial services	New	x			1
C-2-2	Value chains	Value added in exports	New	x			1
C-2-3	Value chains	Domestic value added in final demand	New	x			2
C-2-4	Value chains	RoW share in indirect value added	New	x			2
C-3-1	Cooperation/networks	International co-publications	RES			x	2
C-3-2	Cooperation/networks	International co-inventions	RES			x	1
C-3-3	Cooperation/networks	Innovation cooperation	EIS	x	x	x	1
C-4-1	Regional support	Support services	ECO			x	1
C-4-2	Regional support	ESIF Support for relevant training	RES			x	1
C-5-1	Infrastructure	Transport infrastructure	RES			x	2
C-5-2	Infrastructure	4G coverage	DESI				2
C-5-3	Infrastructure	Energy supply	New				1
C-5-4	Infrastructure	Transport density	New				1
D-1-1	Digitalisation	Broadband penetration	EIS	x	x		1
D-1-2	Digitalisation	eCommerce	DESI	x	x		2
D-1-3	Digitalisation	Business Digitisation	DESI	x	x		1

D-1-4	Digitalisation	M2M SIM card penetration	New				2
D-1-5	Digitalisation	Data professionals	New		x		2
D-2-1	Financing	Venture capital	EIS				2
D-2-2	Financing	Country Credit Rating	RES				2
D-2-3	Financing	SME real interest rate	New				1
D-3-1	Regulation	Time to start business	RES				2
D-3-2	Regulation	Protecting minority investors	RES				1
D-3-3	Regulation	Strength of legal rights	RES				1
D-4-1	Public support	Financial support to innovation	RES				2
D-4-2	Public support	Government loan guarantees for SMEs	New				1
D-5-1	Skills	Lifelong learning	EIS			x	2
D-5-2	Skills	Firms with ICT training	EIS	x		x	1
D-5-3	Skills	ICT Specialist Skills	DESI				2

(x): availability depends on the ability of data producers to provide such a breakdown, which may depend on confidentiality and sample size of the surveys used to generate the data.

* 1: high priority - 2: medium priority

Source: authors, based on conceptual work in the project

Using 61 indicators for a monitoring system requires sufficient resources to maintain and update the monitoring system, and sufficient capacity to fully analyse the diversity of information provided by the indicators. For that reason, a prioritisation of indicators could be useful. Table 5 provides a proposal for such a prioritisation. The last column in the table marks indicators of high priority by "1", and other indicators by "2". High priority was assigned to indicators with a high data quality and reliability, a very close connection to key conceptual foundations of industrial modernisation (including relevance to large parts of the manufacturing sector) and a regular update and to indicators that allow for a break down by sector, size class or region, and that enable international comparison. Of course, no indicator meets all these requirements. The prioritisation also considered that each dimension is covered by at least one indicator. We propose 37 indicators as being of high priority.

6/ A final list of priority indicators for monitoring industrial modernisation

This section presents a concrete and viable outline for a future indicator system on industrial modernisation. It is structured along the four main conceptual building blocks outlined above. Concrete indicators have been selected based on conceptual quality, with a key focus on availability. The indicators shown in Table 6 are of sufficient conceptual quality and relatively easily available. Indicators from studies that are available but have some limitations with regard to validity or accuracy and reliability are removed from the final list of indicators. This final list of 33 priority indicators is suitable and intended for a cross-sectional monitoring of industrial modernisation. A table with more detailed information on each of these indicators is provided in Annex 1.

Compared to Table 5, a small number of indicators were removed, for reasons of coverage, quality, or relative availability and ease of collection. The proposed indicators on AMT diffusion and on value chains, for example, were dropped due to currently limited data coverage. Overall, however, alterations to Table 5 could be kept rather limited as the pertinence of most indicators was confirmed in the process.

Table 6: Final list of priority indicators for monitoring industrial modernisation

Indicator number	Dimension	Indicator name	Data source	Breakdown		
				Sector	Size	Region
A-1-1	Productivity	Labour productivity	Eurostat/OECD	x	x	x
A-1-2	Productivity	Total factor productivity growth	EU KLEMS	x		
A-2-2	Exports	Revealed comparative advantage	Eurostat/UN	x		
A-2-3	Exports	Trade balance	Eurostat/UN	x		
A-2-4	Exports	Export share of SMEs	Eurostat	x	x	
A-3-1	Growth	Change in manufacturing share	Eurostat/OECD	x	x	x
A-3-2	Growth	Change in real value added	Eurostat/OECD	x	x	x
A-3-3	Growth	Job growth	Eurostat/OECD	x		x
A-3-4	Growth	Growth of role of industrial services	Eurostat/WIOD	x		
A-3-5	Growth	Growth of value added in exports	OECD	x		
A-4-3	Sustainability	Change in Energy Intensity	Eurostat/OECD	x		
A-4-4	Sustainability	Environmental process innovation	Eco-IS	x		
B-1-1	R&D, innovation	Business R&D expenditure	EIS	x	x	x
B-1-2	R&D, innovation	SMEs with innovations	EIS	x	x	x
B-1-3	R&D, innovation	Sales of new products	EIS	x	x	x
B-2-1	AMTs	KET generation in production	KETsO	x	x	x

B-2-2	AMTs	KET and AMT patents	KETsO	x	x	x
B-3-3	Entrepreneurship	Scale-up rate	Eurostat	x		
B-5-1	Investment	Non-R&D innovation expenditure	EIS	x	x	x
B-5-2	Investment	Expenditure for machinery & equipment	Eurostat/OECD	x	x	
B-5-3	Investment	Software expenditure	Eurostat/OECD	x	x	
B-5-4	Investment	Investment in ICT equipment	Eurostat/OECD	x		
C-1-1	Industry structure	Specialisation in clusters of emerging ind.	ECO			x
C-1-2	Industry structure	Manufacturing share	Eurostat/OECD	x	x	x
C-3-2	Cooperation/networks	International co-inventions	RES			x
C-3-3	Cooperation/networks	Innovation cooperation	EIS	x	x	x
C-4-1	Regional support	ESIF support for industrial modernisation	RES			x
C-4-2	Regional support	ESIF Support for relevant training	RES			x
C-5-1	Infrastructure	Transport infrastructure	RES			x
D-1-1	Digitalisation	Broadband penetration	EIS	x	x	
D-1-2	Digitalisation	eCommerce	DESI	x	x	
D-1-3	Digitalisation	Business Digitisation	DESI	x	x	
D-5-2	Skills	Firms with ICT training	EIS	x		x

Source: authors, based on conceptual work in the project

7/ Recommendations

7.1 Recommendations by Building Block

The future monitoring of industrial modernisation has to cover many different aspects. The monitoring system proposed in this report focuses on industrial modernisation as a transformative process that aims at maintaining or upgrading the competitiveness of European manufacturing in an increasingly competitive global environment. In order to assess industrial modernisation with a monitoring system used to support evidence-based policymaking, several conceptual aspects need to be taken into account.

In this study, four main sub-dimensions of measurement ("building blocks") have been identified to assess industrial modernisation: **Industrial Modernisation Performance, Innovation Strengths, Regional Specialisation** and **Business trends and environment**. As outlined above, the availability of pertinent indicators differs both between and within these building blocks.

Based on the project's findings, the following recommendations can therefore be formulated:

- 1) to establish the abovementioned monitoring system for industrial modernisation;
- 2) to improve and complement it with further indicators in the future for the three building blocks.

7.1.1 Building Block A: Industrial Modernisation Performance

In assessing the "performance of industrial modernisation", a distinction is made between outcomes and impact of industrial modernisation (i.e. its contribution to policy objectives) and the actual process of industrial modernisation (i.e. the uptake of new production technologies or the introduction of new business models).

From the analysis, it is clear that a number of pertinent, high quality indicators on outcome and impact can be made available using existing data sources. There is no need for additional data collection, but rather a need to combine and present the existing data in a suitable format. This can be largely done by accessing available information from public statistics and process it accordingly.

7.1.2 Building Block B: Innovation Strengths and Investment

For the building block on innovation strengths and investment, previous projects have collected a substantial amount of high-quality indicators with good coverage. In general, it seems viable and useful to complement available indicators from studies like the KETs Observatory with pertinent information from official statistical sources. To that end, the study recommends an intensified dialogue with Eurostat and those in charge of existing innovation monitors like the KETs Observatory.

Moreover, there is a lack of reliable and meaningful data sources on the actual process of industrial modernisation - i.e. the diffusion of new technologies and business models. Therefore, the study recommends engaging in a dialogue with relevant experts to explore if firm-level surveys could be conducted for all EU Member States and to assess how much time and resources this would require.

Case study 1 on "Provision and uptake of advanced manufacturing technologies" explored ways to fill these gaps by using company-level surveys resembling the "European Manufacturing Survey", which so far remains limited to 10 EU Member States and lacks a centralised data repository. As advances in the process of industrial modernisation should be a central element of future monitoring, the study recommends engaging in a dialogue with relevant experts to explore whether a similar survey could be conducted for all EU Member States and to assess how much time and resources this would require.

Case study 5 on "The identification and better monitoring of business investment enabling and supporting industrial modernisation" provided additional insights. It is recommended to build upon the existing statistics available through Eurostat and EU KLEMS and the indicators developed in the framework of the KETs Observatory projects to monitor this aspect of industrial modernisation.

7.1.3 Building Block C: Regional Specialisation

In the building block on regional specialisation, the study considered options to describe relevant framework conditions from a regional perspective. One of the main challenges in this area, is the availability of relevant indicators with sufficient breakdown at the regional level.

In general, however, it is often neither necessary nor even desirable that every single indicator is disaggregated both sectorally and regionally at the same time. For example, regulation is often simply not regionally specific. Where it is conceptually useful, however, future studies should make efforts to estimate the regional disaggregation of existing sectoral indicators as long as a robust basis for such estimation is available.

Against this background, case study 2 "Region- and industry specific framework conditions to support industrial modernisation", suggested an indicator framework that captures regional framework conditions relevant for industrial modernisation, and piloted it for two sectors (textiles and automotive).

A second concern in this area is the broad, generic notion of "framework conditions" at the regional level. For the time being, the final list of indicators presents single indicators. To avoid that an eventual indicator system for this building block becomes overly complex or too partial, such specific indicators will eventually have to be aggregated to convey a meaningful picture. Therefore, this study recommends the use and further development of composite indicators for regional framework conditions as they are already used by various European Commission initiatives (Regional Innovation Scoreboard, Regional Ecosystem Scoreboard, etc.).

Finally, this area suffers strongly from the fact that traditional, numeric indicators are either too partial or the object of measurement itself is by definition not very amenable to quantitative, leave alone one-dimensional, measurements (e.g. 'local culture and networking'). Hence, this is the area in which the use and potential utility of novel methods like web-scraping and big data analysis should be explored with priority.

7.1.4 Building Block D: Business Trends and Environment

In the building block on business trends and environment, the study considered options to describe relevant framework conditions from sectoral and/or technological perspective. One of the main challenges in this area, is the availability of relevant indicators with sufficient breakdown at the sectoral level.

In general, it is often neither necessary nor even desirable that every single indicator is disaggregated by sector. Certain technological trends, business models and governance framework conditions have an impact across diverse sectors, and it may well be meaningful to look at them from a generic perspective. Nonetheless, business trends and environments remain fundamentally sector and firm-type specific, so a good balance needs to be found between indicators that are generally relevant and those that are sector or firm-type specific. Among the currently available indicators, this balance remains missing.

Accordingly, further efforts have to be made to conduct sector specific inquiries into business trends and environments - or to increase the sample sizes behind existing indicators, so that available, generic information can be meaningfully disaggregated by sector or firm type. New surveys or the extended collection of additional data by statistical offices (cf. EU statistics on ICT usage and e-commerce in enterprises) could pave the way ahead.

Against this background, case study 4, "Analysis of business environment and public support to improve SME participation in industrial modernisation" constructed a composite indicator was constructed to measure the extent to which the business environment influences SME internationalisation in EU Member States.

A second concern in this area is the notion of "framework conditions" which may be slightly less generic than that discussed for the regional level, but still at jeopardy of becoming either too complex or too partial. For the time being, the final list of indicators presents single indicators. To convey meaningful insights on whether the current business trends or environments are favourable for certain sectors or firm types, specific indicators will eventually have to be aggregated. Unfortunately, templates for this process are less developed than in the case of regions and will require further conceptual thinking.

7.2 Actions to advance future monitoring systems

In addition to the above recommendations on how to compile data for the proposed core set of indicators, the following sub-sections outline recommendations on how to further improve the coverage and quality of future monitoring efforts. Not all these steps are required immediately to compile a minimum set of core data in line with the proposal outlined in section five above. In the long run, however, attention must be devoted to these steps in order to realise the full potential of the options explored in this study.

7.2.1 Launch new efforts to collect data

This study has identified gaps in data regarding industrial modernisation processes, hence a partial closure of this gap is a prominent and primary recommendation of this report. Considering the challenges at hand and their potential implications, two key areas that reflect the essence of industrial modernisation, technology uptake and new business models, would benefit from further investigation.

As an inclusion in existing survey efforts, like the CIS, is unlikely in the short term, additional data collection in this area could contribute to more reliable evidence-based policy making. Dialogues with organisations experienced in firm-level survey exercises to scope possible options should be considered. In the short term, excerpts of already collected data could be acquired, in the long run, relevant survey efforts would have to be supported.

With priority, this concerns the following indicators:

New Indicator	Precise Specification	Justification	Source
<i>On the uptake of AMT technologies i.e. the core process of technological modernisation</i>			
Use of AMT technologies (differentiated by technology) ⁵	- share of firms that are using 'beyond robotics' AMT in their production processes	Both indicators could provide much more differentiated insight into those advanced manufacturing technologies in the field of high-performance manufacturing and digitalisation that go 'beyond robotics' and constitute the actual fundament of current competitiveness.	<i>short term: acquisition of data from European Manufacturing Survey</i> <i>mid-long term: future dedicated surveys</i>
Planned use of AMT technologies (differentiated by technology)	- share of firms that have concrete plans to introduce 'beyond robotics' AMT in their production processes		
<i>On the introduction of new business models i.e. the core process of organisational modernisation</i>			
New management models	Share of firms that have introduced new management models	The area of business model innovation and servitisation is a substantially understudied field whose relevance was repeatedly highlighted during this project.	
New servitisation models	Share of firms that have introduced new servitisation models		

Source: authors, based on evidence from case studies

⁵ for an illustration of a detailed (yet non-exhaustive) list of technologies cf. Deliverable 1 of the 2015 DG GROW study on "drivers, barriers and readiness factors of EU companies for adopting advanced manufacturing products and technologies" <https://ec.europa.eu/docsroom/documents/20926/attachments/2/translations/en/renditions/native>

7.2.2 Pilot new approaches to data collection

Some of the issues of interest, such as companies positioning in value chains mean that the collection of data through "traditional" methods can be problematic. In these cases, novel, big data-based methods of data collection promise additional insights and should be piloted. For the time being, however, most of these novel methodologies, such as text mining company websites, continue to have strong limitations so that their results cannot not be considered at face value and/or directly taken over into a monitoring system. If pursued, their quality needs to be monitored, reviewed and extended to the extent possible. Eventually, it is possible that reliable indicators could be generated on this basis and integrated into future monitoring approaches.

With priority, this concerns the following indicators:

New Indicator	Precise Specification	Justification	Source
Regional Value Chains and Value Chain Position	<ul style="list-style-type: none"> - presence of localised regional value chains, e.g. presence and density of local clusters - position of regional manufacturing firms in international value chains, e.g. share of suppliers, system suppliers, OEMs 	<p>The position of local firms and economies in global value chains is one of the most relevant issues in industrial policy, likewise, there is a necessity to understand the localisation of value chains in clusters</p> <p>for both, pertinent indicators remain missing</p>	<p>new methods of data collection e.g. Big Data, Web-Scraping</p> <p>dedicated analysis of patent and economic microdata</p>

Source: authors, based on evidence from case studies

7.2.3 Communicate relevant information

While the direct combination of indicators from existing EU monitors and observatories was an initial ambition of this project, most case studies have found that it is not always easy to combine such indicators in a straightforward manner. The reason for this is the different orientation and objectives of many studies and scoreboards that remain "incompatible" because future merging was not considered a possibility at the time of their conception. If these studies and scoreboards are regularly re-tendered, however, this problem could be addressed by targeted amendments to tender specifications. Once it has been agreed which studies and scoreboards should feed into a future monitoring system on industrial modernisation, standardised data templates could be included in the tender specifications, while maintaining the nature and orientation of each specific observatory to enable detailed analysis.

8.1 Annex 1: Final list of 33 priority indicators for monitoring industrial modernisation

Table 7: List of 33 priority indicators on industrial modernisation with descriptive information

	Dimension	Indicator	Definition	Data source	Scoreboard, Observatory	Sector breakdown	Regional breakdown	Size breakdown	Frequency	Timeliness	Country coverage	International comparability	Data reliability	Implementation effort*
A-1-1	Productivity	Labour productivity	Value added at factor costs per hour worked by employees	Eurostat/OECD	none	NACE divisions	country (NUTS 2 for value added per person employed)	SEs, MEs, LEs	annual	2016	EU-28, IS, IL, MK, NO, RS, CH, TR, UA	for OECD countries (based on STAN or WIOD)	very high	2
A-1-2	Productivity	Total factor productivity growth	Growth rate of value added minus growth rate of hours worked minus growth rate of capital stock	EU KLEMS	none	NACE divisions	country	no	annual	2015	EU-28	USA, other countries from WIOD data base	very high	2
A-2-2	Exports	Revealed comparative advantage (RCA)	Share of a sector in a country's total exports per share of the same sector in world's total exports	Eurostat/UN	none	NACE divisions	country	no	annual	2016	EU-28	yes, for almost all countries (based on UN Comtrade data)	very high	3
A-2-3	Exports	Trade balance	Exports minus imports per sum of exports and imports	Eurostat/UN	none	NACE divisions	country	no	annual	2016	EU-28	yes, but requires linking of UN Comtrade data and	high	3

												value added data (e.g. OECD STAN database)		
A-2-4	Exports	Export share of SMEs	Exports to all countries of the world by SMEs per total turnover of SMEs	Eurostat	none	NACE divisions	country	SEs, MEs, LEs	annual	2016	EU-28	no	high	2
A-3-1	Growth	Change in manufacturing share in value added	Change over time in gross value added in manufacturing per total gross value added	Eurostat/ OECD	none	NACE divisions	country, NUTS 2	SEs, MEs, LEs	annual	2017	EU-28, IS, IL, MK, NO, RS, CH, TR, UA	for OECD countries	very high	2
A-3-2	Growth	Change in real value added	Growth rate of value added at factor costs	Eurostat/ OECD	none	NACE divisions	country, NUTS 2	SEs, MEs, LEs	annual	2017	EU-28, IS, IL, MK, NO, RS, CH, TR, UA	for OECD countries	very high	2
A-3-3	Growth	Job growth in manufacturing	Growth rate of numbers of persons employed in manufacturing	Eurostat/ OECD	none	NACE divisions	country, NUTS 2		annual	2017	EU-28, IS, IL, MK, NO, RS, CH, TR, UA	for OECD countries	very high	2
A-3-4	Growth	Growth of role of industrial services	Growth of role of industrial services	Eurostat/ WIOD	none	NACE divisions	country		annual	2015	EU-28, IS, IL, MK, NO, RS, CH, TR, UA	other countries from WIOD data base	very high	2
A-3-5	Growth	Growth of value added in exports	Growth of value added in exports	OECD	none	NACE divisions	country		annual	2017	EU-28, IS, IL, MK, NO, RS, CH, TR, UA	for OECD countries	very high	3

A-4-3	Sustainability	Change in energy intensity	Change in energy consumption per value added	Eurostat	none	NACE divisions	country		annual	2017	EU-28	no	very high	2
A-4-4	Sustainability	Environmental process innovation	Enterprises that introduced an innovation with environmental benefits obtained within the enterprise per all enterprises	Eurostat	Eco-IS	NACE divisions (partly aggregated)	country (NUTS 2 based on special calculation)	SEs, MEs, LEs	irregular	2014	EU-28	no	high	1
B-1-1	R&D, innovation	Business R&D expenditure	Business expenditure on R&D per value added at factor costs	Eurostat	EIS	NACE divisions (partly aggregated)	country, NUTS 2	SEs, MEs, LEs	annual	2016	EU-28, IS, IL, MK, NO, RS, CH, TR, UA	all OECD	very high	1
B-1-2	R&D, innovation	SMEs with innovations	SMEs with product/processes/marketing/organisational innovation per all SMEs	Eurostat	EIS	NACE divisions (partly aggregated)	country, NUTS 2	SEs, MEs, LEs	bi-ennial	2014 (update for 2016 soon)	EU-28, IS, IL, MK, NO, RS, CH, TR, UA	most OECD	high	1
B-1-3	R&D, innovation	Sales of new products	Share of sales of product innovations in total sales	Eurostat	EIS, RIS	NACE divisions (partly aggregated)	country, NUTS 2	SEs, MEs, LEs	bi-ennial	2014 (update for 2016 soon)	EU-28, IS, IL, MK, NO, RS, CH, TR, UA	most OECD	high	1
B-2-1	AMTs	KET generation in production	Share of KETs in total production	Eurostat	KETs Observatory	no	country	no	annual	2013 (update will follow soon)	most EU-28 countries	yes, but with significant additional assumptions	high (but difficult to extend to whole AMT field)	1
B-2-2	AMTs	KET and AMT	KETs/AMTs patent applications per	EPO	KETs Observ	no	country, NUTS 2	no	annual	2011 (update will	complete	almost all countries	high	1

		patents	value added		atory					follow soon)		globally		
B-3-3	Entrepreneurship	Scale-up rate	Share of employment in firms established in the past five years in total employment	Eurostat	none	NACE divisions (partly aggregated)	country, NUTS 2	SEs	annual	2016	EU-28, CH, NO, IS, MK, TR	no	high	2
B-5-1	Investment	Non-R&D innovation expenditure	Sum of total innovation expenditure of enterprises excluding R&D expenditures	Eurostat	EIS	NACE divisions (partly aggregated)	country, NUTS 2	SEs, MEs, LEs	bi-ennial	2014 (update for 2016 soon)	EU-28, MK, NO, RS, CH, TR, UA	no	medium	1
B-5-2	Investment	Expenditure for machinery and equipment	Expenditure for machinery and equipment as a percentage of value added	Eurostat/OECD	none	NACE divisions	country	SEs, MEs, LEs	annual	2015	EU-28, CH, NO, IS, MK, BA, LI, TR	for OECD countries	very high	2
B-5-3	Investment	Software expenditure	Gross fixed capital formation in software and databases per value added	Eurostat/OECD	none	NACE divisions (partly aggregated)	country	no	annual	2015	EU-28	most OECD countries	high	2
B-5-4	Investment	Investment in ICT equipment	Gross fixed capital formation of computing and communication equipment per value added	Eurostat/OECD	none	NACE divisions (partly aggregated)	country	no	annual	2016	EU-28, NO, BA	most OECD countries	high	2
C-1-1	Industry structure	Specialisation in clusters of emerging	Number of enterprises in emerging industries per	BvD	ECO	no	country, NUTS 2	no	annual	2017	EU-28	yes	high	4

		industries	total number of enterprises											
C-1-2	Industry structure	Manufacturing share	Share of manufacturing sectors in total value added	Eurostat/OECD	none	NACE divisions	country, NUTS 2	SEs, MEs, LEs	annual	2017	EU-28, IS, IL, MK, NO, RS, CH, TR, UA	for OECD countries	very high	2
C-3-2	Cooperation/networks	International co-inventions	International co-inventions in themes relevant for industrial modernisation per population	EPO	RES	no	country, NUTS 2	no	annual	2017	EU-28	yes	high	4
C-3-3	Cooperation/networks	Innovation cooperation	Share of SMEs cooperating with others on innovation	Eurostat	EIS	NACE divisions (partly aggregated)	country, NUTS 2	SEs, MEs, LEs	bi-ennial	2014 (update for 2016 soon)	EU-28	no	high	1
C-4-1	Public support	ESIF support for Industrial Modernisation	Amount of ESI funds dedicated to industrial modernisation	DG REGIO	RES	no	country, NUTS 2	no	irregular	2017	EU-28	no	high	2
C-4-2	Skills	ESIF Support for relevant training	Amount of ESI funds dedicated to training services related to restructuring	DG REGIO	RES	no	country, NUTS 2	no	irregular	2017	EU-28	no	high	2
C-5-1	Infrastructure	Transport infrastructure	Average of motorway and railway potential accessibility	Own calculations based on Eurostat/national statistics	RES	no	country, NUTS 2	no	irregular, but slowly changing over time	2014	EU-28	no	high	1

D-1-1	Digitalisation	Broad-band penetration	Number of enterprises with a maximum contracted download speed of the fastest fixed internet connection of at least 100 Mb/s	Eurostat	EIS	NACE divisions (partly aggregated)	country	SEs, MEs, LEs	annual	2017	EU-28, MK, NO, RS, TR, UA	yes, but from other data sources	high	2
D-1-2	Digitalisation	eCommerce	Share of sales from eCommerce in total turnover of SMEs	Eurostat	DESI	NACE divisions (partly aggregated)	country	SEs, MEs, LEs	annual	2017	EU-28, MK, NO, RS, TR, UA	no	high	2
D-1-3	Digitalisation	Business Digitisation	Index of the adoption of 5 technologies: electronic information sharing, RFID, social media, eInvoices, cloud services	Eurostat	DESI	NACE divisions (partly aggregated)	country	SEs, MEs, LEs	annual	2017	EU-28, MK, NO, RS, TR, UA	no	high	2
D-5-2	Skills	Firms with ICT training	Share of enterprises that provided any type of training to develop ICT-related skills of their personnel	Eurostat	EIS	NACE divisions (partly aggregated)	country	SEs, MEs, LEs	annual	2017	EU-28, IS, MK, NO, RS	no	high	2

* 1: easy to implement, 2: implementable with reasonable effort, 3: requires substantial effort to implement, 4: requires specific analyses

Source: authors, based on conceptual work in the project

8.2 Annex 2: Definition of indicators and data sources

The following table provides a data-based definition for each indicator along with a link to the data source. If different data sources for European and non-European countries exist, only the EU data source is shown.

Note that most links lead to the databases from which the relevant data that are needed to calculate the proposed indicators can be extracted. These databases often contain other data as well. The links listed below were active on January 22nd, 2019. No guarantee can be given that they will be active at later dates.

Table 8: Indicators for monitoring industrial modernisation: definition and data sources

<i>Ind. No.</i>	<i>Indicator name</i>	<i>Definition</i>	<i>Data source</i>
A-1-1	Labour productivity	Value added at factor costs per hour worked by employees (national currencies converted by purchasing power parities)	http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=sbs_na_ind_r2&lang=en and http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=prc_ppp_ind&lang=en
A-1-2	Total factor productivity growth	Growth rate of value added minus growth rate of hours worked minus growth rate of capital stock	http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nama_10_a10&lang=en and http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nama_10_a10_e&lang=en and http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nama_10_nfa_st&lang=en
A-2-1	Medium/high-tech exports	Exports of medium-tech and high-tech goods per total exports	http://appsso.eurostat.ec.europa.eu/nui/show.do?query=BOOKMARK_DS-018995_QID_-8D60BE6_UID_-3F171EB0&layout=PERIOD,L,X,0;REPORTER,L,Y,0;PARTNER,L,Z,0;PRODUCT,C,Z,1;FLOW,L,Z,2;INDICATORS,C,Z,3;&zSelection=DS-018995INDICATORS,VALUE_IN_EUROS;DS-018995PRODUCT,TOTAL;DS-018995PARTNER,EU28_EXTRA;DS-018995FLOW,1;&rankName1=PARTNER_1_2_-1_2&rankName2=INDICATORS_1_2_-1_2&rankName3=FLOW_1_2_-1_2&rankName4=PRODUCT_1_2_-1_2&rankName5=PERIOD_1_0_0_0&rankName6=REPORTER_1_2_0_1&sortR=DND_-1&prRK=FIRST&prSO=PROTOCOL&pprRK=FIRST&pprSO=PROTOCOL&sortC=ASC_-1_FIRST&rLShi=0:2-26,27:0,29:1,28:29&rStp=&cStp=&rDCh=&cDCh=&rDM=true&cDM=true&footnes=false&empty=false&wai=false&time_mode=ROLLING&time_most_recent=true&lang=EN&cfo=
A-2-2	Revealed comparative advantage	Share of a sector in a countries total exports per share of the same sector in world's total exports	http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=ext_lt_intratrd&lang=en

A-2-3	Trade balance	Exports minus imports per sum of exports and imports	http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=ext_lt_intratrd&lang=en
A-2-4	Export share of SMEs	Exports to all countries of the world by SMEs per total turnover of SMEs	http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=ext_tec01&lang=en
A-3-1	Change in manufacturing share	Change over time in gross value added in manufacturing per total gross value added	http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nama_10_a64&lang=en
A-3-2	Change in real value added	Growth rate of value added at factor costs (deflating value added with producer price index)	http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=sbs_na_ind_r2&lang=en and http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=sts_inpp_a&lang=en
A-3-3	Job growth in manufacturing	Growth rate of numbers of persons employed in manufacturing	http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=sbs_na_sca_r2&lang=en
A-3-4	Growth of role of industrial services	Growth rate of value added at factor costs in NACE 52, 62, 70.2, 71, 72, 73 per value added at factor costs in manufacturing	http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=sbs_na_1a_se_r2&lang=en
A-3-5	Growth of value added in exports	Growth rate of domestic value added per total exports	https://stats.oecd.org/Index.aspx?DataSetCode=TIVA_2016_C2
A-4-1	Material efficiency	Domestic material consumption per capita	https://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&language=en&pcode=t2020_r110&plugin=1
A-4-2	Energy efficiency	Change in energy consumption per value added	http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=sbs_na_ind_r2&lang=en
A-4-3	Environmental management	Enterprises that had procedures to identify and reduce the environmental impacts per all enterprises	http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=inn_cis9_ecodr&lang=en
A-4-4	Environmental process innovation	Enterprises that introduced an innovation with environmental benefits obtained within the enterprise per all enterprises	http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=inn_cis9_env&lang=en
B-1-1	Business R&D expenditure	Business expenditure on R&D per value added at factor costs	http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=rd_e_berdindr2&lang=en
B-1-2	SMEs with innovations	SMEs with product/process/marketing/organisational innovation per all SMES	http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=inn_cis9_type&lang=en
B-1-3	Sales of new products	Turnover from new or significantly improved products per total turnover	http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=inn_cis9_prod&lang=en

B-1-4	Design applications	Number of industrial design applications at the European Intellectual Property Office per value added	http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=ipr_dfa_gdp&lang=en
B-2-1	KET generation in production	Production value of KET-based goods per total production value	https://ec.europa.eu/growth/tools-databases/kets-tools/kets-observatory/analytics/technology/timeseries
B-2-2	KET and AMT patents	Number of patent applications at the European Patent Office or through the PCT procedure at the World Intellectual Property Office in KETs and AMTs fields per value added - the indicator can be calculated using the "share of patents" indicator from the KETs observatory, weighting it with the total number of patents, and dividing by GDP	The indicator has to be calculated from raw data on patent applications provided by the European Patent Office through the Patstat database: https://www.epo.org/searching-for-patents/business/patstat.html Indicators of the KETs Observatory can be obtained from here: https://ec.europa.eu/growth/tools-databases/kets-tools/kets-observatory/analytics/technology/timeseries
B-2-3	AMT use in production	Number of enterprises that are using AMT in their production processes per total number of enterprises	The indicator has to be calculated from raw data of the European Manufacturing Survey (EMS) which is conducted in 15 countries. Details on the EMS can be found here: https://www.isi.fraunhofer.de/en/themen/industrielle-wettbewerbsfaehigkeit/fems.html
B-2-4	Planned AMT use in production	Number of enterprises that have concrete plans to introduce AMT in their production processes per total number of enterprises	The indicator has to be calculated from raw data of the European Manufacturing Survey (EMS) which is conducted in 15 countries. Details on the EMS can be found here: https://www.isi.fraunhofer.de/en/themen/industrielle-wettbewerbsfaehigkeit/fems.html
B-2-5	Use of robots	Number of industrial robots used in manufacturing per value added in manufacturing	Number of industrial robots is provided by a commercial provider (IFR), details can be found here: https://ifr.org/downloads/press/Executive_Summary_WR_2017_Industrial_Robots.pdf
B-3-1	Opportunity driven start-ups	Number of persons involved in improvement-driven entrepreneurship per number of persons involved in necessity-driven entrepreneurship	The indicator has to be calculated from raw data collected within the Global Entrepreneurship Monitor (GEM) project: https://www.gemconsortium.org/data/sets?id=aps Results on the indicator (called 'motivational index' in the GEM report) for each country can be found here: https://www.gemconsortium.org/report
B-3-2	Gazelles	Number of young high-growth enterprises (20% or more growth in employment) per total number of enterprises	http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=bd_9n_r2&lang=en
B-3-3	Scale-up rate	Number of persons employed in year t in enterprises born in year t-5 per total number of employed persons	http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=bd_9bd_sz_cl_r2&lang=en
B-5-1	Non-R&D innovation expenditure	Total innovation expenditure minus expenditure for in-house and for external R&D per total turnover	http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=inn_cis9_exp&lang=en

B-5-2	Expenditure for machinery & equipment	Gross investment in machinery and equipment per value added at factor costs	http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=sbs_na_ind_r2&lang=en
B-5-3	Software expenditure	Investment in purchased software per value added at factor costs	http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=sbs_is_inv_r2&lang=en
B-5-4	Investment in ICT equipment	Gross capital formation in ICT equipment per gross value added	http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nama_10_a64_p5&lang=en and http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nama_10_a10&lang=en
C-1-1	Specialisation in clusters of emerging industries	Number of enterprises in emerging industries per total number of enterprises	The indicator is calculated based on firm-level data from the Orbis database of Bureau van Dyk and was published in the European Cluster Observatory: http://ec.europa.eu/growth/industry/policy/cluster/observatory_en
C-1-2	Manufacturing share	Gross value added in manufacturing per total gross value added	http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nama_10_a64&lang=en
C-2-1	Industrial services	Value added at factor costs in NACE 52, 62, 70.2, 71, 72, 73 per value added at factor costs in manufacturing	http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=sbs_na_1a_se_r2&lang=en
C-2-2	Value added in exports	Domestic value added per total exports	https://stats.oecd.org/Index.aspx?DataSetCode=TIVA_2016_C2
C-2-3	Domestic value added in final demand	Domestic value added of manufacturing products per final domestic demand for manufacturing products	https://stats.oecd.org/Index.aspx?DataSetCode=TIVA_2016_C2
C-2-4	RoW share in indirect value added	Inputs from outside the EU per total value added	https://stats.oecd.org/Index.aspx?DataSetCode=TIVA_2016_C2
C-3-1	International co-publications	International co-publications in themes relevant for industrial modernisation per population	The indicator has to be calculated from raw data on scientific publications provided by Elsevier through the Scopus database: https://www.scopus.com/search/form.uri?zone=TopNavBar&origin=sbrowse&display=basic
C-3-2	International co-inventions	International co-inventions in themes relevant for industrial modernisation per population	The indicator has to be calculated from raw data on patent applications provided by the European Patent Office through the Patstat database: https://www.epo.org/searching-for-patents/business/patstat.html
C-3-3	Innovation cooperation	Enterprises cooperating on product/process innovation per all enterprises with product/process innovation activity	http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=inn_cis9_coop&lang=en

C-4-1	Support services	Amount of ESI funds dedicated to industrial modernization	http://s3platform.jrc.ec.europa.eu/esif-viewer
C-4-2	Support services	Amount of ESI funds dedicated to training services related to restructuring	http://s3platform.jrc.ec.europa.eu/esif-viewer
C-5-1	Transport infrastructure	Average of motorway and railway potential accessibility	The indicator was calculated by Spiekermann and Wegener (2016) for the Regional Competitiveness Index: http://ec.europa.eu/regional_policy/en/information/maps/regional_competitiveness/
C-5-2	4G coverage	Number of households with 4G coverage per total number of households	The indicator has been calculated as part of a study on Digital Agenda key indicators. Details on the indicator can be found here (note that this link has to be copied into the link address field of a browser in order to open it): https://digital-agenda-data.eu/datasets/digital_agenda_scoreboard_key_indicators/indicators#mobile-market
C-5-3	Energy supply	Average price for gas and electricity for medium and large non-household consumers	http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nrg_pc_203_c&lang=en and http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nrg_pc_205_c&lang=en
C-5-4	Transport density	Length of motorways and high-speed railway lines per capita	http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=road_if_motorwa&lang=en and http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=rail_if_line_sp&lang=en
D-1-1	Broadband penetration	Number of enterprises with a maximum contracted download speed of the fastest fixed internet connection of at least 100 Mb/s per total number of enterprises	http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=isoc_ci_it_en2&lang=en
D-1-2	eCommerce	Turnover from eCommerce per total turnover	http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=isoc_ec_evaln2&lang=en
D-1-3	Business Digitisation	Index of the adoption of 5 technologies by enterprises: electronic information sharing, RFID, social media, eInvoices, cloud	http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=isoc_eb_iip&lang=en and http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=isoc_cismt&lang=en and http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=isoc_eb_ics&lang=en

			and http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=isoc_cicce_use&lang=en
D-1-4	M2M SIM card penetration	Number of M2M SIM Cards per capita	The indicator is calculated by a private company, GSMA, and published by OECD in the STI Scoreboard: http://www.oecd.org/sti/oecd-science-technology-and-industry-scoreboard-20725345.htm Information on the original data can be obtained here: https://www.gsma.com/iot/iot-knowledgebase/gsma-intelligence-cellular-m2m-forecasts-2010-2020/
D-1-5	Data professionals	Number data professionals in ICT companies per total employment	The indicator is calculated based on survey data from IDC Europe. The indicator can be found in the European Data Market project: https://ec.europa.eu/digital-single-market/en/news/final-results-european-data-market-study-measuring-size-and-trends-eu-data-economy
D-2-1	Venture capital	Private equity raised for early stage, expansion and replacement per value added	The indicator has to be calculated from non-public data provided by a private organisation, Invest Europe. Details on the data can be found here: https://www.investeurope.eu/research/activity-data/annual-activity-statistics/investments-(2017)/
D-2-2	Country Credit Rating	Index based on an assessment by the Institutional Investor Magazine Ranking	The indicator is part of the indicators of the IMD World Competitiveness Rankings: https://www.imd.org/wcc/world-competitiveness-center-rankings/world-competitiveness-ranking-2018/
D-2-3	SME real interest rate	Interest rate for loans to SMEs, minus inflation rate	https://www.oecd.org/cfe/smes/Highlights-Financing-SMEs-and-Entrepreneurs-2018.pdf
D-3-1	Time to start business	Number of calendar days that are required for starting a business	http://databank.worldbank.org/data/reports.aspx?source=doing-business
D-3-2	Protecting minority investors	Index based on six sub-indices (disclosure, director liability, shareholder suits, shareholder rights, ownership and control, corporate transparency)	http://databank.worldbank.org/data/reports.aspx?source=doing-business
D-3-3	Strength of legal rights	Index ranging from 0 to 12	http://databank.worldbank.org/data/reports.aspx?source=doing-business
D-4-1	Financial support to innovation	Number of product/process innovation active enterprises receiving public financial support per total number of product/process innovation active enterprises	http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=inn_cis9_pub&lang=en

D-4-2	Government loan guarantees for SMEs	Amount of government loan guarantees for SMEs per GDP	https://www.oecd.org/cfe/smes/Highlights-Financing-SMEs-and-Entrepreneurs-2018.pdf
D-5-1	Lifelong learning	Number of 25 to 64 years old persons with training per total number of 25 to 64 years old persons	http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=trng_lfse_04&lang=en
D-5-2	Firms with ICT training	Number of enterprises that provided any type of training to develop ICT-related skills of their personnel per total number of enterprises	http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=isoc_ske_itn2&lang=en
D-5-3	ICT Specialist Skills	Number of employed ICT specialists per total number of employees	http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=isoc_sks_itspt&lang=en

Source: authors, based on conceptual work in the project

8.3 Annex 3: Summary of the case studies

8.3.1 Case Study 1: Provision and uptake of advanced manufacturing technologies

This case study outlines the need for data collection regarding the provision and uptake of advanced manufacturing technologies, including but not limited to Key Enabling Technologies (KETs). As a first main objective, it moves beyond the currently prevalent, technology driven to an industry-centred approach to measure the availability of advanced manufacturing technologies. It will explore and propose ways to integrate and reformat available data on the generation and availability of 'non-KET' technologies that are relevant for the upgrading of industrial production processes. As a second main objective, it compiles references on existing approaches to collect data on the uptake and use of advanced manufacturing technologies in and across different Member States. It will outline established methodological standards to address this gap through differentiated surveys and demonstrate how such combined studies on technology generation and uptake could generate policy-relevant information in the future.

In this case study, two combinations are conducted, which empirically combine (and partly generate) data for different technologies and/or provide empirical examples for certain technologies and countries to combine indicators along the generation and uptake. Those empirical exercises are part of more general analyses about the empirical possibilities and political relevance of respective data sets.

The first combination elaborates a coherent set of technologies regarding their delineation (e.g. in terms of patent groups, key techniques) and conducts an empirical exercise to show potential insights of such broader assessment. We identify and classify technologies related to the digitalization of production ("Industry 4.0"), because the main shortcomings in current measurement approaches refer to those technologies. The empirical investigation focuses on patents as others indicator for the innovation process are hardly available. Hence, relevant patent classifications are identified and the amount of transnational patents for those digitalization technologies compared to KETs (as measured in the KETs Observatory) is counted by using the World Patents Index. Moreover, the geographical distribution is analysed geographically over time. The results show a high significance of patents directly linked or related to manufacturing. Moreover, the landscape regarding technological competitiveness differs highly compared to existing KETs. Hence, the inclusion of such relevant technologies provides policy relevant conclusions.

In the second combination, the uptake and use of technology is considered. It aims to identify where and to what extent known potentials for industrial modernisation manifest themselves in practice. To that end, it proposes the systematic generation of additional evidence on technology uptake which has and can so far only be made available in dedicated studies, based on proprietary datasets. By means of this combination, it is proposed to prepare the ground for a later matching of data on the generation of advanced manufacturing technologies with data on their uptake and use. Such studies should provide relevant additional insights on both the actual impact of advanced manufacturing technologies produced in Europe, including additional dimensions such as planned uptake, and differentiation by sector, company size and production structure. Furthermore, they can provide insights into their uptake and use in those Member States which may not produce many of these technologies themselves - but nonetheless need them to move ahead in industrial modernisation. By contrasting the locations of technology generation and those of technology uptake, future studies could improve indications of the likely flow of advanced manufacturing technologies within the European Union. Indicative examples will be provided for Germany, Spain, Slovenia and the Netherlands.

More generally, the combination of data sources increases the coherence and coverage of technologies, key challenges and limitations of those faced by the individual monitoring/ studies. The most critical ones are that identifying those technologies in the existent classifications for the indicators (patents, production, etc.) relies on using expert knowledge, which can hardly guarantee the same quality than surveys based on official classifications. In particular, the limitations of data availability remains a key issue for the uptake of ADMAN technologies where high quality datasets are currently not public available - and would have to be generated through dedicated surveys in the future. In principle, however, this restriction also applies to various indicators for technology generation (e.g. production related to key components) - in particular when moving beyond the established methodologies for patent indicators - and the well-explored area of key enabling technologies.

8.3.2 Case Study 2: Region- and industry specific framework conditions to support industrial modernisation

Advanced manufacturing including digitalisation forms the backbone of industrial modernisation. An important feature of modern industrial and innovation policies should be to address the necessary framework conditions

that enable industrial modernisation through new manufacturing technologies, digital technologies or new business models on a sector by sector basis. The research question for policy-makers is what region-specific framework conditions they should strengthen in order to support digital modernisation of their core economic sectors and what gaps policy can address.

In this case study, two sectors (textiles and automotive) are selected, focusing on digitisation as a relevant pillar of industrial modernisation of the selected sectors. We then piloted the data collection on the regions specialised in these sectors. The conceptual design used as basis for the framework conditions enabling industrial modernisation has been the one of the Regional Ecosystem Scoreboard of the European Observatory for Clusters and Industrial Change (EOCI) which was designed primarily for policy-makers responsible for regional, industrial and cluster policies. The emphasis of the Scoreboard has been on the Conditions and on the Dynamics that characterise the quality and nature of the regional ecosystem and not about measuring performance. Also, performance indicators of digital transformation have been explored in order to provide for a complete monitoring package and allow policy makers to identify the front runners in digital transformation and stimulate exchange of good practices and synergies between regions.

For this case study, five key dimensions have been analysed, following the framework conditions identified by the Regional Ecosystem Scoreboard. The dimensions are: Entrepreneurship, Access to finance, Collaboration and internationalisation, Knowledge basis and skills, and Government. Each dimension is composed of indicators collected from the existing major EU monitoring platforms/ EU initiatives. For the gaps encountered 'new' data sources have been explored and assessed, including: 1) alternative sources consolidated by public or private data providers in a structured database, 2) data collected by the regions themselves that are not available in Eurostat, 3) consolidated but unstructured information available in e.g. EC websites that could be turned into databases with the help of web crawling and 4) data from traditional data sources included in EU monitoring platforms/initiatives but re-calculated in order to obtain the necessary granularity i.e. sectoral focus on textiles and automotive and digital technology/ICT sector. This was the case for indicators from the KETs observatory (patent based indicators) and the Regional Innovation Scoreboard (bibliometric based indicators) for which the raw data was kindly provided by Fraunhofer ISI and CWTS respectively for the purpose of this study.

This case study is built on the assumption of simultaneous combinations of data from all the different major EU monitoring initiatives (e.g. Regional Ecosystem Scoreboard, KETs observatory, RIS3, Regional Innovation Scoreboard etc.). However, given the scope of the case study and the particularly demanding data needs combining regional level with sectoral information and digitisation (depending on the indicator either combined with the sector in focus or separately) the existing monitoring frameworks are insufficient to cover a great number of indicators, necessary to respond to the research question. The addition of new sources, other existing data sources and recalculations based on existing data from the major EU monitoring initiatives to construct the indicators and their assessment has thus been critical for this case study.

In total 39 indicators have been considered, calculated and assessed, for the framework conditions under the five dimensions and performance indicators suggested to measure digital transformation performance. Data sources used for this case study are: World Bank, OECD, Regional Competitiveness Index, European Observatory for Clusters and Industrial Change (EOCI), Eurostat, IDC, Digital Innovation Hubs, KETs Observatory, EPO, FP7 CORDIS database, CWTS (WoS/Scopus), PATSTAT, Cohesion Data, European Investment Fund, RIS3 data, Crunchbase. Final results are presented in the form of rankings, by dimension and a synthetic index. Further analysis includes a bottleneck analysis to empirically identify the dimensions with the most notable impact on the synthetic index once improved. Further empirical analysis to identify the framework conditions contributing to the performance of top ranking regions can also be performed upon collection of the proposed performance indicators at regional level. Preliminary results by dimension are presented in the case study report.

In this case study, an indicator framework was constructed that captures regional framework conditions relevant for industrial modernisation, piloted for two sectors (textiles and automotive) and a pillar of industrial modernisation, digitisation. The main challenge to overcome was the availability of indicators at the level of region and sector. The main outcome of this analysis is that it is possible to use partially existing indicators, but also the indicator design that exists in the current major EU monitoring platforms/ EU initiatives, to recalculate a good number of indicators at sectoral level for regions. New indicators are however also needed considering especially the new methods to mine and organise data available on the web and other unstructured databases. Also, a good number of indicators can be collected as time series to allow for the monitoring of dynamics.

8.3.3 Case Study 3: Capturing cross-regional cooperation patterns and potential synergies for industrial modernisation

This case study aims at investigating cross-regional cooperation linked to industrial development in the EU as one of the dimensions of industrial modernisation and it aspires to shed more light on potential synergies and cooperation patterns across EU regions and along industrial value chains. The research has explored how data

from different observatories, monitors and complementary databases could be combined to identify cross-regional flows and collaboration opportunities. The case study has created an indicator framework for capturing cross-regional flows according to specific dimensions and investigated how the results can be used by and linked to the ongoing Thematic Smart Specialisation Platforms and to the conducted value chain analysis and mapping.

This analysis has been performed simultaneously at the level of region and at certain stages of the case study at the level of industry. This case study combined indicators that capture flows and linkages extracted from various EU level monitors and observatories and its added value is that this combination is assessed against the existing qualitative studies that are being conducted at the thematic smart specialisation platforms.

We have captured four dimensions of cross-regional flows that are also relevant to industrial transformation 1) trade flows; 2) investment flows; 3) technology flows; and 4) skills flows. To respond to the research questions, we have combined several indicators from several key European monitors and observatories and complement this with further data obtained from text mining specific types of studies and exploiting new types of data sources. The key databases include the Regional Ecosystem Scoreboard as part of the European Observatory for Clusters and Industrial Change, the Smart Specialisation Platform, the Regional Innovation Monitor, the Regional Competitiveness Index and the KETs Observatory that are also databases of relevance that can be linked on the basis of industry. Some of the databases are at the moment available at national level. Regionalisation would thus be necessary for such application which is technically feasible given the possibility to regionalise patents and technological service centres in the field of KETs.

We have implemented two main types of combinations. One is the combination of indicators and data sources from existing EU monitors complemented with the suggestion for the use of novel data that enabled us to reflect about the regional openness of European regions and identify their main connections and links both industry-neutral and industry/theme-specific way. Secondly, we have performed a test analysis for the theme of 3D printing collecting indicators specific for this area, capturing geographical linkages and complementing the existing qualitative case studies performed at the thematic smart specialisation platform.

Following the indicator framework, data for each indicator and each sample region have been collected and organised into a database, both industry-neutral and specific for the theme '3D printing'. Some of the indicators have been already constructed and available through other EU monitors such as the share of medium and high-tech manufacturing, share of international co-publications or regional export and import data, while other new types of indicators have to be collected or recalculated for the purpose of this study such as foreign acquisitions/venture capital investments, regional FDI or share of foreign PhD students. Some of the indicators were only available at the national level and had to be regionalised such as KETs export share or the mobility of researchers. Data has been normalised for each indicator for the sake of comparability and in order to be able to calculate a composite score. The original indicators have been expressed in different forms of statistical units and they have been normalised using the Min-Max normalization technique and to get an identical range (0,1).

8.3.4 Case Study 4: Analysis of business environment and public support to improve SME participation in industrial modernisation

This case study explores a novel way of conceptualising and analysing the business environment specific to SME development, sustainability and growth in industrial modernisation in Europe. Particularly, we focused on internationalisation as an important and indispensable part of industrial modernisation in Europe. First of all, we assessed the concept of business environment by emphasising different areas relevant to SME activities and performance. Secondly, we evaluated the business environment for SMEs by constructing composite indicators and measuring the extent to which the business environment influences SME internationalisation in EU Member States. This case study aims at advancing the conceptual understanding of factors and determinants of the business environment for SMEs, while highlighting gaps and limitations of available data.

The case study combines indicators that capture different dimensions of the business environment specific to SMEs from different international scoreboards. Its added value is that in order to capture external influences affecting SMEs, we included digital infrastructure and human capital accumulation as part of the business environment and explored the relationship between both, business environment and internationalisation.

We identify four dimensions of business environment specific to SME development and growth: (1) regulations, (2) access to finance, (3) digital infrastructure and (4) human capital and knowledge diffusion. The revision of policy and research literature has demonstrated that these dimensions are the most relevant to advanced economies. To answer our main research questions, we assessed the availability of relevant indicators from international sources and scoreboards, such as the Global Competitiveness Index (GCI) of the World Economic Forum, the Doing Business Ranking of the World Bank, the European Innovation Scoreboard and survey data publicly available from Eurostat.

We identified two main combinations for this case study. For Combination 1, we analysed relevant indicators in order to provide an assessment of the business environment among EU Member States and then we clustered the countries based on those scores. Secondly, for Combination 2, we combined the business environment dimensions (from Combination 1) with indicators for internationalisation, in order to analyse whether or not there is a statistically significant correlation between business environment and SME internationalisation.

Based on the proposed conceptual framework for this case study, we identified relevant data sources and indicators. In order to calculate composite indicators, we normalised the data for each indicator and used arithmetic aggregation. To make the data compatible for the analysis, we used the Min-Max normalisation technique to create a range between 0 and 1 for all selected indicators.

Based on the analysis of 4 business environment dimensions, we were able to cluster countries into 3 groups with high, medium and low scores. The analysis of the combination 1 has demonstrated that business environment among EU member states is influenced by different business environment dimensions. Furthermore, the analysis of the Combination 2 confirms that there is a statistically significant relationship between business environment and internationalisation.

8.3.5 Case Study 5: Identification and better monitoring of business investment enabling and supporting industrial modernisation

The main objectives of the case study are to shed light on the role of investment by firms for advancing industrial modernisation and to assess the extent to which current monitoring systems can provide sufficiently relevant and detailed information on the types of investment that are identified as crucial for the modernisation of industry.

The key motivation for the case study is that investment in capital goods, which has long been a major indirect driver for modernisation, is changing its nature in times of digitisation and upcoming new (generic) key enabling technologies. Economic analysis traditionally has focused on investment in fixed assets such as machinery, equipment and building ('tangible investment'). Intangible capital goods such as knowledge and skills, data, reputation and organisational competencies are increasingly gaining in importance. Another important motivation for the case study is the importance to analyse investment patterns in 'combination': in order to be put to productive use, investment in specific types of assets should be complemented by investment in other types of assets. Combining different capital goods may result in positive spill-overs. The case study therefore investigates different types of investment and combinations to propose ways to better monitoring investment related to industrial modernisation. While the case study starts with investigating all main categories of investment by firms, a particular focus is devoted to investment by existing firms in new equipment, new facilities and new knowledge, directly contributing to the modernisation of their capital stock. The case study elaborates a comprehensive framework that describes main categories and dimensions of investment (both in tangible and in intangible assets) and identify, for each of them, the available data sources (Orbis, Amadeus, SBS, SNA, CIS, CVTS, Innodrive, INTAN-Invest, EIB Investment survey, etc.).

Based on a multi-criteria selection process, the case study then further investigates a selection of specific types of investment, which are expected to be combined because of 1) their intrinsic importance in modernising industry and 2) their expected complementary (spill-overs) impacts in modernising industry (i.e. measured by an increase in productivity). A first combination focuses on investments that are 1) directly related to transformations that allow companies to transform into 'Factories of the Future', and 2) for which current monitoring systems provide timely indicators. Combinations 2 and 3 analyse further subset of complementary indicators, including also indicators that are currently less adequately monitored.

Combining and analysing data from several data sources provided some insights. First, despite the limitations in terms of data availability and quality, current monitoring systems can be combined in order to provide relevant information related to the following aspects: 1) cross-country and cross-sectorial differences in terms of 'investment profiles' and investment intensity and 2) extent to which firms in different countries and sectors are effectively modernising their production process and outputs through investment in impactful assets. Relying on comparisons with other EU countries, results can help signalling possible imbalances to be further investigated.

This case study highlights the necessity to improve methods and systems to measure intangible assets and to improve data collection harmonization and completeness of all types of crucial investment for industrial modernisation.

