

# MANUFACTURING A STARTUP

A CASE STUDY OF INDUSTRY 4.0 DEVELOPMENT  
IN THE CZECH REPUBLIC

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# **Manufacturing a Startup: a case study of Industry 4.0 development in the Czech Republic**

Anwar Aridi and Daniel Querejazu

June, 2019



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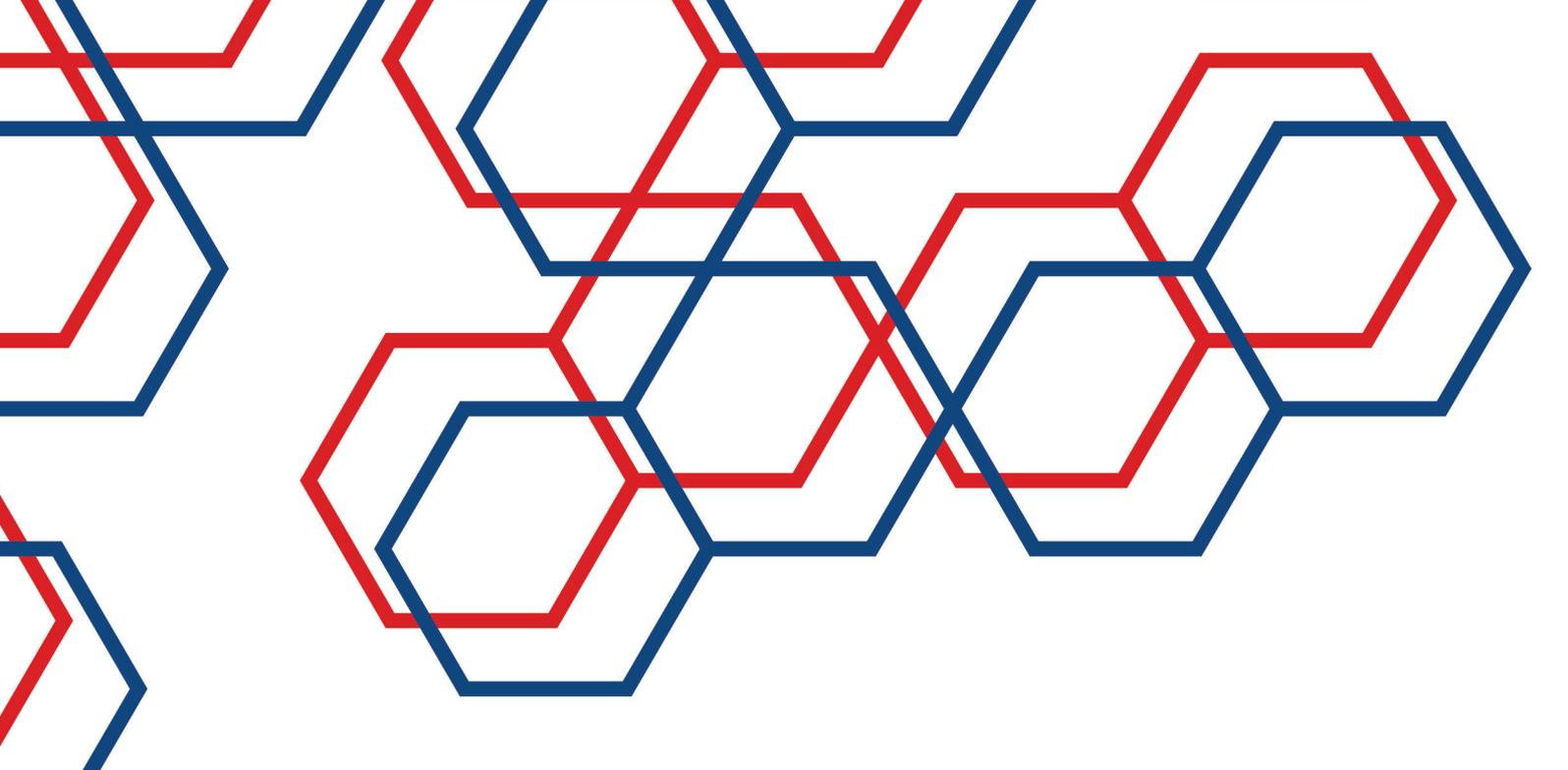
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# 1. INTRODUCTION

This paper investigates the current state of creation and adoption of Industry 4.0 (I4.0) technologies within the Czech Republic. I4.0 technologies, which include technologies such as big data analytics, cloud computing, the Internet of Things, and advanced robotics, hold great promise for increasing the economic competitiveness of adopters. These technologies are also often discussed in terms of their potential to disrupt existing business models and value chains, particularly in the manufacturing sector.

The Czech Republic presents an interesting case study for I4.0 technology creation and adoption: the country boasts one of the strongest manufacturing sectors in Europe relative to the size of its economy but suffers from low productivity and an increasingly acute labor shortage. To remain competitive in the global economy and avoid the middle-income trap, the Czech Republic has a critical need for technologies that can substitute labor through automation and increase the productivity of the existing workforce.

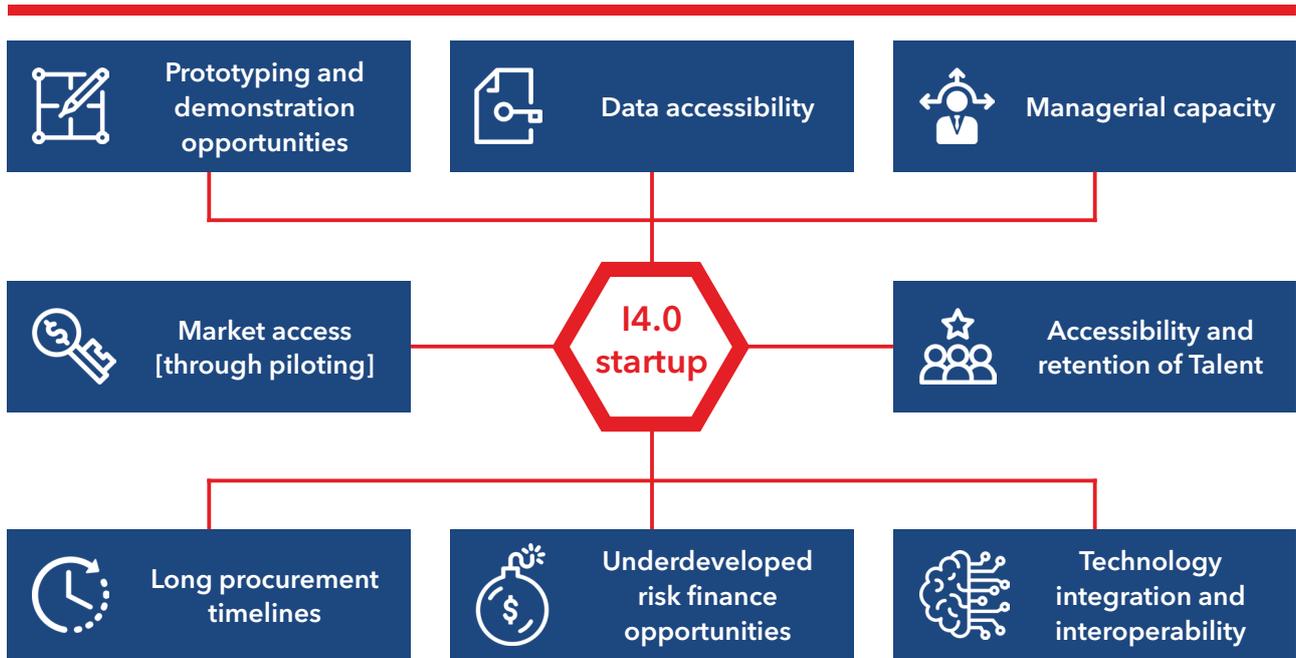
**The focus on I4.0 startups in the Czech Republic is meant to highlight the importance of these agents in enabling the country to ride the next wave of innovation through bridging the digital-physical divide promised by the digital revolution.<sup>1</sup>** Innovative startups and the high growth subset of new market entrants tend to introduce disruptive innovations to the marketplace. In this case, I4.0 startups are unique as compared to regular ICT-based startups, because their innovations are usually engineering and science-based and thus are inherently riskier. This report analyzes the lifecycles of startups creating I4.0 technologies in the Czech Republic, exploring the startups' knowledge origins, their pathways to markets and customers, and the unique challenges they face within the context of the Czech business environment. The emerging challenges are summarized in the table below.

The case study approach offers a comprehensive picture of the I4.0 knowledge landscape, challenges and enabling factors of the technology adopters, and the operating environment where these interactions take place.

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<sup>1</sup> The number of startups based on I4.0 technologies is growing globally, as highlighted in the 2019 Global Startup Ecosystem Report, which found that Advanced Manufacturing & Robotics and Artificial Intelligence were two of the fastest growing startup sub-sectors: <https://startupgenome.com/reports/global-startup-ecosystem-report-2019>

**Figure 1. Key Challenges Faced by I4.0 Startups**



## 1.1 Study Objectives

The objective of this work is to examine the lifecycle of Czech I4.0 startups, with the intent to understand their knowledge, market access, and scaling challenges. Our key assumption is that I4.0 startups face a unique set of uncertainties related to their technologies, customers, investors, and business environment they operate within. These startups have to overcome substantial “knowledge gaps” when it comes to the development of their technologies and solutions (from invention to innovation), accessing their markets (piloting to show results), and scaling (finding smart investors and connecting to value chains). These information asymmetries represent a series of roadblocks to the

development of these startups and could hinder both entrepreneurs and investors from entering this potentially promising space.

In this case study, we aimed to understand:

- How does the Czech Republic fair in terms of its I4.0 knowledge base and research collaborations?
- How do I4.0 startups develop their technologies/ services and access customers, markets, and investors?
- Finally, what are the set of policies and support instruments that could overcome the uncertainties and challenges of I4.0 startups?

## 1.2 Conceptual Framework

To answer the questions above, we developed an ecosystem-based analytical framework to guide our analysis. We aim to not only capture the internal workings of I4.0 startups, but also understand their sources of external knowledge, markets, customers,

and environment. Thus, the framework, shown in Figure 1, takes an ecosystem-level view of the I4.0 technology lifecycle from the perspective of Czech startups.

Within this framework, information flows through direct and indirect pathways between research organizations, I4.0 solutions providers (including startups and large incumbents), and I4.0 adopters. Direct knowledge transfers include research collaborations; licenses; and purchases of intellectual property; while indirect transfers include students, researchers, professors transitioning into industry; dissemination of research through publications, presentations, and conferences; and through informal discussions between framework actors.

The I4.0 market consists of a wide range of potential adopters of I4.0 technologies. I4.0 solutions providers and startups sell their solutions through direct sales to end users (B2C) and/or through B2B business models. Both sets of actors may need access to data and/or access to industrial/manufacturing equipment and processes to be able to develop their I4.0 solutions.<sup>2</sup>

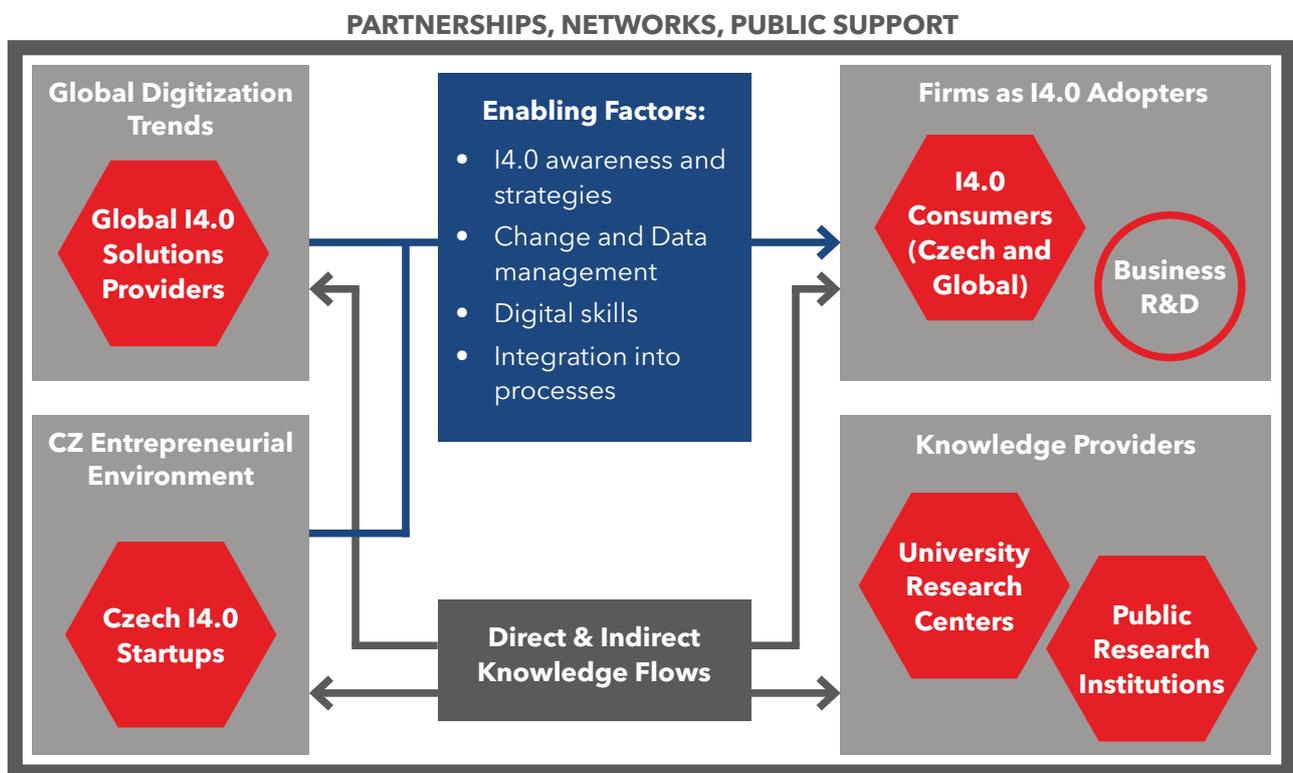
For some I4.0 solutions, adoption is a simple “plug and play” process. For more complex and/or data

intensive I4.0 solutions, adoption may require a number of enabling factors:

- adopters may need to understand their own data and process challenges (Schröder 2016);
- adopters may need information about what I4.0 technologies can do (McKinsey 2015, PricewaterhouseCoopers 2016, Ren et al. 2015);
- adopters may need skills and expertise (in analysis, forecasting, automation, etc.) to make use of I4.0 technology outputs (Kagermann et al. 2013, PricewaterhouseCoopers 2016, McKinsey 2015, Walendowski et al. 2016);
- and/or adopters need the capacity to transform company processes and value chains (Schröder 2016, Sommer 2015, Moeuf 2018).

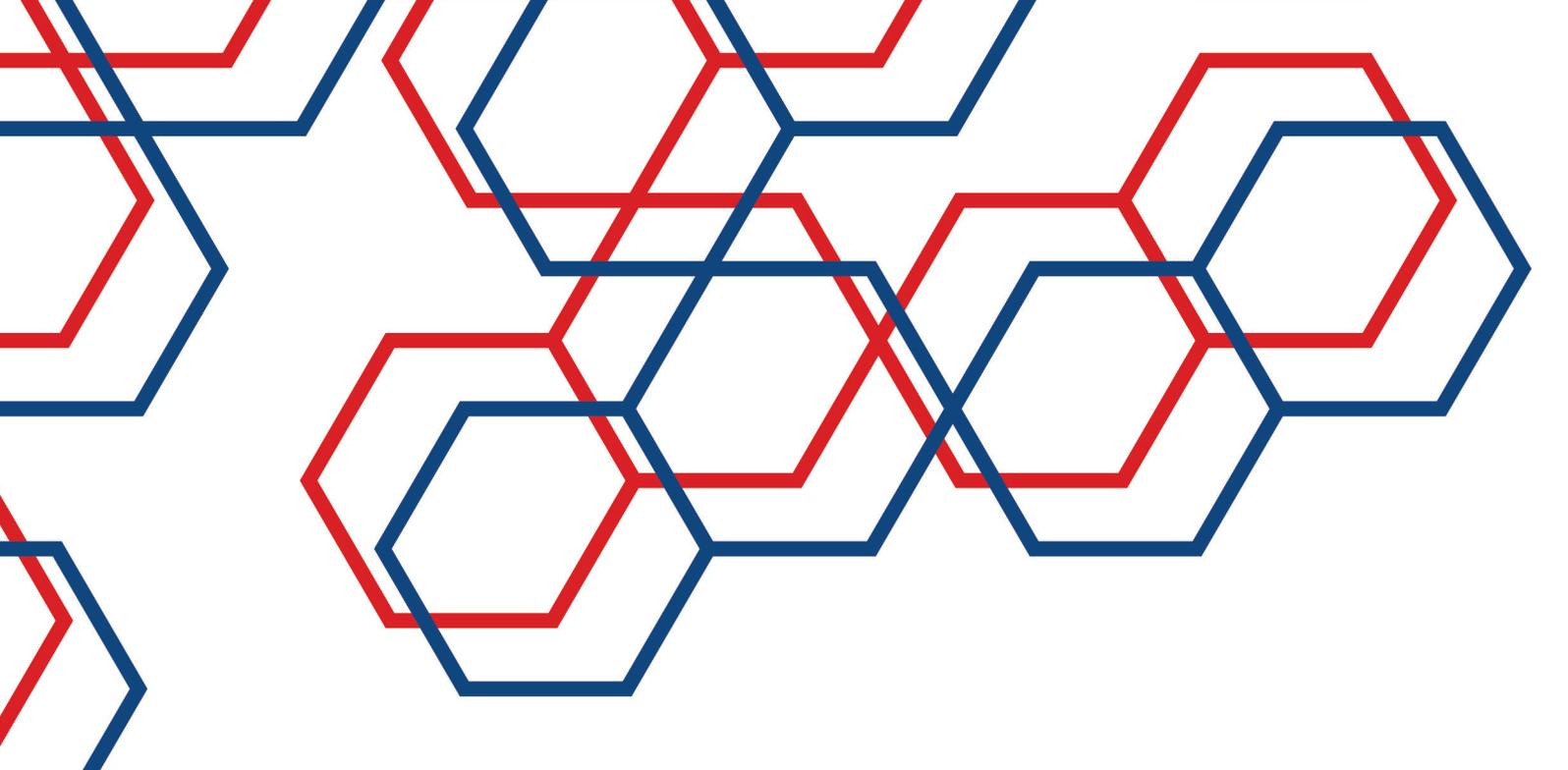
This report follows a case study approach to describe the experiences and lifecycles of Industry 4.0 startups in the Czech Republic. Appendix I includes a description of the methodology, data sources, the survey and interviewed stakeholders.

**Figure 2. Case Study Framework: Czech I4.0 Actors, Networks, and Enabling Conditions**



Sources: authors.

<sup>2</sup> I this paper we are mainly focused on B2B and firms as adopters.



## 2. WHY THE CZECH REPUBLIC AND INDUSTRY 4.0?

### 2.1

#### Need for innovation and productivity improvements in the Czech Republic

**The manufacturing sector is a critical part of the Czech economy, leading all sectors of the economy in terms of employment and gross value added.** The manufacturing sector made up 28.6 percent of the value added by the Czech economy in 2017, well above the EU average of 16.4 percent and highest among its regional peers.<sup>3</sup> Manufacturing, particularly automotive manufacturing, has grown in size and importance due, in large part, to the high levels of net foreign direct investment (FDI) that the Czech Republic received in the 1990s and early 2000s.

**While the manufacturing sector and the rest of the Czech economy have been growing in recent years, the Czech Republic is challenged by weak labor productivity and labor productivity growth.** Labor productivity per hour worked was USD \$38 in 2017, around 60 percent of German and Austrian

productivity levels and only above Poland among its regional peers. The Czech Republic has also seen low labor productivity growth, experiencing lower growth than Poland, Hungary, and Slovakia from 2016 to 2018.<sup>4</sup> Czech SMEs, in particular, drag down the country's labor productivity, with small firms experiencing about half the labor productivity of larger Czech firms.<sup>5</sup>

**The Czech Republic is also facing an increasingly acute labor crunch.** It had an unemployment rate of 2.4 percent in 2016, the lowest in the EU and well below the EU average of 8.2 percent.<sup>6</sup> Labor shortages, especially among blue collar workers, are a growing concern for Czech employers. In 2018, 45 percent of Czech manufacturers and 40 percent of builders cited labor shortages as a factor limiting production.<sup>7</sup>

<sup>3</sup> World Bank national accounts data, and OECD National Accounts data files. <https://data.worldbank.org/indicator/NV.IND.MANF.ZS> (Accessed on 5 March 2019)

<sup>4</sup> The Conference Board, "Total Economy Database: Growth Accounting and Total Factor Productivity, 1950-2016". (November 2018)

<sup>5</sup> OECD (2017), Entrepreneurship at a Glance 2017, OECD Publishing, Paris, [https://doi.org/10.1787/entrepreneur\\_aag-2017-en](https://doi.org/10.1787/entrepreneur_aag-2017-en)

<sup>6</sup> World Bank national accounts, <https://data.worldbank.org/indicator/SL.UEM.TOTL.ZS> (accessed March 5, 2019)

<sup>7</sup> 2018 European Business and Consumer Survey

The Czech Republic, having achieved modest productivity gains through attracting FDI in the previous two decades, is now at risk of falling into the middle-income trap (MIT), whereby it can no longer compete internationally in labor-intensive industries because wages have increased, but it can also not compete in higher value-added activities because productivity is too low (Gill and Kharas 2007). The Czech Republic already has a high degree of export complexity, ranking fourth in the EU in the

Observatory of Economic Complexity's Economic Complexity Rankings.<sup>8</sup> However, automation and digitization through the adoption of Industry 4.0 technologies will be key to increasing nationwide TFP, while human capital accumulation, in the form of ICT and STEM skills, is a critical enabler of the adoption of Industry 4.0 and other digital technologies (Glawe and Wagner 2018, World Bank 2016, Russman et al. 2015).

## 2.2

## Industry 4.0 Overview

The term "Industry 4.0" originated with the German government as part of a national high-tech initiative launched in 2011. There is no single agreed upon definition of Industry 4.0. The concept is sometimes used interchangeably with the term "The Fourth Industrial Revolution" which is characterized by a fusion of technologies that is blurring the lines between the physical, digital, and biological spheres. (Schwab 2016). Industry 4.0 is most often described as increased digitization and automation in the manufacturing environment (Oesterreich and Teuteberg 2016, Kohler and Weisz 2016, Roblek et al. 2016), and much of the literature characterizes Industry 4.0 as the integration of manufacturing value chains through digitization (Kagermann et al. 2013, Dombrowski and Wagner 2014, Geissbaue et al. 2016).

Industry 4.0 and the Fourth Industrial Revolution are umbrella terms that cover a set of technologies related to cyber-physical systems and broader access to advanced computing power, covering technologies such as the Internet of Things (IoT); artificial intelligence and machine learning; data analytics; cloud computing; robotics, 3D printing, and other advanced manufacturing technologies.

This paper adopts the three categories of Industry 4.0 technologies utilized by the World Bank's Europe 4.0 framework: informational, operational, and transactional technologies.

- **Information** technologies take advantage of the exponential growth of data to reduce the costs of computing, transactions, and coordination. This goes beyond the spread of computers and the Internet and includes big data analytics, cloud computing, IoT, artificial intelligence, and machine learning.
- **Operational** technologies combine data with automation to reduce the importance of labor costs in determining competitiveness and enable greater customization. This includes robots and 3D printing, which can disrupt the current structure of global value chains based on specialization, scale economies and low labor costs.
- **Transactional** technologies combine data with market exchange to reduce information asymmetries and, therefore, the costs of matching buyers and sellers. This matching process, enabled by e-commerce platforms, the sharing economy, and blockchain, creates new markets.

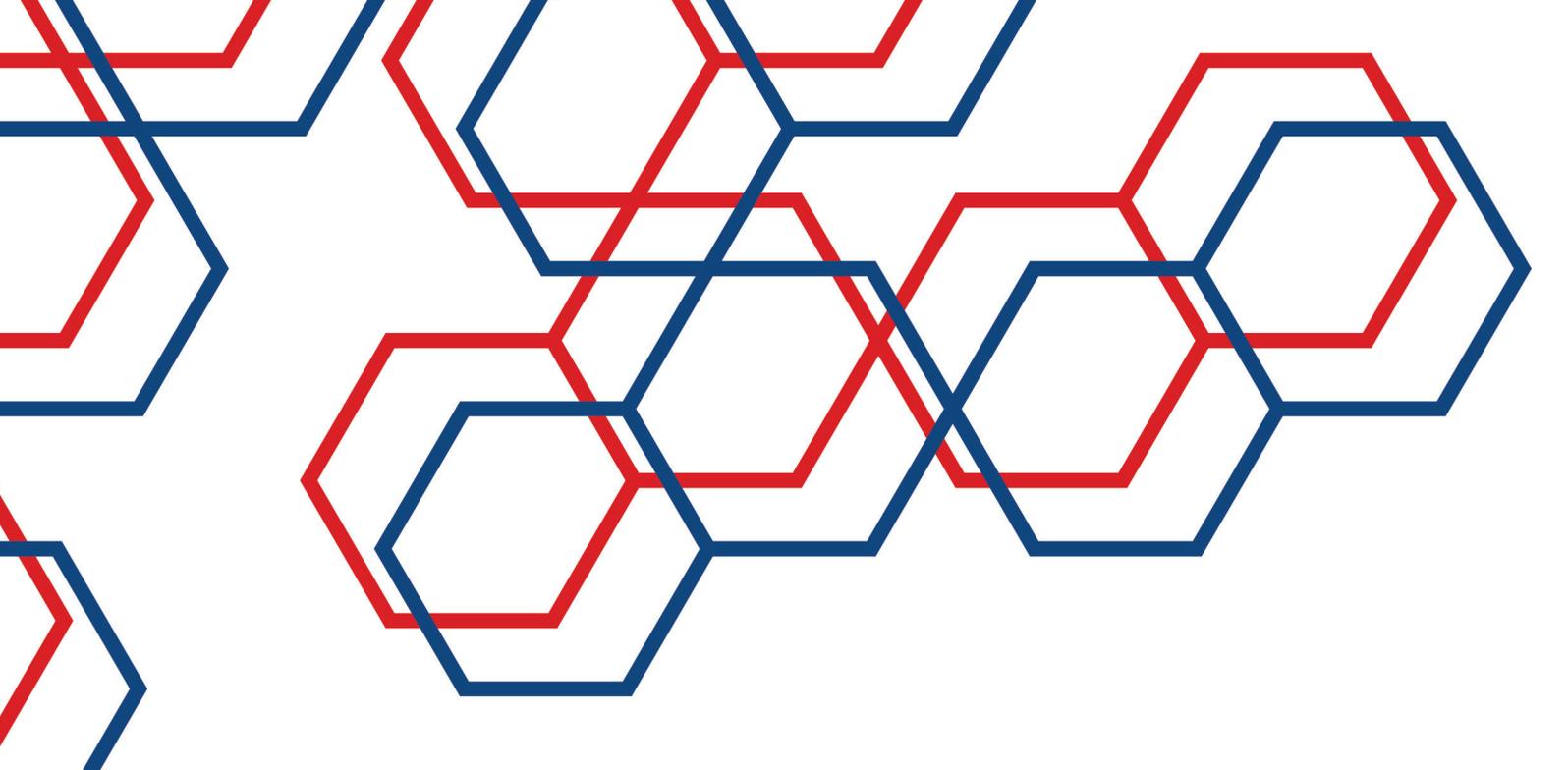
<sup>8</sup> MIT. The Observatory of Economic Complexity. <https://atlas.media.mit.edu/en/rankings/country/eci/> (accessed March 20, 2019)

A review of Industry 4.0 literature identifies three primary areas where Industry 4.0 technologies impact adopters: operational improvement; the disruption of existing value chains and business models; and the demand for skills.

**Operational improvement:** Operational improvements can be achieved through value chain digitization and integration, which results in accelerating and optimizing firm processes (Kagermann et al 2013, Dombrowski and Wagner 2014, Geissbaue et al 2016). Industry 4.0 technologies can also improve firms' decision-making and forecasting capacities, allowing firms to make decisions and predictions based on real-time data and big data analysis (Espejo and Dominici 2016, Posada, et al. 2015). Automation will allow firms to substitute labor and reduce costs (Autor & Salomons 2018, Espejo & Dominici 2016, Roblek et al. 2016), while advances in human-machine interaction will allow workers to interact with equipment more efficiently (Posada, et al. 2015).

**Disruption of existing value chains and business models:** Industry 4.0 technology adoption may enable firms to integrate their horizontal and vertical value chains (Kagermann et al 2013) and lead to the creation of new value chain activities, such as product data analytics and data security (Porter and Heppelmann 2016). Adoption may also enable new business models that employ more "as-a-service" offerings (Porter and Heppelmann 2016, Jazdi 2014, Dujin et al 2014, Foidl and Felderer) and allow for more customization of products and services (Dombrowski and Wagner 2014, Kohler and Weisz 2016). Industry 4.0 technologies may also allow closer interaction with customers and the adaptation of business models to more closely mirror market requirements (Geissbaue et al. 2016)

**Changes in demand for skills:** adopting Industry 4.0 technologies will increase demand for ICT and STEM skills, as well as interdisciplinary thinking, and reduce demand for unskilled labor (Glawe and Wagner 2018, World Bank 2016, Rüssmann et al. 2015).



## 3. ANALYSIS

Our analysis investigates components of the framework presented in Figure 1, consisting of five sections: 1) I4.0 Knowledge Base in the Czech

Republic, 2) Czech I4.0 Startups, 3) Czech I4.0 Adopters, 4) Framework Conditions, and 5) Public Support for I4.0.

### 3.1

#### Czech Industry 4.0 Knowledge Base

In this section, the Czech Republic is benchmarked against other EU countries in terms of publication and patent outputs related to I4.0 technologies.<sup>9</sup> While publications and patents do not directly translate to new startups and commercialized products and services, these outputs indicate the size of a country's knowledge base and provide indicative information about the absorptive capacity of the internal market for I4.0 technologies.

**Overall I4.0 knowledge creation in the Czech Republic, in the form of I4.0 publications and patents, is relatively modest** - below the outputs

of its more developed regional peers, Germany and Austria, as well as below the normalized EU averages. Research and development (at least those I4.0 R&D projects performed with some share of public funding) is largely concentrated among a few universities in Prague and Brno, though there are a large number of private sector companies that have participated in collaborative research projects with local universities and public research institutions.

The share of I4.0-related publications has grown in the Czech Republic, rising from about 1 percent of all publications in 2011 to over 2 percent in 2018.

<sup>9</sup> For the analyses included in this section, I4.0-related technologies comprise Internet of Things (IoT), Artificial Intelligence, Machine Learning, Big Data Analytics, Cloud Computing, Robotics, and 3D Printing. Transactional technologies (blockchain, e-commerce platforms, etc.) are not typically patented, and thus were not included.

**Figure 3. Number of Czech publications and share of I4.0-related Czech publications, 2010-2018**



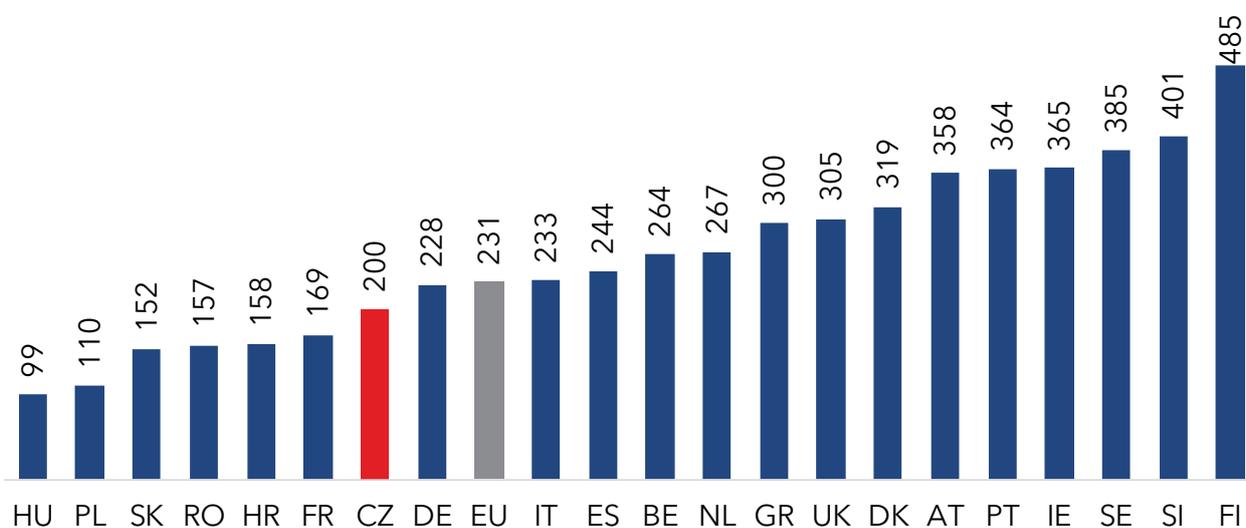
Source: Web of Science.

However, despite the growth in I4.0-related publications, the Czech Republic ranks below the normalized EU average and in the middle of its

regional peers for I4.0-related publication outputs - above Hungary, Poland, and, Slovakia; but below Germany and Austria.

**Figure 4. Number of I4.0 publications relative to population, EU countries with more than 500 I4.0-related publications, 2010-2018 (Publications per 1 million population)**

Notes: Population numbers as of 2017.



Source: Web of Science, Eurostat.

Like many Central and Eastern European countries, the Czech Republic's overall patent outputs are low relative to Western Europe, the US, and Japan. This is in part due to the practice of "off-shoring" patents, whereby patents created by domestic subsidiaries are often registered under the subsidiaries' holding companies abroad.<sup>10</sup>

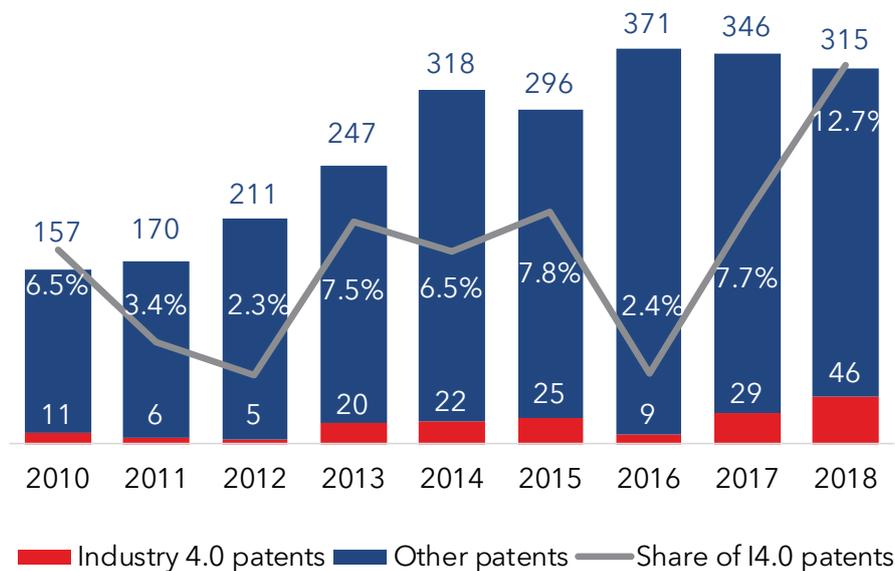
Despite this, patent activity around I4.0-related technologies in the Czech Republic has been increasing in number of patents and in the overall share of patents in the since 2010. The share of I4.0 patents has increased from 2 percent in 2012 to over 12 percent in 2018.

Czech patents tend to focus on operational technologies (robotics and 3D printing) more so than informational technologies (Internet of Things, Artificial Intelligence, Machine Learning, Big Data Analytics, Cloud Computing), with 95 operational patents registered to Czech assignees between 2000 and 2018, compared to 59 informational patents. The dominance of operational technology patents could also be explained by the nature of informational technologies, which is usually less patentable and rely mainly on other IP protection business models, such as market capture, control of standards, data ownership, trademarks, and copyright.

Like publications, the Czech Republic lags behind the normalized EU average and its peers Germany and Austria in the number of I4.0 patents, as shown in Figure 5.<sup>11</sup>

**Figure 5. Number of Czech patents and share of I4.0-related Czech patents, 2010-2018**

**Notes:** Only active patents included in analysis, years according to earliest publication date



Source: Orbit by Questel.

<sup>10</sup> The patent offshoring impacts of the foreign ownership-subsidary relationship among Spanish firms was recently explored by Tamayo and Huergo (2017).

<sup>11</sup> The national rankings in Figure 5 are likely somewhat skewed by corporate patenting patterns related to national IP policies and tax laws, which may lead corporations to patent in countries with lower corporate and royalty taxes. EU countries that likely benefit from these patenting patterns include Luxembourg and Cyprus (ranked 1 and 9 respectively in Figure 5). See Dischinger and Riedel (2011) and Karkinsky and Riedel (2012) for further discussion on this topic.

## Top Czech Organizations in I4.0 Knowledge Creation

Publicly available data on Czech I4.0 R&D projects shows that R&D activity is largely concentrated among a few universities in Prague and Brno. The Czech Technical University in Prague (CTU), home of the Czech National Centre for Industry 4.0 and the Czech Institute of Informatics, Robotics and Cybernetics, is the leading center for I4.0 R&D in the Czech Republic, followed by the Brno University of Technology.

The CTU is also the top performer in the country for patent outputs, but notable Czech private sector actors also rank highly, including Avast Software, a Czech cybersecurity firm; Zoom International, a Czech company developing customer management

and workforce optimization solutions; and Skoda Auto, a Czech automotive manufacturer and subsidiary of the Volkswagen Group.

## Research Collaborations

A network analysis of patent collaborations (for patents with more than one assignee), as can be seen in Figure 6, shows Czech Technical University of Prague (CTU) as the most active collaborator in the Czech I4.0 patent space; unsurprising, given that the university also holds the largest number of I4.0 patents in the country. The network also shows that, aside from patent collaborations involving CTU, the most common linkages are among private companies.

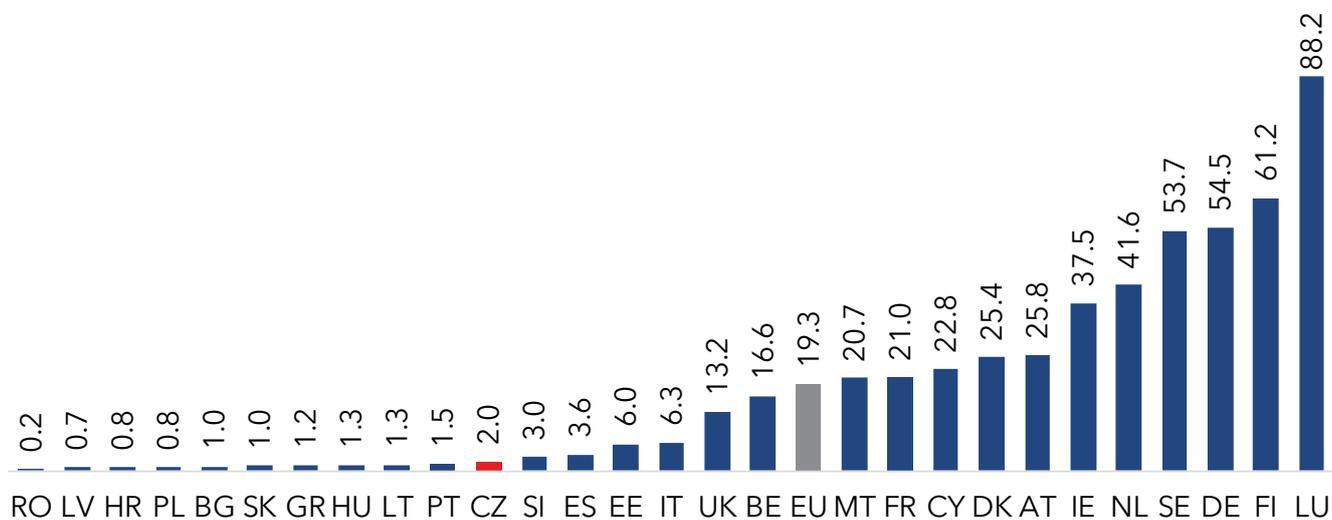
**Table 1. Top R&D institutions in Industry 4.0 by number of R&D projects, Czechia, 1991–2019**

R&D institution name	Location	Publicly funded R&D Projects	Contractual Research Projects
Czech Technical University in Prague / Faculty of Electrical Engineering	Prague	160	36
Brno University of Technology / Faculty of Electrical Engineering and Communication	Brno	60	21
Technical University of Liberec / Institute for Nanomaterials, Advanced Technology and Innovation	Liberec	15	51
Charles University in Prague / Faculty of Mathematics and Physics	Prague	58	3
Czech Technical University in Prague / Faculty of Mechanical Engineering	Prague	44	17
Brno University of Technology / Faculty of Information Technology	Brno	42	14
University of West Bohemia / Faculty of Applied Sciences	Pilsen	37	6
Brno University of Technology / Faculty of Mechanical Engineering	Brno	33	8
Institute of Information Theory and Automation of the Czech Academy of Sciences	Prague	34	0
VSB - Technical University of Ostrava / Faculty of Electrical Engineering and Computer Science	Ostrava	31	3

Source: Starfos TACR.

**Figure 6. Number of active I4.0 patents relative to population, EU countries, 2019 (Number of patents on 100,000 population)**

**Notes:** Only active patents included, population numbers as of 2017.



Source: Orbit by Questel, Eurostat.

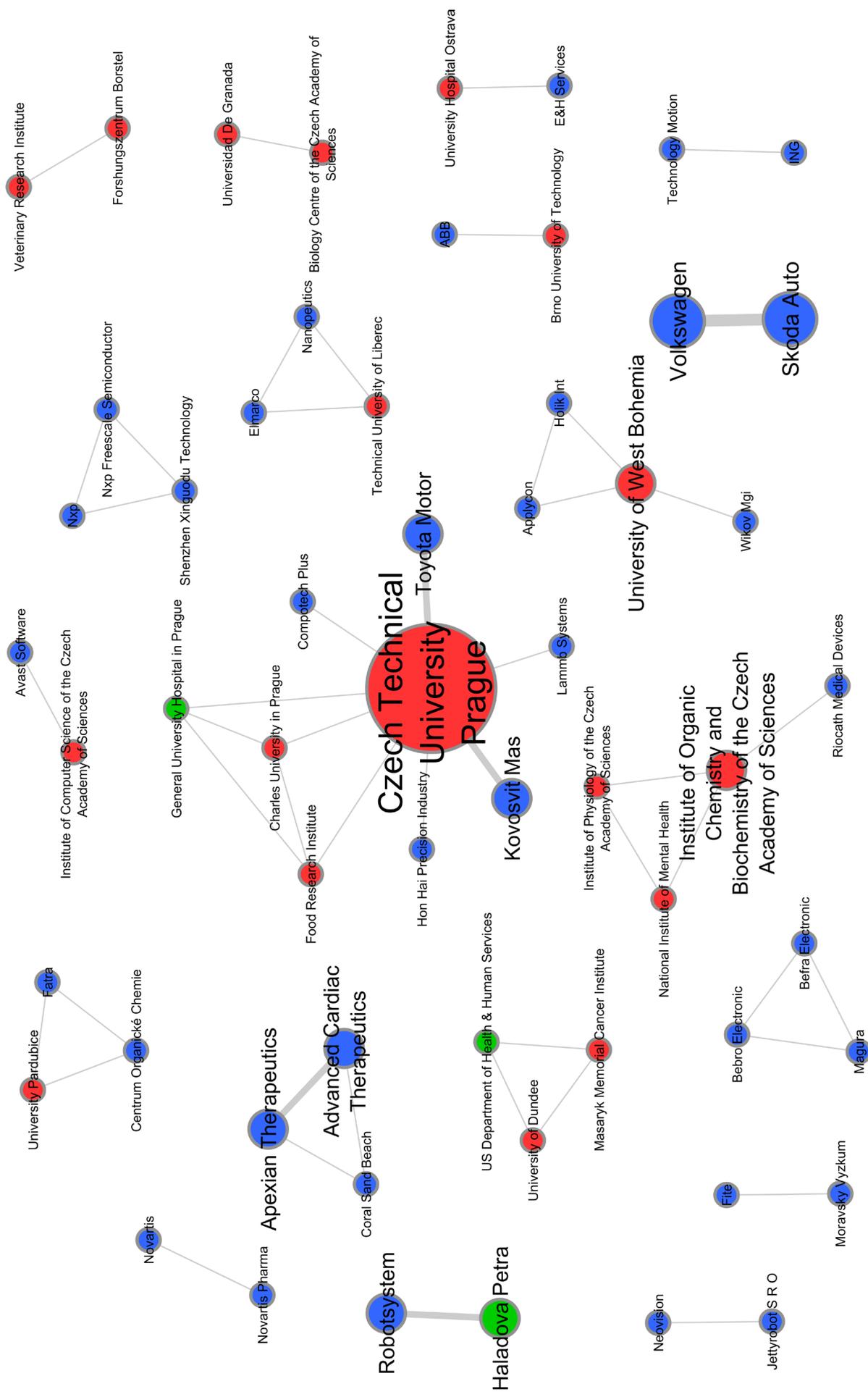
**Table 2. Top institutions in Industry 4.0 according to number of patents, 1999–2019**

Name of the institution	Type of Org	Number of patents
Czech Technical University of Prague	University	24
Avast Software	Company	15
Zoom International	Company	13
Rieter	Company	8
Robotsystem	Company	7
Robe Lighting	Company	6
Skoda Auto	Company	5
Brno University of Technology	University	4
Moravsky Vyzkum	Company	4
IQRF Technology	Company	4

Source: Starfos TACR.

**Figure 7. Network patent space in Industry 4.0, Czech Republic, 1999–2019**

**Notes:** Only active patents included in the analysis; red indicates R&D institutions, blue indicates companies, green indicates others; edge width illustrates number of patents among two subjects (range 1-3); circle size and label size illustrate number of patents (range 1-8).



Source: Orbit by Questel.



A network analysis of research collaborations, as can be seen in Figure 7, shows that collaborations are concentrated among five universities: CTU-Prague, University of West Bohemia, VSB - Technical University of Ostrava, Brno University of Technology, and Technical University of Liberec. However, the network includes a large number of actors from across the Czech ecosystem, including large participation from the private sector (486 private companies), as well as 157 university faculties and public research organizations, and 73 other types of organizations (including hospitals, NGO, government ministries, etc.).

The center of the network includes a cluster of private companies on the supply side of I4.0 technology development, including Camea (camera systems and sensors for transportation and industry solutions),

Certicon (software development, embedded systems development and hardware design), VÚTS a.s. (spectrum R&D services), Neovision (robotics), Gaben (RFID sensors), and Spechtech (automated voice solutions). The local nature of these research and patenting collaborations between universities and local firms corroborate with evidence from other OECD countries that proximity matters for knowledge flows between industry and academia. Evidence from the US has shown that citations from industry patents to university research publications, for instance, increase with proximity to those universities (Jaffe, Trajtenberg, and Henderson, 1993) and this remains the case with the dominance of digital technologies and reduction in the cost of communication (Figueiredo, Guimarães, and Woodward, 2015).<sup>12</sup>

## 3.2

### Czech Industry 4.0 Startups: Potential in the Making

#### Characteristics of the I4.0 Startup Population in the Czech Republic

Through interviews with stakeholders in the Czech ecosystem, a population of 54 startups was identified that had marketed one or more products/services based on an I4.0 technology. Of the 21 startups that responded to the survey, most were generally small in size, with 88 percent of the surveyed companies having fewer than 50 employees, and 71 percent having annual revenues of less than CZK 25 million (approximately \$1.1 million).

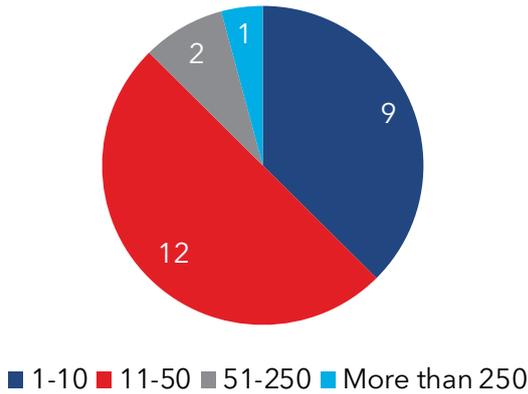
Informational technologies (Internet of Things, Artificial Intelligence, Machine Learning, Big Data Analytics, Cloud Computing) are the most common technology offered by surveyed companies, with

81 percent offering at least one informational technology. 24 percent have at least one operational technology (robotics and 3D printing) and 5 percent have at least one transactional technology (e-commerce platforms and blockchain).

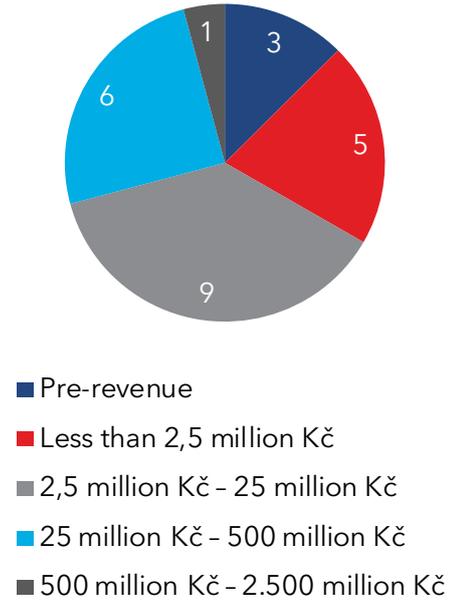
**Founders of Czech I4.0 startups generally have prior professional experience**, often in the fields of data science, analytics, or artificial intelligence. Several interviewed founders started their companies after coming up with a new business idea over the course of their career. Stakeholders noted that, because I4.0 solutions generally target manufacturing and industry applications, it is valuable for founders to have at least some knowledge of these applications and processes when developing their products and services.

<sup>12</sup> OECD, 2019. "University-Industry Collaboration: New Evidence and Policy Options". <http://www.oecd.org/fr/innovation/university-industry-collaboration-e9c1e648-en.htm>

**Figure 9. Number of employees of surveyed startups**



**Figure 10. Annual revenues of surveyed startups**



**The extent to which I4.0 startups tap into the local knowledge base in unclear due to the difficulties of licensing IP and spinning out from Czech universities.** A large majority (78percent) of the surveyed startups had developed a technology internally, while 38 percent had co-developed or licensed a technology from a university and 14 percent had co-developed or licensed a technology from another company. However, academic spinouts in the Czech Republic are hindered by institutional issues such as complicated processes in starting spinouts, ineffective TTOs, and weak incentive structure for the commercialization of ideas. Universities are generally hesitant to enter into IP licenses with the private sector, and there are few university centers capable of providing business services to spinouts. The low numbers of university developed or licensed technologies among the surveyed startups may be due in large part to these challenges. The companies may have officially developed the technology internally, but relied on a large degree of expertise and know-how gained from local research organizations.

### Perception of Markets, Customers, and Impact

**Early customers, usually found locally, often provide startups with essential access to data and equipment for developing new solutions and are important for validating solutions for the I4.0 market.** Czech I4.0 startups rely heavily on their initial customers to provide them access data,

equipment, and platforms they need to develop their technologies (see the Challenges section below) and serve as critical bridges to markets abroad by providing platforms for validating I4.0 technologies.

**A majority of interviewed startups found their first customer in the Czech Republic, where they tested and validated their solutions.** Once the solution had been validated with one or more local adopters, the startups would then seek customers outside of the Czech market. One startup founder said that getting early customers requires a local manager or executive willing to “take a chance” on a new company and product where others will not. Many of these startups develop case studies to use as marketing materials, which show potential customers how their solution was implemented, how it operates, and the benefits gained by previous customers - these case studies are key to helping potential customers better understand the I4.0 solutions offered by startups.

**For startups seeking to sell solutions to large multi-national companies, their access point into the supplier network is usually to pilot their solution in one of the multi-national’s local plants or offices** (in the Czech Republic or CEE region). Transitioning into these large supplier networks is often a difficult, multi-phase process; many of the startups interviewed had this process brokered by an early investor or facilitated by a local mid-level manager within the adopting company who acted as a champion for the solution within their organization.

**While proximity to early customers appears to be very beneficial to startups, the importance of proximity diminishes as I4.0 startups mature and gain market traction.** Despite the fact that many I4.0 startups find their early customers in the local market, none of the surveyed startups felt that proximity to customers was essential to their business model and only 19 percent believed that proximity was “very important, but not essential” to their business model. Nevertheless, many interviewed founders considered proximity advantageous for establishing and managing client relationships.

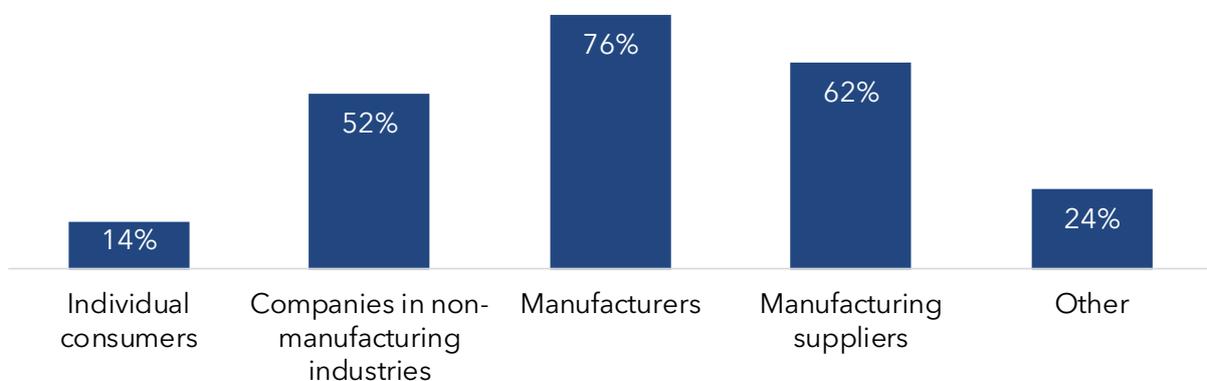
The majority of surveyed companies utilized B2B business models, most often targeting manufacturers and manufacturing suppliers (producers of manufacturing equipment and platforms). 42 percent of the startups surveyed drew more than 50 percent of their revenue from outside of the Czech Republic. Larger, more established startups (those with more than 10 employees) tended to draw a higher portion of their sales from outside of the Czech Republic, which aligns with the early local customer story described above. It can be inferred that these larger startups have already validated their solutions, likely either in the local or regional market, and moved on to customers in the larger EU or global markets.

**Piloting of the I4.0 startups’ solutions represents the primary gateway for adoption, and but comes with major drawbacks.** Customer relationships usually start with a pilot project to test the I4.0 solution, even for I4.0 products and services that have been successfully adopted by other firms. Adopters feel pilots are necessary to ensure the solution provides its intended benefits, and, more critically, ensure that the solution will not disrupt important company processes and operations. Pilots include an assessment period, after which the adopting company may spend some time deliberating whether to adopt at a wider scale. This *pilot-assessment-deliberation* process can extend procurement timelines by years and severely restrict the cash flows of I4.0 startups.

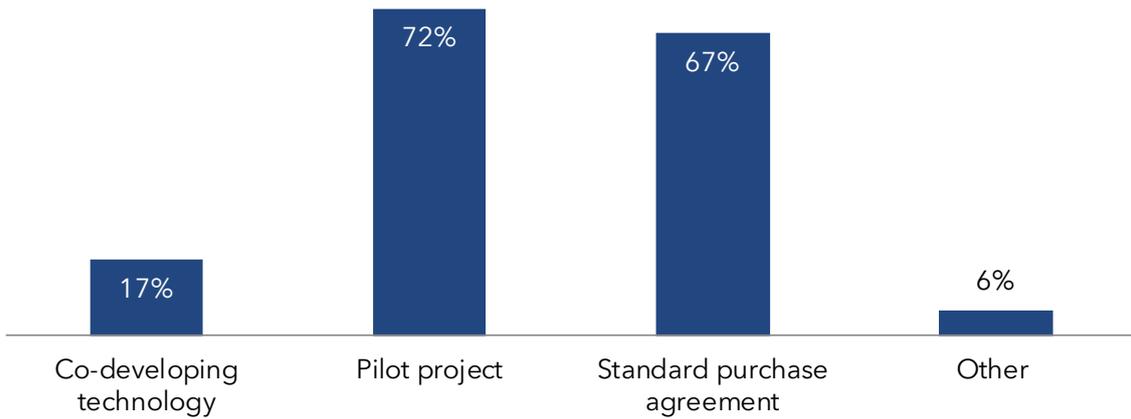
**Startups perceive that their solutions impact their customers most in the area of operational performance.** Over 80 percent of startups believed their solutions impacted their customers’ operational performance, while about half of startups believe they impacted customers’ big data usage, decision making and forecasting capabilities, and/or operational flexibility.

Czech I4.0 startups largely perceive their competitors coming from the international market, with the majority of surveyed startups perceiving that they compete with large international companies (68 percent) and/or international startups (57 percent), rather than with domestic companies.

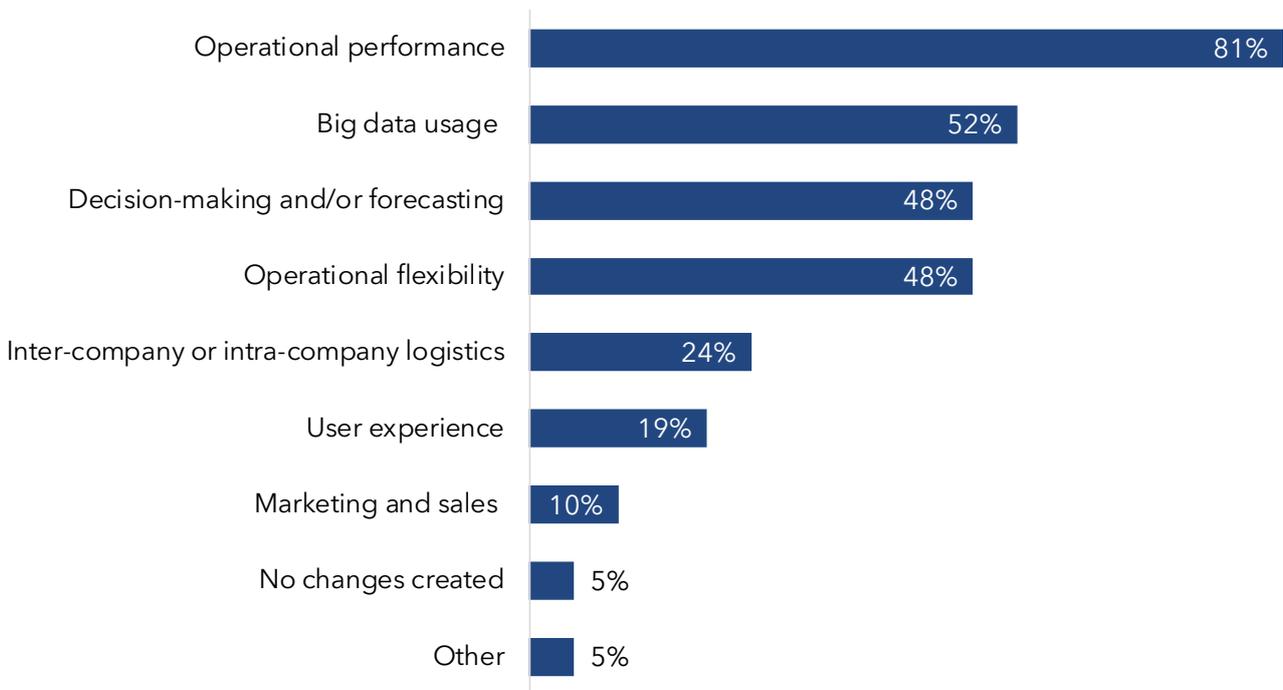
**Figure 11. Types of customers targeted by surveyed startups**



**Figure 12. Surveyed companies' relationships with manufacturing clients**



**Figure 13. Perceived impacts on customers**



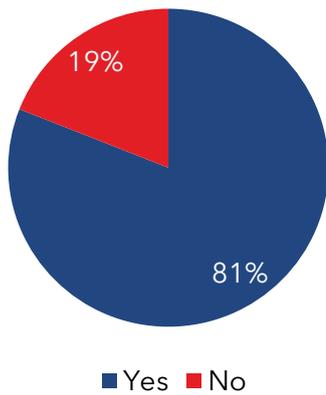
## 14.0 Startups [Perceived] Challenges

### Data Accessibility

A large majority (81 percent) of the startups surveyed required some type of real-world data to develop their solutions. This data was primarily supplied by manufacturers and manufacturing suppliers. When asked whether data access was challenging for I4.0 startups, most startups and stakeholders did not

describe data access as a major challenge. Startups said they generally acquired the data they needed from their early customers, which is reflected in the survey response data. However, because access to data appears to be a prerequisite to developing many I4.0 solutions, failure to acquire needed data likely has dire consequences for early-stage I4.0 startups. The experiences related to us may represent a degree of survivorship bias - those companies that could not get access to needed data may not have survived to take part in our study.

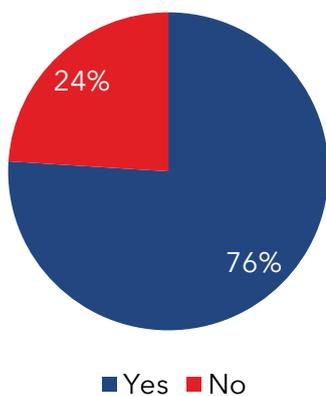
**Figure 14. Percent of surveyed startups that required access to data to develop their I4.0 solution(s)**



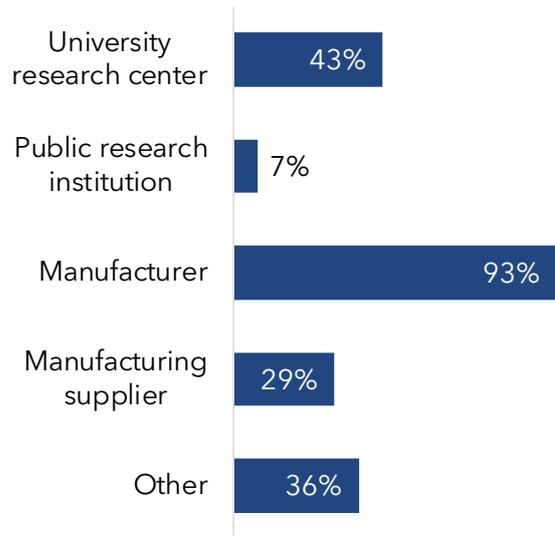
**Proof of Concept (PoC), Prototyping, and Demonstration Opportunities**

A majority of the startups surveyed (76 percent) required some type of support to develop PoCs, prototypes, or demonstrations. Most startups had received PoC, prototyping, or demonstration support from a manufacturer (64 percent), but many received support from universities, suppliers, and research institutions. Additionally, the Czech Republic, through its Technology Agency, has made available several policy instruments that support PoC and prototyping of technologies emerging from public research institutions (more on this in section

**Figure 16. Percent of surveyed startups that required support for proof-of-concept, prototypes, or demonstration**

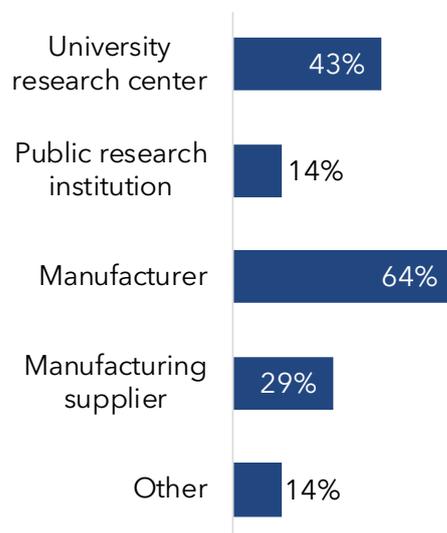


**Figure 15. Source of data for surveyed startups to develop their I4.0 solution(s)**



3.5). Like data access, the interviewed startups and stakeholders did not describe PoC, prototyping, and demonstration as a challenge. The startups we spoke to generally developed with their early customers, though one startup had made use of one of the small number of I4.0 test beds in the country (located at the Czech Technical University of Prague and Brno University of Technology). However, much like the data access question, these experiences may represent some amount survivorship bias – those companies that were unable to develop proofs-of-concept, prototypes, or demonstrations may not have survived to take part in our study.

**Figure 17. Source of support for proof-of-concept, prototypes, or demonstration**

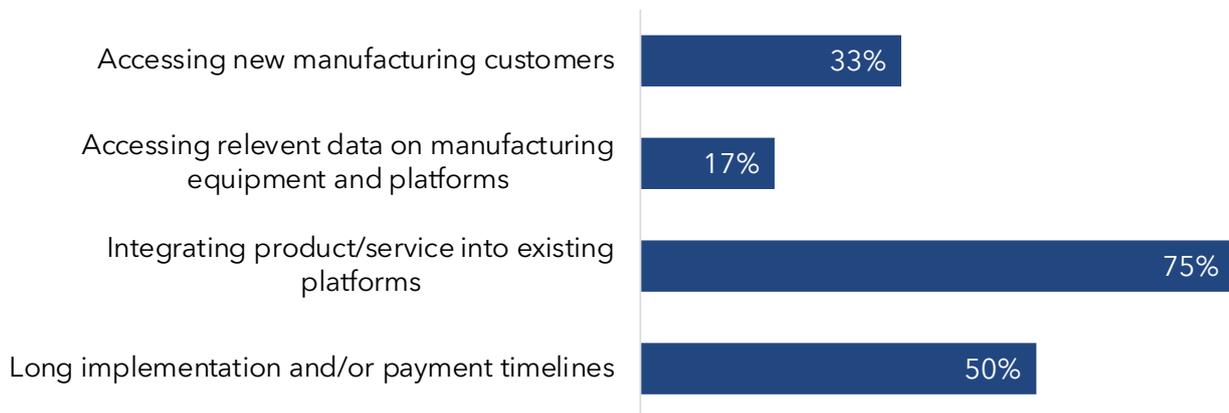


### Technology Integration and Interoperability

94 percent of the startups we surveyed said they always or sometimes needed to integrate their products and services into existing manufacturing or logistics platforms. Of those, 78 percent said this integration always or sometimes required them to

work with third-party platform developers, such as Honeywell or Cisco. Surveyed startups said that the need to work with third-party developers to implement their technologies raised a number of challenges, including long implementation and payment timelines and accessing new customers.

**Figure 18. Challenges related to working with third-party platform developers**



### Long Procurement Timelines

The frequent requirement that B2B customer relationships begin with a pilot and assessment period can lead to very long sales and procurement timelines for I4.0 startups. These long timelines, typical for knowledge and technology intensive products and services, can severely restrict startup cash flows and negatively impact their risk capital investment prospects. This challenge was raised frequently in interviews with startup founders, as well as investors.

### Managerial Capacity to Grow

Czech I4.0 startups also face many of the managerial and business challenges that “typical” startups face. The Czech entrepreneurial ecosystem is still emerging and concentrated in few sectors with few successful exits. Many of the required managerial skills of entrepreneurs, such as business model development, team building, and sales and marketing strategy development, are in short supply. Surveyed entrepreneurs perceived growth-oriented managerial skills, such as the development of marketing and sales strategies, as the most challenging managerial task.

**Table 3. Management challenges faced by surveyed startups**

Challenge	% of surveyed startups that experienced challenge
Identifying a viable business model	62%
Creating marketing and/or sales strategies	81%
Managing logistics (including procurement, internal operations, and distribution)	24%

### Accessibility and Retention of Talent

Talent recruitment also poses a challenge for Czech I4.0 startups, with 57 percent of startups surveyed saying they had difficulties recruiting and/or retaining talented employees. While the Czech Republic’s labor shortage is most acute in blue collar workers, the market for data scientists, analysts, and other ICT professionals is also highly competitive (see Section 3.4).

### Underdeveloped Risk Financing Opportunities

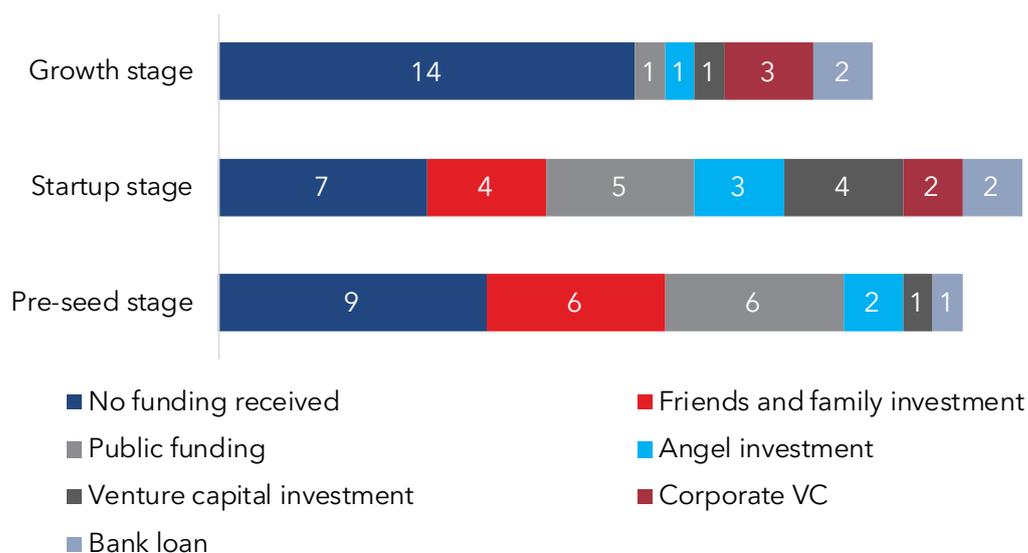
I4.0 startups face several challenges when seeking investment: they are usually riskier, more capital intensive (even at the early stage), have longer sales cycles, and require more patient financing than a “typical” (i.e., software-based) startup. In addition, in countries with young risk capital sectors, many local investors lack the knowledge to recognize and assess some of the more complex, advanced I4.0 technologies, such as artificial intelligence-based solutions. This represents a challenging information asymmetry that can hinder the startups’ abilities to access funding.<sup>13</sup>

There is only one active investment fund (Y Soft) focused on nurturing and growing I4.0 startups in the Czech Republic. This scarcity could reflect the small

number of investment opportunities (deal flow) and the lack of I4.0 investor knowhow. Investment rounds for Czech I4.0 companies are usually larger than a typical Czech investment round, where VCs are more accustomed to investing startups based on travel websites or SaaS. The longer sales and procurement cycle mean that investors will need to wait longer to see if their investments will pay off or not. One interviewed investor explained that they would know the next day if a travel startup they had invested in would get traction, whereas they might not know about the growth prospects of a manufacturing-focused startup for two or three years. Investors often lack the knowledge to source and vet I4.0 technologies – one local investor acknowledged that their VC firm initially lacked the capacity to assess and conduct due diligence on startups developing AI and machine learning platforms and had to build expertise in those areas to enable them to make such investments.

Of the surveyed companies that received investment, they tended to rely on friends and family and public funding in earlier growth stages, while venture capital and corporate VCs and investment funds became more important in later stages, both of which are in line with investment activity of “typical” startups.

**Figure 19. Type of investment received by growth stage of surveyed startups**



<sup>13</sup> A recent report by the EIB details the challenges facing Deep Tech startups in Europe when accessing financing. EIB, 2018. Financing Deep Tech Revolution: [https://www.eib.org/attachments/pj/study\\_on\\_financing\\_the\\_deep\\_tech\\_revolution\\_en.pdf](https://www.eib.org/attachments/pj/study_on_financing_the_deep_tech_revolution_en.pdf)

The Czech I4.0 startups' exit market is nascent and dominated by M&As. Risk investments in fast growing startups are usually driven by the prospects of successful exits. Interviewed entrepreneurs and stakeholders reported that the typical exit strategy for I4.0 startups is M&A – either be acquired by a large manufacturer or by an incumbent I4.0 solutions provider. In fact, there have been only two such acquisitions in the Czech Republic in the last two years: Cleerio, which develops mapping and asset management tools, was acquired by Bio-Nexus in 2017, and Stories, developer of a business intelligence AI assistant, was acquired by Workday

in 2018. A number of multinational companies operating in the I4.0 are actively scouting, working with, and investing in startups through programs such as Siemens' next47, Airbus' BizLab, and Skoda's Digilab.

Additionally, surveyed startups were evenly split between those that preferred M&A and those that preferred to maintain private ownership of their company. This partial equity aversion combined with weak investor readiness reflect the immaturity of the risk investment markets in the CR and in this emerging sector specifically.<sup>14</sup>

**Table 4. Preferred exit strategy of surveyed companies**

Exit strategy	% of surveyed startups
Merger & Acquisition	47%
Initial Public Offering	6%
Maintain Private Ownership (No Exit)	47%

## Sewio: from local to global player

Sewio, a Czech startup established in 2014, has developed a real-time location tracking system (RTLS) using ultra-wideband (UWB) technology. The company was founded by two researchers at Brno University of Technology, who developed expertise in UWB while working on a research project related to satellites. Realizing UWB had potential applications for location tracking in indoor settings, the two developed a prototype RTLS that could track objects over a 500 m<sup>2</sup> area, which garnered a lot of interest from the commercial sector and became the foundation for their company.

In the early stages of development, Sewio's founders relied on "smart money" investors, including Y Soft Ventures (a Czech VC firm specializing in IoT startups), to help them refine their business model, scale up the technology, and identify early customers. Shortly after founding, Sewio was approached by Cisco and PwC, who were scouting and partnering with startups

who could expand their IoT capabilities. Through this partnership, Sewio found many of its initial customers, including PRAKAB, a local cable manufacturer, Budweiser Budvar, a Czech brewer, and Volkswagen.

Sewio relies heavily on customer testimonials and case studies to show potential customers how their technology is implemented, how it operates, and the benefits provided to previous customers – sometimes going so far as to take new customers to the factory floors of previous customers to show their solution in action.

For their large customers, implementation usually begins with a proof-of-concept in a small area to demonstrate and validate Sewio technology before large-scale installation, resulting in a sales cycle of approximately 12 to 16 months. For small- or medium-scale installations, the sales cycle is usually reduced to three months.

Today, Sewio has 25 employees with customers in 37 countries. Its customers include Volkswagen, Budweiser Budvar, Pirelli, and Škoda.

<sup>14</sup> For more information on the Czech early stage risk investment activities see: Aridi, Anwar; Gray, Nelson Campbell; Ong Lopez, Anne Beline Chua. 2018. Stimulating Business Angels in the Czech Republic (English). Washington, D.C.: World Bank Group. <http://documents.worldbank.org/curated/en/633181541532716870/Stimulating-Business-Angels-in-the-Czech-Republic>

To better understand the customers and markets that I4.0 startups are trying to access, we also explored the adopters and potential adopters of I4.0 technologies in the Czech Republic, trying to understand what drives I4.0 technology adoption, identify how and where do adopters find I4.0 solutions, and understand the internal and external challenges related to adoption.<sup>15</sup>

### Drivers of adoption

**Czech manufacturers described three primary motivations for adopting I4.0 technologies: labor substitution, cost reduction, and quality assurance.** Labor substitution through automation addresses a critical need for Czech firms, given the extremely acute shortage of blue-collar workers in the country. One manufacturer interviewed for this work stated that “our number one goal in adopting automation technologies is to replace workers”. Labor substitution has the significant added benefit of reducing costs; Czech firms believe they need automation, along with other cost-reducing digital technologies, to remain competitive in the global market. The need for quality assurance is largely driven by customer requirements and/or the demands of foreign ownership.

**There is very little evidence of value chain or business model transformation in the Czech Republic among existing enterprises,** despite the fact that much of the I4.0 literature discusses the potential for I4.0 technologies to disrupt existing value chains and business models. Some Czech companies and multi-nationals with manufacturing plants in the Czech Republic have set ambitious goals for automation, digitization, and new digital services, but at present most activity is restricted to pilot scale with no wide-scale reconfiguration or transformation at the company level.

**Interviewed stakeholders largely agreed that some I4.0 technologies can enable the disruption/transformations of value chains and business models, but the adopters themselves would need to drive these organizational changes.** Internal company inertia and lack of management capacity

were identified as the key factors impeding large-scale transformation.

### Adoption strategies and processes

**Adoption of I4.0 solutions is still sporadic and lacks scale for strategic transformation.** Adopting and implementing individual I4.0 solutions is usually done on an ad hoc basis. Most Czech companies, particularly Czech SMEs, have no formal (or informal) strategies or processes for adopting I4.0 solutions. A few companies with a large-scale presence in the Czech Republic have launched Industry 4.0 strategies or initiatives, including Skoda Auto, Foxconn, and Siemens. These typically outline high-level company goals for digitization and automation and include new pilot production facilities that make use of new digital or advanced manufacturing technologies. However, these strategies and initiatives do not include systematic processes for piloting or adopting individual I4.0 solutions.

Because of the ad hoc nature of I4.0 adoption, the decision to adopt (or pilot) could come from many parts of a firm's management: by executives in an overseas headquarters, in the case of multinational companies, by local upper-level executives, or by mid-level operations managers who have identified a problem in production.

In the Czech Republic, only the big multinational companies like Siemens, Skoda Auto, and Foxconn have the resources to develop I4.0 solutions internally. The vast majority of Czech firms look for I4.0 solutions available on the market. Companies typically approach established incumbents, such as Honeywell or Cisco, for “off-the-shelf” products and services – solutions perceived as validated by the market and/or with a simple “plug-and-play” installation. For more tailored or experimental solutions, Czech companies turn more often to local startups and universities. As mentioned in Section 3.2, these tailored or experimental solutions require a pilot and testing period to make sure they will not disrupt operations and that they provide the desired benefits, whereas the “off-the-shelf” solutions do not.

<sup>15</sup> Note that the following discussion on I4.0 adopters draws on qualitative interviews with a number of firms, industry associations, and other relevant stakeholders. We did not survey Czech adopters, and thus our analysis may not capture the full landscape of I4.0 adoption in the Czech Republic.

## Skoda Auto's Digital Transformation

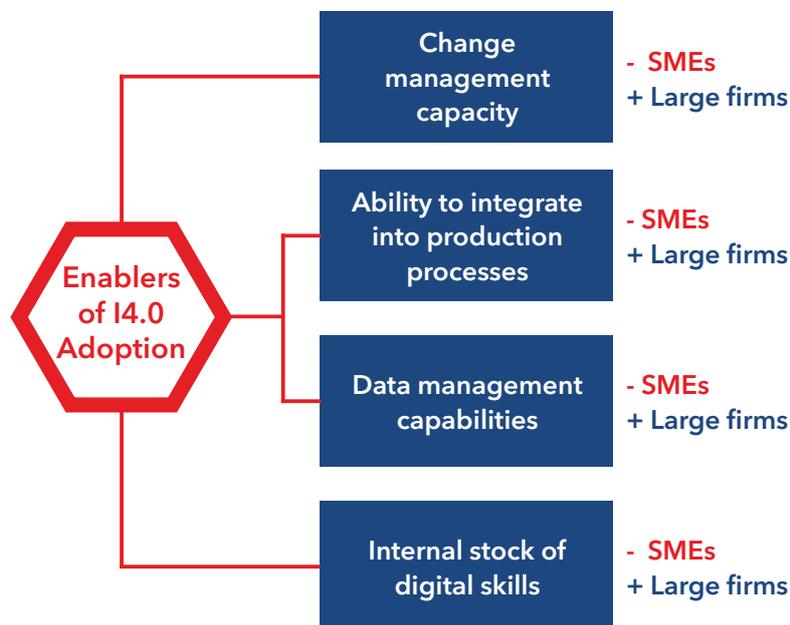
Skoda Auto's 2025 Strategy has defined digitization and creating digital mobility services as the cornerstones of its future corporate development, with ambitions to make the same profits from digital services as it does from car sales. Skoda plans invest billions of Czech crowns (tens to hundreds of millions of euros) in digitization and automation.

As part of the 2025 strategy, Skoda launched the Skoda Digilab in 2016 to develop and pilot new

business models, solutions, and products based on digital services. These new products and services include:

- HoppyGo: peer-to-peer carsharing platform
- CareDriver: mobility services for children and vulnerable older people in the form of trained chauffeurs
- ŠKODA Connect: online services, such as traffic information, roadside assistance, remote access, and the Alexa assistant available via Skoda vehicles

**Figure 20. Enablers of I4.0 Adoption**



### Enablers of adoption: new sets of capabilities

A firm's capacity to innovate depends not only on its internal managerial and technological capabilities, but also on external complementary factors and sources of knowledge (Arnold & Thuriaux, 1997; Cirera and Maloney, 2017). This holds true for the ability to adopt I4.0 technologies, which depends on the firm's ability to navigate and leverage a set of internal capacities and constraints and ones that are external to the firm. Consequently, these abilities are also correlated with the size of the firm where larger and more established enterprises fair better in most, especially resource-dependent. We identify *four key internal capacities needed for effective adoption of I4.0 solutions*:

### Change management capacity

I4.0 technologies can enable new business models and process changes, but adopters need to have the capacity and willingness to make these organizational changes. Interviewed startups said that while some of their technologies could disrupt their customers processes and value chains, the customers themselves need to drive this change. These startups mentioned the need for change management capacity of their customers to overcome internal company inertia and drive organizational changes. Ideally, smaller firms should be more agile and able to adapt compared to big and vertically integrated firms.

### Ability to integrate into production processes

Manufacturers and other stakeholders continually stressed that the adoption of new technologies cannot disrupt company operations and production – hence the need for piloting new I4.0 solutions. SMEs, in particular, are largely driven by tight production timelines and short planning horizons and rarely have the time or resources for sourcing and implementation of I4.0 solutions. One manufacturing SME reported that the company designs its production lines first using “old” technology to begin production as soon as possible to satisfy customer demands and will then later upgrade using more automated equipment when time allows because of the longer time requirements needed to set up automated production lines.

### Data management capabilities

Companies need to know what their internal data challenges are, and need to be able to collect, clean, and manage their own data for it to be useful. Several I4.0 startups explained that this often presented a challenge when working with new customers. They

would need to help their customers build their internal data management capacity before being able to implement their I4.0 solution. Beyond the implementation of individual I4.0 solutions, industrial companies may have large amounts of data on industrial processes and equipment of great value to I4.0 solutions providers. Very few, if any, industrial companies have formal strategies for when and how they provide access to this data.

### Internal stock of digital skills

Potential adopters may need to recruit new digitally savvy workers with data management and analytics skills to develop, implement and utilize I4.0 solutions. Depending on the I4.0 solution, they may also need to retrain equipment operators and maintenance crews. Interviewed manufacturers were primarily concerned with the shortage of blue collar workers, but specifically highlighted the rising competitive pressures for digital skills. In such environment, SMEs are not able to offer the high market salaries for senior developers and data scientists to compete with large MNEs.

## 3.4

## Framework Conditions

There are three key framework conditions that can catalyze the creation and diffusion of I4.0 technologies and solutions in the Czech Republic. These relate to:

- v. The sustainable supply of digitally-skilled labor
- vi. The entrepreneurial environment where the I4.0 startups and entrepreneurs operate
- vii. The level of awareness and adoption trends of I4.0 technologies in the Czech market, especially among local SMEs

Generally enhancing these conditions could result in more startups and more commercialized I4.0 solutions (supply), and more diffusion and adoption (demand) among local enterprises and consequently further improving economic outcomes.

### The supply of digitally skilled labor

The most important factor in determining the future success of both the supply and growth of I4.0 startups and the diffusion of these solutions among Czech enterprises is the availability of digitally-skilled labor. There is a large body of literature (including Glawe and Wagner 2018, World Bank 2016, Russman et al. 2015, and others) showing that human capital is a critical factor for adoption of I4.0 and other digital technologies. Overall, the Czech Republic is an average performer in terms of general digital skills, ranking 13th in the EU in the DESI Human Capital Index in 2018, which ranks European member states by internet use and digital skills. The Czech Republic ranked 15th in the EU in the number of ICT specialists as a percent of total employment and 14th in the number of STEM graduates per 1,000 population.<sup>16</sup>

<sup>16</sup> European Commission. The Digital Economy and Society Index (DESI). <https://ec.europa.eu/digital-single-market/en/desi> (Accessed on 5 March 2019)

Companies developing I4.0 technologies, including both startups and incumbents, generally need workers with advanced digital and technical skills in artificial intelligence, data science, automation, or similar fields. While the Czech labor crunch is most severe for blue collar workers, there are also shortages of workers with advanced technical skills. I4.0 startups have to compete with established tech companies, such as Avast, as well as large manufacturers, such as Skoda and Siemens, who are attempting to develop their own internal I4.0 capabilities. IBM has also recently opened the new IBM Watson iLab in Prague, which seeks to add 30 new AI researchers over the next few years. Competition for advanced digital skills has driven up salaries for skilled workers in recent years, adding to the wage burden and investment needs of I4.0 startups.

I4.0 adopters also need technical skills, particularly in data analytics, data management, networking, and programming, to be able to internally develop, implement and use I4.0 technologies. Technology adoption is also not a purely technical exercise. Cirera et al. (2019) identified significant number of management skills needed by existing businesses to absorb industry 4.0 technologies, including business model review and adaptation; developing strategic partnerships and collaborations; supply chain management; talent management, retention, and training; market and customer analysis; and logistics planning. Sommer (2015) noted that the capacities needed to meet the challenges of I4.0 adoption strongly depend on the enterprise size, and that SMEs are at higher risk of becoming victims, rather than beneficiaries, of the new digital revolution.

## Entrepreneurial environment

Entrepreneurship, in terms of new business density, has grown in the Czech Republic in recent years, with nearly four new businesses registered per 1,000 people in the working age population in 2016. However, despite improvement in new business density, the country remains below the European average of 4.8 new businesses registered.<sup>17</sup> There have been several success stories among Czech startups in the last decade, particularly in the area

of cybersecurity. AVAST Software had an IPO in 2018 and had the largest market share among anti-malware application vendors in January 2018,<sup>18</sup> while Cognitive Security was acquired by Cisco in 2013.

Entrepreneurship support, in the form of incubators, accelerators, networks, VCs and other actors, is largely centered in Prague and Brno. Some of these actors specifically focus on support for Industry 4.0 startups, such as the I4.0 test beds at the Czech Technical University of Prague and Brno University of Technology, the AI Startup Incubator and Prague IoT Centre in Prague, and Y Soft Ventures, a VC focused on Industry 4.0 hardware startups in Brno.

I4.0 startups, like all startups, have a great need for general entrepreneurial and managerial skills. The entrepreneurship culture in the Czech Republic is still developing and these skills are in short supply, as are experienced entrepreneurs and mentors to help train and spread those skills. Czech university graduates generally possess good technical skills but less developed soft skills, in particular, managerial, sales, and marketing skills. These weaknesses are attributable in part to the rigid curriculum (e.g., facts-based and with little room for creative thinking that helps develop the soft skills) found within the Czech education system.

One potential bottleneck for the Czech Republic's entrepreneurs and high-growth companies is the country's nascent risk capital sector. In terms of venture capital investments as a percentage of GDP, the Czech Republic ranked lowest among its regional peers and among the lowest in the European Union in 2016. The Czech Republic also ranks among the lowest in Europe in number of venture-backed companies in 2016.<sup>19</sup> There is an emerging angel investment community in the Czech Republic, but it is small both in terms of the number of investors and the amount invested and also concentrated geographically in Prague.<sup>20</sup>

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<sup>17</sup> World Bank, "World Development Indicators."

<sup>18</sup> Statista. <https://www.statista.com/statistics/271048/market-share-held-by-antivirus-vendors-for-windows-systems/>

<sup>19</sup> OECD (2017), *Entrepreneurship at a Glance 2017*, OECD Publishing, Paris, [https://doi.org/10.1787/entrepreneur\\_aag-2017-en](https://doi.org/10.1787/entrepreneur_aag-2017-en)

<sup>20</sup> World Bank (2018). *Stimulating Business Angels*. Retrieved from <http://documents.worldbank.org/curated/en/633181541532716870/Stimulating-Business-Angels-in-the-Czech-Republic>

## 14.0 knowledge flows and 14.0 adoption trends

Knowledge barriers related to the range of Industry 4.0 solutions available on the market and the benefits they can provide are a challenge for Czech companies, especially for SMEs. In their scan of the current state of I4.0 adoption in the Czech Republic, Marek et al (2016) found a highly limited awareness of Industry 4.0, particularly among top management of Czech companies, caused by an absence of successful business cases and studies that clearly presented successful implementations of Industry 4.0. In a survey of Czech manufacturers, Basl (2017) found that 60 percent of the surveyed companies had never implemented any Industry 4.0 technologies. Of those non-implementing companies, 75% said they had little to no awareness of Industry 4.0 technologies. Thus, it is important to promote and highlight the productivity and competitiveness benefits of digital solutions among local companies and SMEs.

Information barriers can be particularly acute among SMEs, whose management does not have the time or resources to seek out information on the large amount of I4.0 products and services on the market. Additionally, large I4.0 solution providers usually target and market their solutions among large firms rather than smaller and resource-strained firms. Research collaborations, R&D, and contract research, with local and international knowledge providers represents an important source for external knowledge and experimentation, which

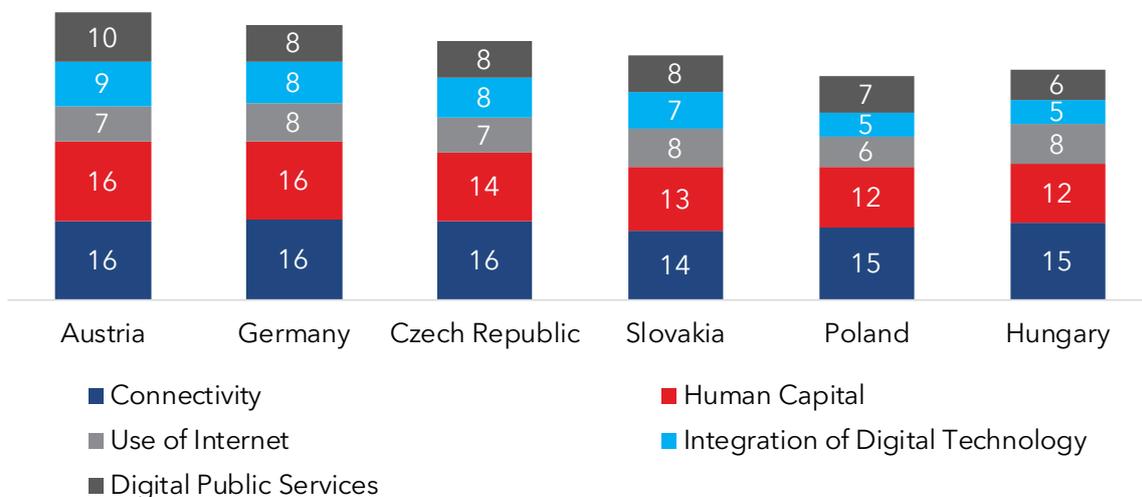
usually leads to the development or adoption of new I4.0 solutions. Large firms are usually more active in such research collaborations and Czech firms are no exception.

Ecosystem stakeholders reported that I4.0 awareness is more widespread now than in previous years, but there is still a need to spread information about I4.0 technologies to many Czech companies – particularly successful use cases that show the process for implementing and using a given I4.0 solution and the benefits provided to adopters.

There are a number of associations and networks active in the I4.0 space (particularly industry associations, such as the Czech Confederation of Industries, Czech Electric and Electrical Association, and CzechInno) that primarily focus on lowering knowledge barriers around I4.0 technologies to potential adopters, particularly to Czech SMEs. Several of these associations also aim to play a matchmaking role between potential adopters and I4.0 solution providers.

The current state of adoption of digital and automation technologies in the Czech Republic is mixed. Czech companies rank very well in the use of basic internet technologies for e-commerce, ranking 2nd in the EU e-commerce turnover, 3rd in online sales across borders, and 6th in SMEs conducting online sales. However, Czech companies rank much lower in the use of more advanced digital technologies, ranking 17th in the EU in the use of cloud services and 27th in the use of Radio Frequency Identification (RFID).<sup>21</sup>

**Figure 21. Digital Economy and Society Index in 2018**



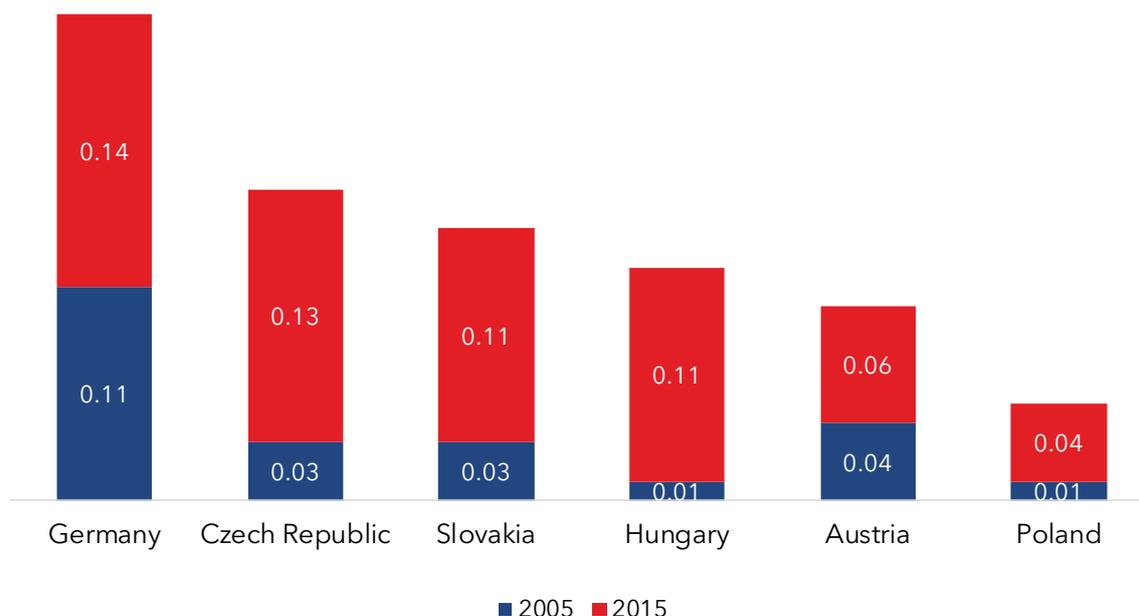
Source: DESI, 2018.

<sup>21</sup> European Commission. The Digital Economy and Society Index (DESI). <https://ec.europa.eu/digital-single-market/en/desi> (Accessed on 5 March 2019)

In terms of automation, the robot intensity (industrial robot stock over manufacturing value added) of the Czech economy increased 400 percent between 2005 and 2015, while the OECD average increase was only 30 percent.<sup>22</sup> However, among Czech SMEs, there is stagnation in the adoption of new product and process innovations (which could include both

automation and digital innovations), with fewer SMEs adopting new product/process innovations in 2017 than in 2010 – a pattern repeated by SMEs around the CEE region, including in Germany, Poland, Slovakia, and Hungary.<sup>23</sup> Therefore, SMEs around the region seem to be missing out on the potential benefits of digital adoption.

**Figure 22. Robot intensity: Industrial robot stock over manufacturing value added, millions USD, current values**



Source: OECD Science, Technology and Industry Scoreboard (2017).

### 3.5

## Public Support for Industry 4.0 in CR

The Czech Republic's Industry 4.0 policies are relatively new and still under development. In August 2016, the Czech government approved the *Prumysl 4.0* (Industry 4.0) Initiative, a national initiative that aims to prepare and guide the Czech Republic's efforts to develop and adopt Industry 4.0 technologies. The initiative has three main objectives:

- Enhance the ability of Czech companies to be involved in the global supply chain;
- Promote widespread implementation of Industry 4.0 principles in the Czech manufacturing sector;
- Enhance the Industry 4.0 R&D collaborations between industry, universities, and the Czech Academy of Sciences.

<sup>22</sup> OECD Science, Technology and Industry Scoreboard (2017). [https://www.oecd-ilibrary.org/science-and-technology/oecd-science-technology-and-industry-scoreboard-2017\\_9789264268821-en](https://www.oecd-ilibrary.org/science-and-technology/oecd-science-technology-and-industry-scoreboard-2017_9789264268821-en)

<sup>23</sup> European Innovation Scoreboard (2018). [http://ec.europa.eu/growth/industry/innovation/facts-figures/scoreboards\\_en](http://ec.europa.eu/growth/industry/innovation/facts-figures/scoreboards_en)

The implementation of the initiative is coordinated by the Czech Ministry of Industry and Trade and includes stakeholders from the business, scientific, and academic communities. However, this effort is still in the planning and preparation stages; the Ministry of Industry and Trade is in the process of preparing an action plan for implementing the initiative's recommendations. Thus far, no new budget has been allocated for the implementation of the initiative.

Other national strategies include the *Innovation Strategy of the Czech Republic 2019-2030*, which was approved by the Czech government in February 2019 and not yet implemented; a national *AI Strategy*, which is still under review by the Czech government, and *Vzdělávání 4.0* (Education 4.0), an action plan to reform of the national education system to promote needed technical disciplines for Industry 4.0 under preparation by the Ministry of Education, Youth, and Sports.

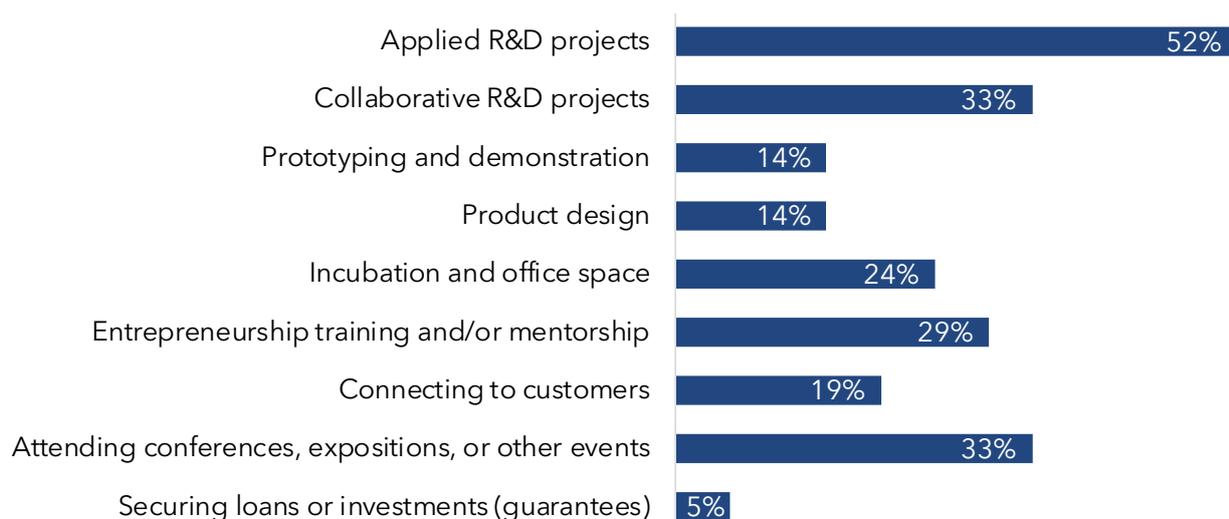
The key umbrella policy instrument targeting Industry 4.0 is the Operational Program Enterprise and Innovation (OPEI), administered by the Ministry of Industry and Trade with a budget of CZK 120 billion (approximately USD \$5.2 billion). Through OPEI and a few other programs, there have been a total of 29 policy instruments related to Industry 4.0, all of which are in the form of grants or matching

grants. 20 instruments are ongoing (of which two started in 2019) and nine are closed. Total budget allocated over the life cycle for these 29 instruments stands at CZK 145 billion (approximately USD \$6.3 billion). Of this budget, 82 percent is funded by the EU and the remainder comes from state funding.<sup>24</sup> The primary Czech agencies concerned with I4.0 are CzechInvest, which dispersed 68 percent of I4.0-related funds from 2013-2017, and the Technology Agency of the Czech Republic (TACR), which dispersed 18 percent of funds.<sup>25</sup>

In terms of objectives, close to one-third of these I4.0-related instruments (measured in terms of disbursed funds) focus on technology adoption and diffusion (i.e., non-R&D innovation), one-fifth focus on business R&D, and over one-tenth focus on technology transfer and collaboration. Another one-tenth focuses on skills formation. In terms of the life cycle stage, the funds are equally disbursed among early-stage startups, scale-up and mature stages. However, only about 10% of funds focus on the concept/idea stage.

Of the surveyed startups, applied R&D grants were the most common type of public support received, followed by collaborative R&D grants and support for attending conferences, expositions, and other events abroad.

**Figure 23. Public support received by surveyed startups**



<sup>24</sup> A similar pattern is detected in other central and eastern European countries.

<sup>25</sup> Based on an ongoing analysis by the World Bank of the CR SME Policy Mix. Aridi, A., and Lopez, A., forthcoming. *CR SME Diagnosis and Policy Mix Coherence*.



## 4. RECOMMENDED POLICY ACTIONS

This case study explored the key elements and actors of the I4.0 ecosystem framework related to I4.0 knowledge creation, commercialization and product development, and adoption. The analysis sought to understand (i) how the Czech Republic compares to the rest of Europe in terms of its I4.0 knowledge base; (ii) how Czech I4.0 startups develop their technologies/services, access clients and markets; (iii) and what challenges and uncertainties startups face, as well as those faced by potential adopters of I4.0 technologies.

I4.0 knowledge creation in the Czech Republic, in terms of publication and patent outputs is modest – below the normalized EU average. However, the extent to which startups connect to this knowledge base is unclear because of difficulties related to spinning out companies and licensing IP from Czech universities and research institutes.

I4.0 startups face a set of challenges above and beyond those faced by startups in other industries, including longer sales cycles, driven by the need to pilot and assess their solutions with new customers. The majority of these startups also require access to data and access to technical support and locations for proof-of-concept, prototyping, and

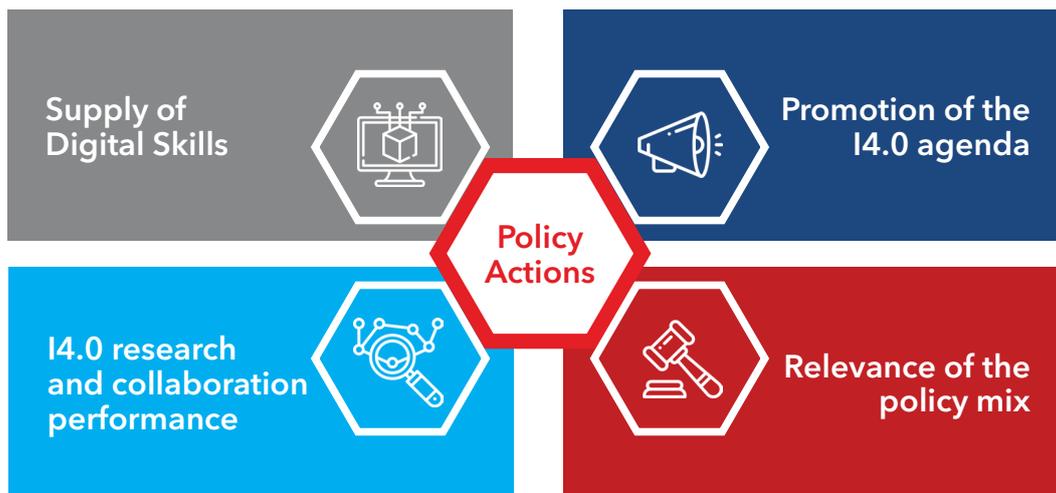
demonstration of their technologies, which they often receive from their initial customers. Lastly, they face serious uncertainties when it comes to availability of risk investments and scaling knowhow due to the infancy of the sector.

On the demand side, Czech firms have strong incentives to adopt I4.0 technologies, including the need to substitute labor, reduce costs, and remain competitive in the global market. However, while there have been ambitious announcements related to digitization and automation, I4.0 implementation remains stalled at the pilot scale. Several major challenges inhibit more widespread adoption, particularly among SMEs, including knowledge barriers, lack of managerial capacity, production constraints, and a digital skills gap.

In this final section we explore policies and policy support instruments that could help overcome these challenges and uncertainties. We identify four key areas for policy action in Figure 24.

It is important to note that most of these policy actions apply to the general innovation and technology adoption agenda. Nevertheless, some are I4.0 and digital specific and address uncertainties faced by I4.0 startups and potential SME adaptors.

**Figure 24. Recommended Areas for Policy Action**



### Promotion of the I4.0 agenda

**Problem:** SMEs specifically face information barriers that impede their awareness of the potential benefits of digitization. Several of the Czech Republic’s industry associations and networks are largely focused on promoting I4.0 adoption, but knowledge barriers remain. A relatively small subset of Czech SMEs has the capacity to generate/collect or analyze their internal data.

**Approach:**

- **Promote successful business cases of I4.0 adoption among SMEs,** showcasing how specific technologies could generate productivity and competitiveness impacts. The Czech SME associations and business chambers/associations on the national and regional levels have a leading role in this.
- **Introduce data-focused competitions:** design national-level competitions that could help incentivize data-generation and create a marketplace for data sharing related to manufacturing and industry processes. This could take the shape of a platform where industry participants describe their digital problems and entrepreneurs/startups and students propose solutions. The competition would encourage more SMEs to collect and share data on their industrial equipment and system performance, as well as provide testbeds and demonstration sites for students and startups to demonstrate their

solutions. The SSP challenge-driven platform and its CoFIT event,<sup>26</sup> administered by the Czech Technical University is well positioned to run such a national competition.

### Supply of Digital Skills

**Problem:** Demand for ICT skills and other advanced skills is high in the Czech Republic and will only grow as more businesses digitize. Developing these skills will be critical to the country’s capacity to absorb and use I4.0 technologies, and thus, digital skill development should be central agenda item for national level-policies and strategies.

**Approach:**

- **Increase the supply of digital talent and support interdisciplinarity** by incorporating digital content into education at all levels. University Industry Advisory Boards, which include representatives of local businesses, could provide input and advise on the content of these courses to ensure relevance and respond to the enterprises’ needs.
- **Prepare and reskill the Czech workforce** with the needed digital skills through training and capacity building modules on data science, analytics and other digital tools. Such training activities could be supported by existing policy instrument related to skills development and training.

<sup>26</sup> See more info here: <https://co.fit.cvut.cz/#info>



## I4.0 Research and Collaboration performance

**Problem:** The performance of Czech universities and public research institutions is modest in terms of I4.0 knowledge outputs and, most importantly, in the commercialization and transfer of this knowledge. Specifically, technology transfer and knowledge collaborations among SMEs and universities remains weak due to institutional barriers and a weak incentive framework for commercialization.

**Approach:**

- **Enhance the I4.0 research and collaboration performance and remove knowledge flows' barriers.** Increase focus of applied research grants and other university funding on commercialization outputs ( licenses, contract research, spin offs, etc.) not only on IP outputs. Improve the incentive framework that allows researchers and students to spin out companies. Encourage universities to pursue research collaborations and contract research with and for industry by addressing informational and IP-related barriers.
- **Improve the performance of existing technology transfer offices and non-academic intermediaries** active in supporting research commercialization and the acceleration of digital startups. There is a particular need for organizations that can provide basic business services for I4.0 university spinouts and startups. Local and regional authorities have a crucial role in supporting and partnering with such intermediaries.



## Relevance of the Policy Mix to I4.0-specific challenges

**Problem:** Most startups surveyed required support for PoC, prototyping, or demonstrating their technologies, and largely received it from their early customers. Despite the availability of a number of active Centers of Excellence and university test-beds, utilization of these facilities has been low. It is evident that there is need for public support, especially at the early stage of I4.0 technology development and demonstration. The market for early stage risk finance is still under developed lacking experience

and knowhow. Finally, the existing tech adoption policy mix targeting SMEs is digitally-agnostic and could benefit from better targeting.

**Approach:**<sup>27</sup>

- **Operationalize the approved Prumysl 4.0 (Industry 4.0) Initiative** by adopting an action plan and allocating a budget for implementation. Ensure that the implementation of the initiative complements the existing policy mix and the planned strategies such as the Innovation Strategy 2019-30, the AI Strategy, the SME Strategy and Action Plan, and the Education 4.0 Strategy. Ensure that I4.0-relevant instruments are well articulated in the MIT proposal for the new OPEI programming period.
- **Improve uptake of the PoC and prototyping support mechanisms.** Technology development services and prototyping instruments can alleviate the pressures off startups to demonstrate the viability and results of their solutions. Improve the reach of these instruments through partnerships with intermediaries and universities' technology transfer offices. Extend the qualifying criteria for technology development support to go beyond technical proof of concept to include commercialization and piloting of projects.
- **Support intermediaries that connect SMEs with digital solution providers:** this could be implemented through supply chain finance instruments to link up potential adopters with local I4.0 startups or SME solution providers.
- **Develop and professionalize the early-stage risk finance market:** A recent analysis by the WB of the business angel market recommended several policy actions that are still relevant to the I4.0 risk finance market.<sup>28</sup> This includes the professionalization of early stage investment activities through the establishment of a Czech Angel Association and improving the investors' readiness and knowhow through I4.0-specific knowledge exchanges.
- **Experiment with I4.0 and digital-specific vouchers and matching grants for SMEs:** Introduce I4.0 and digital-specific vouchers and matching grants to enable SMEs to buy I4.0 and digital solutions and alleviate the cost burden of technology purchases and upgrades.

<sup>27</sup> Majority of the actions suggested here relate to the existing instruments under the Operational Program Enterprise and Innovation (OPEI) and the Technology Agency CR (TACR)

<sup>28</sup> World Bank (2018). Stimulating Business Angels in the Czech Republic. Retrieved from <http://documents.worldbank.org/curated/en/633181541532716870/Stimulating-Business-Angels-in-the-Czech-Republic>



## APPENDIX I. METHODOLOGY

This report follows a case study approach to describe the experiences and lifecycles of Industry 4.0 startups in the Czech Republic. The analytical bases for this report were a literature review; an analysis of publications, research projects, and patents related to I4.0 in the Czech Republic; qualitative interviews with key stakeholders; and a survey of Czech I4.0 startups.

Information about Czech research projects were drawn from the Czech Technology Agency's STARFOS database, a full-text search engine which contains data on all research and development projects performed in the Czech Republic with state financial contribution and all contract research performed by public institutions. Publications were drawn from Web of Science, and patents were drawn from the Orbit Intelligence Questel Database. Research projects, publications, and patents related to I4.0 were identified using keyword searches using nine keywords (Industry 4.0, Internet of Things, Artificial Intelligence, Machine Learning, Big Data Analytics, Cloud Computing, Robotics, 3D Printing) drawn from the World Bank's Europe 4.0 framework.

The network analyses were conducted by Unico AI and Unico Analytics using the Cytoscape software tool. The network visualizations were created using the tool's "organic layout". The Cytoscape visualization algorithm pushed nodes with more connections to the center of the visual, while nodes with a smaller number of interconnected neighbors are pushed to the periphery.

18 qualitative interviews were conducted with public and private stakeholders from the Czech I4.0 ecosystem, including with founders and CEOs of I4.0 startups; manufacturers; as well as actors from industry associations, entrepreneurship support, and risk capital organizations. Section below includes a

full list of persons interviewed. Additionally, survey of 54 I4.0 startups was also conducted, with 21 responding. I4.0 startups were identified through interviews with local I4.0 industry experts and investors. The survey was administered online from April 1 - May 3, 2019.

### Interviewed Stakeholders

#### Startup Founders and CEOs

- Tomas Borovicka, Datamole
- Patrik Juránek, Virtuoso 3D
- Vojtech Kaldec, unnamed early-stage startup
- Pavel Konečný, Neuron Soundware
- Vojta Rocek, Stories.BI
- Jan Sedevy, Alquist
- Milan Simek, Sewio
- Ondrej Vanek, Blindspot Solutions
- Roman Zaks, Aimtec

#### Manufacturers

- Tomas Sedlacek, Kovona
- Petr Hofman, Skoda Auto

#### Ecosystem Stakeholders

- Patrik Juránek, Startup Grind Prague
- Adam Kocik, J&T Ventures
- Jaroslav Liskovec, National Centre for Industry 4.0
- Vaclav Pavlecka, Air Ventures
- Jan Proks, Czech Electronic and Electrical Association
- Tereza Samanova, CzechInno
- Milos Sochor, Y Soft Ventures



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