Background study prepared for the UNCTAD contract on preparing a firm-level survey on frontier technology adoption

Firm-level survey on frontier technology adoption in developing countries: A questionnaire proposal[1]

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1. Introduction

New and emerging technological breakthroughs, including advanced robotics, 3D printing, artificial intelligence, big data analytics, cloud computing, the Internet of things (IoT) and smart sensors, are set to change the way we work and live. Summed up under the notion of the Fourth Industrial Revolution (4IR), these changes build on the ICT revolution of the mid to late 20th century that gave rise to such advances as the personal computer and the Internet. The 4IR is characterized by the integration of new automation technologies with big data analytics and increased interconnectivity through the Internet as a basis for flexible and intelligent manufacturing that can improve enterprise efficiency and competitiveness.

The 4IR extends beyond the factory gates to include the transformation of upstream and downstream value chain relations. Increased interconnectivity, with machines and computer systems connected all along the value chain, promises to increase the capacity of firms to manage in real-time their supply, production and delivery relations across geographically dispersed stages of the value chain, thus providing the basis for satisfying consumer needs in a rapid and flexible manner. The 4IR will also have a major impact on the economy through the transformation of business services involving new uses of data depending on internet interconnectivity and the delivery of new services, including financial, energy and supply-chain services, through digital platforms.

Policy makers at the national and international levels argue that harnessing these new technologies holds out promise for developing nations to increase their industrial productivity and growth rates, while simultaneously assuring more sustainable patterns of production and consumption (UNCTAD, 2018, World Bank 2019). This is linked to the understanding that technological change is now occurring at a more rapid pace than in the past and that the solutions these new frontier technologies offer are better, cheaper and more scalable than what has been available in the past (UNCTAD, 2018). For example, digital technologies, including the Internet of Things, data sharing technologies and mobile money platforms are being propelled by the rapidly falling price of internet connectivity. Advances in renewable energy technologies, including mini-grid solar and wind energy, offer small scale solutions for meeting the electricity needs of rural persons without access to the national grid, which can be readily scaled up. Artificial intelligence and machine learning offer opportunities for improvements both in private sector productivity and in the efficiency of public sector services, including healthcare and transport. Their use in manufacturing for such tasks as predictive maintenance or quality control can deliver substantial gains in terms of both productivity and quality.

As articulated in regional strategies, such as the African Union's 'Digital Transformation Strategy for Africa 2020-2030' or the 'Digital Agenda for Latin America and the Caribbean (eLAC2022)', the diffusion of new and disruptive technologies might offer a window of opportunity for developing countries to accelerate their rate of economic development and catch up. Taking advantage of this opportunity, however, will require making large investments in infrastructure, skills and research capabilities, and important questions have been raised about the preparedness of developing

countries for the 4IR. The relative lack of readiness of many developing countries has raised concerns that the 4IR will contribute to increasing the technological gap between advanced industrial nations at the technological frontier and those with lower levels of production and technological capabilities (UNCTAD, 2020)

Concerns have also been raised that the 4IR might contribute to increasing inequality within nations. For example, if technological change has a biased impact on skills, reducing the demand for the skills of the lower or mid-level occupational categories relative to upper-level occupations, then in the absence of compensating measures targeting those groups, inequality is likely to increase. This might play out both at the level of sectors and regions if those industries most impacted are regionally concentrated. It will be important to put in place policies designed to mitigate these possible negative consequences and to promote the adoption of new technologies in a way that is both inclusive and sustainable.

While much has been written about the promises and future risks of 4IR technologies, there is surprisingly little empirical evidence on their adoption and impact at the firm level, either qualitative or quantitative.[2] For example, in terms of the adoption of robots, while there is publicly available data collected by the International Federation of Robotics (IFR) on worldwide sales or installations of industrial robots, they are limited to aggregate figures at the national and industry levels and the data cannot be used to analyze the impact of the adoption of robots on employment or skills at the firm-level or to identify the organizational obstacles and challenges that firms face in attempting to implement them. This realization has triggered calls for further efforts in gathering data at the firm level (Holm and Lorenz, 2021; Lorenz and Kraemer-Mbula, 2020; Seamans and Raj, 2018).

There is some firm-level survey data measuring the adoption of industrial robots for developed countries, but to our knowledge, none for developing countries. The main source of data on robotics for the European Union is the European Manufacturing Survey (EMS), which is limited to selected European countries from 2001 to 2015.[3] Publications based on the results from the 2012 and 2015 rounds of the survey are instructive in that they identify considerable firm-level heterogeneity in the uptake of industrial robots with higher adoption rates observed for larger firms engaged in producing larger batches of standardized products (Jäger et al. 2015; Dachs and Palčič, 2020). A few national-level studies using combinations of customs data on robot imports, specialized surveys or evidence compiled from robot suppliers have investigated the impact of robots on employment and skills at the firm level. These studies confirm the results from research based on the EMS, showing considerable firm heterogeneity with higher adoption rates for larger firms.[4]

[2] For an overview of the literature, see Lorenz, Kraemer-Mbula and Tregenna (2019).
[3] The survey covers manufacturing firms in Spain, France, Germany, Austria, Sweden, Switzerland and the Netherlands. See: https://www.isi.fraunhofer.de/en/themen/industrielle-wettbewerbsfaehigkeit/fems.html. In addition, the 2018 EUROSTAT Community Survey on ICT Usage and E-commerce in Enterprises includes a variable measuring the adoption of robots by industrial enterprises according to size, sector of activity and nation. See https://ec.europa.eu/eurostat/documents/341889/10082348/Enterprise_survey_variables.pdf
[4] See Acemoglu et al. (2019) for the case of France and Humlum (2019) for Denmark.

For developed countries, there is more information available on the factors that affect the adoption of industrial robots than other 4IR technologies – including machine learning, big data analytics, 3D printing, the use of smart sensors, and the Internet of Things. At present, the only large-scale surveys providing information on the use of AI and big data that we are aware of are the EU's Community Survey of ICT Usage and E-Commerce in Enterprises and the Statistics Canada (StatCan) survey of Digital Technologies and Internet Use.[5] While the StatCan survey provides some information on the factors that encourage and constrain the use of AI and big data, the EU survey does not, as it is primarily designed to provide policy makers with comparative estimates of the frequency of firms' use of new technologies for benchmarking purposes.[6]

The weak knowledge base on the adoption and impact of new and emerging technologies in developing countries provides an inadequate basis for designing policies to help firms and nations to meet the challenges posed by the rapid pace of technological change. In order to contribute to filling this knowledge gap, this report presents a framework and model questionnaire (Annex B) for measuring and interpreting the adoption of new and emerging technologies in business sector firms in developing countries.

2. Objectives and scope of the survey framework

2.1 Business sector firms

The report aims to present a measurement framework for collecting and interpreting information on the adoption of new and emerging technologies by business sector firms in developing countries. The report provides guidelines for both manufacturing and service sector firms. It does not cover non-market oriented public sector enterprises (health, education, public administration), although it does cover government-controlled or owned enterprises operating in market-oriented business sectors. Nor does the report address the specific conditions of agriculture – which in most developing countries is dominated by smallholders and would require a survey framework adapted to their specific conditions. It does, however, cover agro-industry (food products, beverages, and tobacco). For reasons discussed in Section 6 below, the report recommends collecting information on the adoption and use of new technologies at the level of the establishment, local business unit or site as opposed to the level of the enterprise or enterprise group. In many cases, and especially for micro and small enterprises (MSEs), the establishment and enterprise levels will be the same. The report does not

[5] See the Annex for an overview of these surveys. This StatCan survey is a continuation of the Survey of Electronic Commerce and Technology survey carried out periodically since 2000. Until 2014 StatCan also ran a periodic survey on the adoption of advanced technologies that was partially overlapping with the Digital Technologies and Internet Use Survey. See https://www23.statcan.gc.ca/imdb-bmdi/pub/indexth-eng.htm

[6] Researchers at the University of Aalborg in Denmark completed in 2019 the first employee-level skills survey including measures of the use of artificial intelligence. This survey provides evidence on the rate of adoption of AI in the Danish national labor force and the impacts on skills. See Djerding et al. (2020) for an overview.

address adoption at the levels of sectors, regions, or nations though it may be possible in some cases to aggregate data to estimate adoption patterns at a higher level.

2.2 Developing country context

The report aims to provide guidelines that take into account conditions in developing countries and makes no assumption that the 'developing world' is composed of a homogeneous population of countries with similar levels of technological and organizational capabilities, institutional support structures, or capacities for policy intervention. The report does consider that most of the advanced technologies focused on have been developed in mature economies and that processes of technological transfer (including through multinational companies) are central to understanding the adoption and diffusion patterns observed in developing countries. For this reason, the report recommends both identifying the location of the suppliers of new technology adopted and identifying the position of the adopting firm in both national, and global value chains (see Section 3.3 below). While in a developing country context, the identification of business units should be inclusive of those operating informally, the report does not recommend including informal economy establishments in the target population for practical reasons linked to the lack of sample frames for these enterprises in most countries and to the costs associated with developing suitable frames manually (see Section 6.2 below).

2.3 What technologies?

A major challenge for a report of this nature is to identify what constitutes 'new and emerging technologies' and to do so in a manner that is relevant not only to larger firms that may be operating close to the technological frontier in international markets, but also to the larger population of small and medium-sized firms that typically produce for local or national markets and that lack the financial resources and the technological capabilities and skills needed for adopting many of the most advanced technologies and especially those that are capital intensive. For this reason, the report adopts a broad definition of new and emerging technologies and includes the adoption or use of digital tools and services that are associated with what is often referred to as the 'digital transformation' currently taking hold in the developing world.[7] This may include a firm's relatively passive engagement with technologies accessed through the Internet on digital platforms. Examples include the use of mobile money for making payments and the use of social media as a tool for knowledge exchange, marketing and access to information. Section 5 below provides definitions of the new technologies included in the report's guidelines and discusses their main applications, their sector presence, and their use by SMEs.

[7] See the country diagnostic reports from the World Bank's Digital Economy for Africa Initiative. https://www.worldbank.org/en/topic/digitaldevelopment/brief/digital-economy-country-diagnostics-for-africa

3. Key issues in measuring technology adoption

The report aims to develop a framework for collecting and interpreting information on what kinds of firms are adopting new and emerging technologies and how extensively these technologies are diffused in the economy. Which firms adopt new technologies and how extensively these technologies are integrated into their productive activities will be affected by both internal and external drivers and constraints.

3.1 Internal Drivers and constraints

3.1.1 Scale, task standardization and automation

Internal drivers and constraints pertain both to the size or the scale of the firm's operations and to the degree to which tasks and workflows are standardized and repetitive. Size matters for a number of reasons including the superior access of larger firms to the financial resources needed to invest in new technologies, and to the fact that larger firms are better placed to either recruit or to train in-house workers with the skills needed for adopting and using new technologies. The results from the European Manufacturing Survey (EMS) and from the EU's ICT usage survey described in Annex A to this report provide evidence on the importance of firm size or scale of production for technology adoption in Europe. Scale differences can be expected to be equally if not more important in a developing country context, and correspondingly we recommend including measures of establishment size both in terms of the number of employees and in terms of annual turnover.

Standardization of tasks and workflows are important for several reasons. In the case of manufacturing, in general it will be easier to amortize dedicated investments in automation technologies such as industrial robots if the batch size or the number of standardized units or products produced is larger. While an industrial robot taken alone is flexible and can be easily reprogramed, systems of interconnected robots used for industrial production are not, once the costs of the dedicated investments in programming, tooling, fixtures and plant layout are taken into account.[8] For example, in the case of the world auto industry, OEM suppliers located in developing countries working for the major multinational producers typically operate on the basis of a 7-year cycle for car models and putting the entire automated production system in PLC for a new model including the programming and the production of fixtures, tooling and gigs is a lengthy process that may take up to 2 years.[9]

[8] See: "The Real Costs of an Industrial Robot Integration", https://www.engineering.com/ResourceMain?resid=858. The report cites the case of a Kawasaki deburring cell and observes that the integration costs can be as high as four times the cost of the robot. In addition to programming costs, these include the costs of tooling, jigs and fixtures, accessories such as sensors if machine vision is included, and the cost of constructing the robot cell to meet safety requirements of separating the robot from humans.

[9] Based on the authors interviews with a first-tier supplier for BMW in South Africa. See Lorenz and Kraemer-Mbula (2020) for a discussion

Smaller firms cratering to niche markets will tend to place a premium on flexibility and using skilled workers that can adapt to continuous changes in products and processes and that have the skills and experience needed to solve unanticipated problems confronted in production. Such firms will tend to eschew high levels of automation. Even larger manufacturers may decide to avoid the high degree of standardization of workflows that facilitate automation because of the rigidity that such standardization introduces into working practices and methods. In particular, firms that use total quality management (TQM) practices based on giving skilled workers and teams sufficient control and autonomy in their daily work to continuously introduce improvements in methods may eschew high level of automation as being incompatible with continuous employee learning.[10] Such firms may opt for the use of cobots or collaborative robots that work alongside the employee that are adapted to flexible production as they may be readily reprogrammed by the employee.[11]

Industrial robots are the classic case of a dedicated technology used for automation in a large batch or series production in mass production industries, and standardization of work may be less of a constraint for other 4IR technologies used in manufacturing. There has been very little empirical research investigating this issue with survey data, and the only study we know of exploring the link between batch-size and the use of selected 4IR technologies is Dachs and Palčič (2020) based on the results of the 2015 round of the EMS. In addition to finding a strong statistically significant positive relation between batch-size and the use of industrial robots, they find a somewhat weaker statistically significant positive relation between batch-size and the use of digital technologies for logistics and supply chain management.[12] In the case of 3D-printing the relation is reversed, with this technology being more likely in the case of small-batch production. This presumably reflects the fact that 3D-printing at present is too expensive for automating series production and is used primarily for rapid prototyping or possibly as a tool for quality control.[13] Interestingly, the authors find no significant relation between batch-size and the use of enterprise resource planning (ERP) systems, suggesting that this data management technology may be more easily adapted to the needs of SMEs with more customized production.

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[10] Toyota in Japan provides a case in point. The Vice President and Production Manager, Mitsuru Kawai, is quoted as saying, "Such production (the light-off factory) would remain at the same level of development forever… Robots do not improve processes. Only humans can improve processes. That's why they should always be the focus." See, https://www.linkedin.com/pulse/toyota-firing-robots-dirk-fischere. Also see, https://www.fastcompany.com/40461624/how-toyota-is-putting-humans-first-in-an-era-of-increasing-automation.

[11] Markus Schaefer, head of production at Mercedes is quoted as saying "We're moving away from trying to maximise automation with people taking a bigger part in industrial processes again. We need to be flexible. The variety is too much to take on for the machines. They can't work with all the different options and keep pace with changes." See: https://www.theguardian.com/technology/2016/feb/26/mercedes-benz-robots-people-assembly-line.

[12] Their measure of firm's use of digital logistics includes the use of digital exchange of data with suppliers or customers, the use of automation systems for internal logistics, and the use near real-time production control systems.

[13] In an interview with the South African of a major world auto producer we were told that additive printing in addition to rapid prototyping was used as a means for verifying that components produced by suppliers were produced to the exact specifications. See Lorenz et al. (2019)

Batch-size is an industrial concept which affects how standardized and repetitive physical tasks are. The standardization of work, however, is not a concept specific to the manufacturing sector, and it may also be relevant to the use of 4IR technologies for automating work in service sector firms, including the use of big data analytics and machine learning (ML). While it is well known that ML applications are specialized, the relation to task standardization may not be evident. Probably the most thorough discussion of the types of tasks that are susceptible to automation with ML is that of Brynjolfsson and Mitchell (2018). In the context of their work on task unbundling, they developed a 21-item rubric designed to assess the extent to which detailed occupational tasks are susceptible to automation with ML.[14] A basic requirement for ML automation of a task is that the information required to complete the task (inputs and outputs) is recorded or is recordable by a computer. The items in the rubric that pertain to standardization are: 1) tasks that are highly routine and frequently repeated are more susceptible to automation; and 2) tasks where each instance, completion, or execution of the task is similar to the other instances in how it is done are more susceptible to automation. The first condition would be necessary for being able to collect the vast quantities of data needed for purposes of machine training, while the second would preclude novel or unique events occurring in new data but not in the training data set used to train the ML. Such novelty or unique events would tend to increase what is known as test error which is a measure of how well the model predicts new and previously unseen data.[15] As Chollet (2018, p. 327), who works on deep learning at Google, observes, "Show them (neural nets) anything that deviates from their training data, and they will break in absurd ways."

In many cases, as a recent McKinsey report (2018, pp. 26-27) based on multiple case studies points out, collecting or obtaining data sets that are sufficiently large and comprehensive to be used for training can be a major limitation to ML use. This, in turn, will mean that smaller firms with a smaller scale of operations may be at a disadvantage in using ML to the extent that they rely on in-house data. This may be part of the explanation for the finding from the 2019 round of the EU ICT usage in Enterprises survey that the share of large firms (> 250 employees) collecting big data internally is about three times as large as the share of small (10-49 employees).[16] This scale constraint, however, will be less relevant in the case of generic applications of ML applied to tasks that are common across firms. An example is facial recognition software that can be used to automate ATM security in remote locations and predictive software that can be used to anticipate when an ATM will run out of cash. Since the tasks are standardised across ATMs and banks, the size of the bank branch will not be an

[14] See: https://science.sciencemag.org/content/sci/suppl/2017/12/27/358.6370.1530.DC1/aap8062-Brynjolfsson-SM.pdf. There are several other highly relevant constraints identified in the rubric. For example, the task shouldn't require explaining while it being carried out. ML's are not good at explaining why they decide the way they do. It is also desirable that the task output is error tolerant since the predictive performance of an ML never is 100%. This of course is the case for 'next to buy' recommendations one of the main areas of use of neural nets in marketing.

[15] See Chapter 5 of Goodfellow et al. (2016) for a discussion of training and test error which are closely linked to problems of underfitting and overfitting the model.

[16] See https://ec.europa.eu/eurostat/data/database for aggregate results at the national, sector and enterprise size levels from the EU ICT usage in enterprise survey.

issue since the application of this software does not require the branches to collect their own data as a basis for training and testing the machine learning software.[17]

Given the potential impact of workflow standardisation on the adoption of automation technologies, we recommend that a survey develop indicators not only of the size of the business unit but also of the degree to which tasks are standardised and routine as opposed being variable and requiring flexibility and continuous adaption. Skills and capabilities are also important internal drivers or constraints. A firm may be operating in a market segment that is suitable for the use of advance automation technologies but lack the necessary skills and capabilities to adopt and use them. We elaborate on measuring this important dimension of the internal firm context of technology adoption below.

3.1.2 New digital service technologies

While much of the debate about new and emerging technologies has focused on their potential for automating work and substituting for the skills of the existing workforce, it has become apparent that many of the new technologies being adopted are being done so in order to gain access to new services that increasing are available on-line and may be accessed through digital platforms. These new digital technologies are transforming the way goods and services are distributed and consumed. These technologies include social media that can be used to share or diffuse information, cloud computing that can be used to store information or share it with clients, e-commerce platforms that can be used to market goods and services, and fintech including mobile money that can be used for gaining access to financial services. They may be accompanied by the use of new business models such as pay-as-you-go payment systems using e-money on mobile money platforms. These technologies are more accessible to smaller firms than the automation technologies reviewed above as the capital investments are relatively small. In many cases, all that is needed is a business mobile phone or a computer. Constraints on the adoption of these technologies may have more to do with a lack of awareness of their uses or to a lack of the skills needed to integrate them into the firm's daily operations than they have to do with high investment costs. In a developing country context where many of the most advanced automation technologies are out of the reach of the large majority of small and micro enterprises, it is important to investigate the factors that may hinder or promote the adoption of new digital services, including skills and capabilities.

3.1.2 Capabilities and skills

[17] See https://www.visionet.com/blog/optimizing-atm-cash-management-using-machine-learning for a provider of ATM cash optimization software with machine learning. As the provider notes, with machine learning humans can limit their input to a supervisory role, identifying and addressing exceptions that historical analysis can't account for.

In the global, interconnected world that we inhabit, where technologies are rapidly replaced, improved and modified, the speed of technology adoption could determine a firm's ability to survive and compete. Becoming aware of an existing technology itself is the first step in the process of technology adoption. Once the firm becomes aware, a conscious decision is made to adopt it or not. In this respect, one can differentiate between the "diffusion of information", and the "diffusion of the adoption" of a technology. This is captured by the concept of 'absorptive capacity', defined as "the ability of a firm to recognize the value of new external information, assimilate it and apply it to commercial ends" (Cohen, Levinthal, 1990: 128). There are various modes by which technology can be adopted, including licensing or purchasing a patent, partnering, equipment maintenance or simply purchasing the foreign technology itself. Each one of these routes involves a different level of absorptive capacity. We, therefore, suggest that the survey should include some questions capturing the absorptive capacity of the firm as an important driver in the adoption of frontier technologies.

There is a general assumption that technology adoption in developing countries largely depends on access and availability. However, less attention has been given to the types of skills and capabilities that firms need to successfully implement such technologies. There appears to be some evidence indicating that digital technologies are strongly complementary with other intangibles (Brynjolfsson et al., 2017), including workers' skills or managerial talent. However, the skills needs will differ depending on the types of adopted technologies and the complexity regarding their use and implementation. Some of these skills and capabilities may materialise in quality-related certification, known to have positive impacts on the firm's innovation performance. To test these hypotheses, we recommend the inclusion of questions capturing the capabilities that the firm has developed. These can be capture by asking about the firm's experience in importing technologies, including by means of licensing agreement, purchasing software, cooperation with foreign experts or consultants. We also recommend collecting a limited amount of information on changes in employment through the use of retrospective questions and collecting information on the employer's perception of how new technology is changing the firm's skills needs.

Finally, the propensity to adopt frontier technologies may also depend on having an organizational culture of open-mindedness, which creates an environment of inquiry, proactiveness and responsiveness to new technological developments. This kind of mindset may help firms cultivate a digital orientation that relates positively to their acceptance of new digital technologies.

3.2 External drivers and constraints

The external drivers and constraints faced by firms in adopting new and emerging technologies can be divided between those related to the institutional context and those related to possible infrastructural gaps in the country or region. The national innovation system theory identifies the main institutions and organizations which have an impact on the firm's decision to engage in process innovation, of which the adoption of new technology is a type. These include the educational and

training system, including both formal education institutions as universities and technical training institutes and informal training that may be provided by employers on the job. These institutions and arrangements affect the types of skills that firms can find on the labor market, and they affect their ability to develop further skills as needed over time. A country's financial system, including banks and other institutions providing credit to firms (e.g. micro-credit organizations) affect the ability of firms to finance investments in new technology. Professional and industry associations and institutions may impact the transfer of knowledge, the development of domain-specific skills in different sectors of activity and the development of these forms of association will also bear on firms' awareness of what new technologies are available and on their suitability for their specific production needs. The institutional context includes the legislative setting that may set rules on the use of equipment and technology in relation to health and safety and other working conditions at the workplace and in relation to environmental impacts. Firms' behavior will also be affected by the policies the state adopts in relation to new technology adoption and the extent to which policies are in place to subsidize or provide tax incentives for adoption. In a wider macro context, the state's policies on tariffs, competition will impact the expected profitability of new technology investments.

Infrastructural gaps will often be a factor hindering the effective use of new digital technology in a developing country context. The weak development of the country's information and communication technology infrastructure will impact directly the ability and interest that firms have in using new digital technologies which depend on the internet or the network infrastructures invested in by mobile network operators. The energy infrastructure will also have an obvious impact since energy outages will affect access to the internet or mobile networks. Access to electricity is also needed for charging mobile phones, which in turn may be used for purchasing services or goods on-line through digital platforms on a 'pay as you go' basis.

The structure of the market and the extent of competition should also be considered as a possible driver or constraint on adoption. If the firm's main competitors have adopted the technology in order to differentiate their productive capacity, the firm may be motivated to do the same.

A survey of private sector firms is not well placed to provide the information needed to characterize the national institutional setting. A firm-level survey can collect some relevant information on the external factors that are perceived by the firm as hampering or posing an obstacle to the adoption of new technology. These obstacles will be connected to the characteristics of the national institutional context. A firm-level survey can also provide information on whether firm's have or have not benefited from government policies designed to promote adoption. We recommend asking questions about the following external factors that may hamper or promote adoption.

Hampering factors	Promoting factors
- Lack of finances from external sources (banks, venture capital, public sources)	- Government policies and support programs supporting new technology adoption

- Difficulties in finding qualified personnel on the labor market - Uncertain market demand for the firms' products - Lack of information on new technologies - Inadequate telecommunications infrastructure - Inadequate access to electricity or frequent power shortages - Too restrictive regulations or standards	- Support from professional or industry associations - Support from technology transfer institutions - Market structure and competition

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3.3 Technology transfer and GVCs

Most of the new and emerging technologies that may be adopted in developing countries have been developed in developed countries and developing country firms are in many cases dependent on foreign technology suppliers or on foreign-owned suppliers operating in the developed country. This is especially the case for capital intensive technologies used in manufacturing as industrial robots or 3D-printers where the global market is dominated by a small number of developed country multinational companies. Dependence on developed country technology suppliers will be less universal in the case of software applications such as big data analytics services using machine learning techniques or predictive analytics where local business service providers may have the capabilities to establish a position in the local market.[18] In order to provide information on the extent and possible variations in the degree of dependence on foreign technology suppliers, we recommend including questions on the geographical location of the supplier of new technology. By identifying cases where the new technology is sourced locally or developed in-house, this information will provide insight into the level of development of local technological capabilities.

There is a lively debate on the importance of being integrated into global value chains (GVC) to improve the organizational and technological capabilities of developing country firms. The literature identifies different possible forms of up-grading, including process and product upgrading and what is referred to as 'functional upgrading' involving a move into new and higher value-added activities in the chain. The adoption of new technology most obviously contributes to process upgrading, and value chain participation might conceivably lead to such upgrading due to the knowledge acquired from more technically advanced international clients or due to their requirements for improvements in productivity and product quality to meet international certification standards. Multinational firms

[18] The authors participated in a 4IR case study project in South Africa during 2019 in which interviews were carried out in the business service sector. Several of these firms offered advanced digital technology services including machine learning and virtual reality applications. See Lorenz et al. (2019) for an overview.

that are sourcing component production in developing countries might be motivated to promote such upgrading through providing information on which new technologies should be adopted and contributing to the provision of the employee training skills development needed to adopt and use them. Critics of this view of GVCs have argued that causation will tend to operate in the other way with the prior development of higher-level capabilities and skills being needed as a basis for the firm gaining access to GVCs (Reddy et al. 2020). There is also a lively debate on the extent of upgrading and how likely it is for local supplier firms to move beyond making improvements in productivity and product quality thus ultimately leaving local firms dependent on developed country multinational enterprises for the higher value added stages of conception and design, marketing and after-sales. While a survey on the adoption of new technologies cannot address all the issues of interest in the GVC debate, it can provide the information needed to determine whether there is an association between technology adoption and a local producer's participation in GVCs.

3.4 Performance outcomes

The adoption of new and emerging technologies by firms will impact their performance, their employment levels, and their skills needs. Adopting new technologies are often linked to process innovation, which is closely tied to coming up with new products. The adoption of new digital technologies such as social media also can result in marketing innovation. Many frontier technologies are designed to increase productivity. We recommend collecting information on firm performance both in terms of productivity and innovation.

There is a heated discussion about the ways in which frontier technologies may impact employment. Evidence of the displacing effect of frontier technologies on employment is inconclusive, and studies that predict widespread labour displacement effects are based on questionable assumptions concerning the adoption of new technologies and their impact (e.g. Frey and Osborne, 2013; World Bank Development Report, 2016). Others have highlighted the adverse effects of automation on low-skilled employment, particularly for workers who perform routine-based tasks that can more easily be displaced. Despite the importance of these dimension of impact, a cross section survey instrument is not suitable to capture dynamic changes in employment over time even if it is possible to collect some limited information on recent past changes through retrospective questions Measuring the impact of technology adoption on employment changes over time can best be done with a panel that could only be constructed over time.

3.4.1. Productivity

The scope for automation is of course, an important motivation for adopting new technologies, and it is important to assess its impact on productivity in both manufacturing and services. We recommend collecting information on employment levels and on annual sales to calculate labour productivity. While statistical business registers will necessarily include employment information to classify firms

for the register, they will not necessarily include information on sales and other firm demographics. A recent UNDESA report on statistical business register found that less than 50% of statistical business registers in developing countries include complete firm demographics (UNDESA, 2014, p. 44). Moreover, the information will not necessarily take into account recent changes in employment. Similar limitations may apply to commercial registers.

New technology might impact labour productivity by increasing the number of units produced with a roughly constant level of employment, and there should be no presumption that new technology will lead to unemployment. A classic service sector example is that of bank tellers in the U.S. and the automation of their work with the adoption of ATMs equipped with digital image processing. As this technology was rolled out during the late 1990s and early 2000s, the number of tellers grew at the rate of 2% per annum because ATMs allowed banks to operate branch offices at lower cost prompting them to open more branches which offset the loss in teller jobs (Bessen 2015).[19]

In addition, in collecting information on the level of employment and sales at the end of the last complete fiscal year, we recommend asking for this information for 2 or 3 complete fiscal years in the past as a basis for estimating the growth in productivity. Some minimal information on how new technology is impacting occupational skills over the previous 2 to 3 can be collected by asking for the breakdown of employees according to broad occupation group (e.g. managers, professionals and technicians; skilled craft and trade workers; skilled clerical and sales workers, low and unskilled workers). [20] We also recommend collecting information on the gender breakdown of the workforce according to the broad occupational group.

3.4.2 Innovation

New technology is closely linked to both the firm's development of new products and services and to its introduction of new methods of marketing. We recommend including questions on these innovation outcomes based on the Oslo Manual guidelines distinguishing between innovations that are new to the firm and those that are new to the market. By combining the responses to these questions with those to whether the firm's main market is local, national, or international, it will be possible to differentiate between degrees of novelty for a 'new to the market' innovation.

There should be no presumption of the direction of causality in phrasing these questions, and issues of causality are best addressed, if at all, with appropriate statistical methods. For example, a firm may be motivated to introduce new production technology to diversify its product range or in response to

[19] At a first-tier auto components producer in South Africa visited by the authors the automation of the firs main plant with an integrated robot system resulted in a 7-fold increase in the number of standardized components produced per day while employment levels remained unchanged due to the increase level of sales to the main auto OEM.

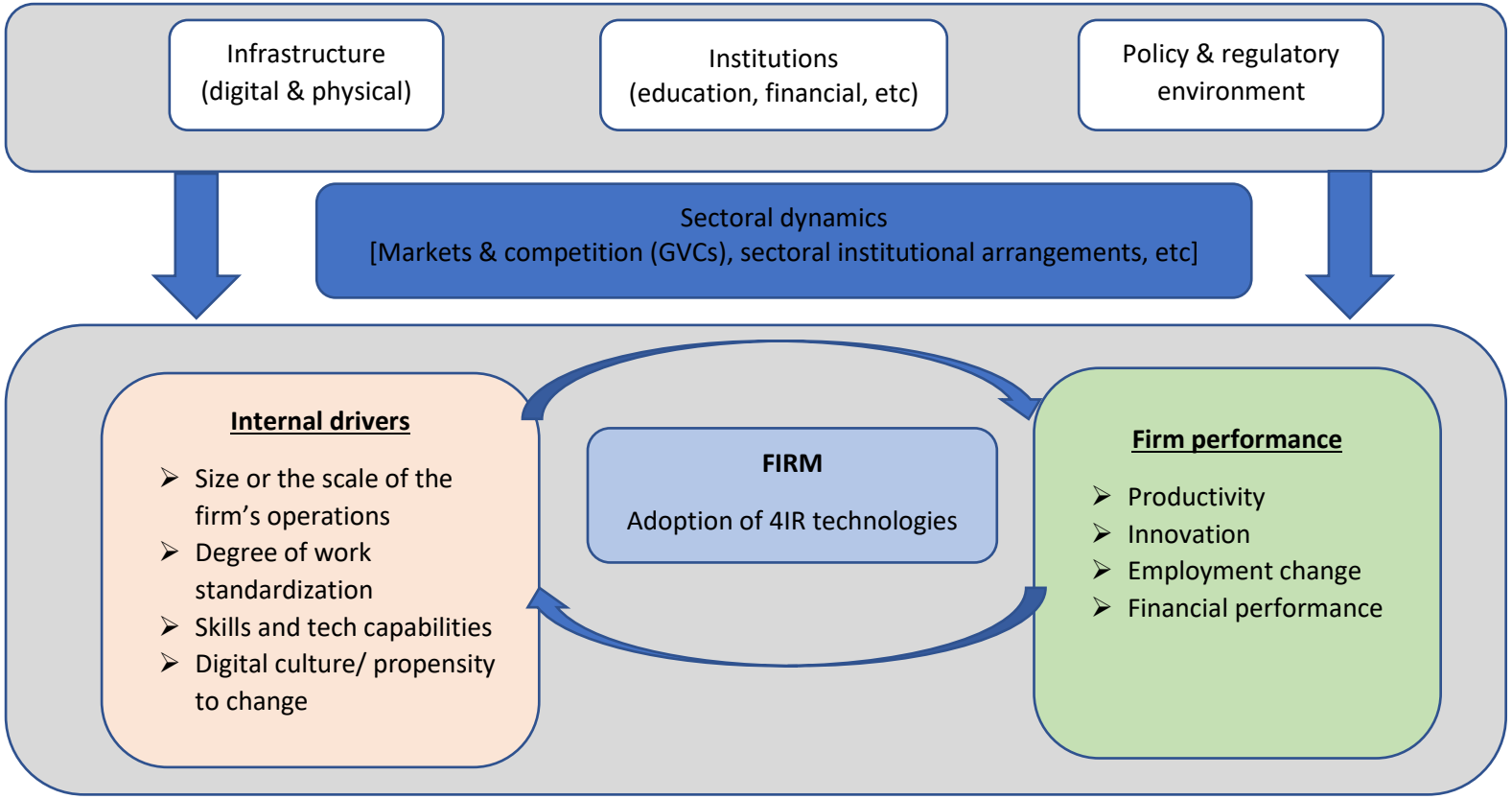
[20] This allow to capture changes associated with the declining or increasing employment of different occupational groups. It does not allow to measure within job or occupation changes in skills which would require an employee-level survey.

quality-related demands from a client. An example in the auto industry is the use of remotely controlled robots for laser welding to assure the quality of the welds on an aluminium plate, which is increasingly being used in the construct of auto bodies to reduce weight. In other instances, the adoption of a new technology may lead to the development of new products or services. For example, a firm that uses machine learning for predictive maintenance of its own equipment might then be encouraged to pursue a servitization strategy and to offer this service remotely to its clients. In the case of marketing, one of the most important innovations in developing countries is the firm's use of e-commerce and digital platforms, which require using a variety of new technologies and possibly investing in customized software. In this case the innovative marketing practice will drive the adoption of the new technologies that are needed.

While new technologies may lead to or be complementary to changes in organisational practices, we do not recommend a general question along the lines of that in the Oslo Manual Guidelines on the introduction of new managerial practices or methods over the previous three years. The general nature of such a question begs the question of what kind of changes have been introduced. Rather we recommend asking focused questions about specific changes in organisational practices and work organisation that may bear on the firm's use of new technology, such as the degree of standardisation of workflows and tasks. These can be included in the section on internal drivers of change.

4. Measurement framework

Figure 4.1: Measurement framework: external and internal drivers of 4IR technology adoption



Governments play a central role in facilitating the development of the overall innovation system in developing countries, as elsewhere, by establishing and maintaining enabling infrastructures (both digital and physical) as well as an institutional environment that incentivizes technology innovation and adoption (Kamperman et al., 2018). National and regional strategies, along with a set of policy mixes, reaffirm governments' commitment to promoting access and adoption of new technologies.

The propensity to adopt specific frontier technologies is often closely connected to the sector in which the firm is situated. For instance, robots are more commonly found in sectors such as auto manufacturing, chemicals and electronics, while artificial intelligence is more frequently applied in sectors such as healthcare and banking. Sectoral considerations are nevertheless highly dynamic and rapidly changing, as frontier technologies become more affordable and start being implemented across a broader range of industrial sectors. The positioning of the firm in global value chains will also be contingent on the sector in which it operates.

At the firm level, the propensity to adopt frontier technologies will be determined by a set of internal drivers (as discussed in section 3.1 above), which include: the size or the scale of the firm's operations, the degree of work standardization, skills and technological capabilities in the firm, and the existence of a digital culture/ culture of open-mindedness. A survey directed to the employer (as it is the case of this survey) is not an adequate tool for an in-depth engagement with important issues related to skills. This is because an employer survey can mainly tell us quantitative aspects related to the availability of skills on the market and the overall skills needs of the firm, but it cannot tell us if an individual employee is over or under-skilled in relation to the task being performed since this would require an employee level survey. While we have included some questions related to skills in the survey questionnaire, tackling this important issue in-depth would require its own survey.

It is also important to note that a firm-level survey is not well fit to characterise sectoral dynamics (besides capturing the sector of activity in which the firm operates), except as these are experienced by the respondent firm.

The adoption of frontier technologies, in turn, will have effects on the firm's performance, including productivity and innovation (as discussed in section 3.2 above) as well as employment effects. While employment is a central impact dimension, especially in developing countries that often operate under high unemployment rates, a firm-level survey is unable to capture the temporal dynamics of employment since the changes of interest are often not observable during the reference period. The same applies to performance measures.

5. Review of 4IR technologies: definitions and application in small firms

Frontier technologies are bringing new opportunities for business growth in multiple ways. We often hear about the current and potential transformation of production through robotics, IoT, big data analytics, artificial intelligence, 3D printing and other advanced digital technologies. However, the available evidence for developed countries shows that most of these technologies are only adopted by a minority of firms and are concentrated in larger establishments.[21] Less is known about adoption in developed countries. The recent surveys coordinated by UNIDO in Brazil, Argentina, Ghana, Vietnam and Thailand identify higher rates of adoption of more advanced generations of digital production technologies in larger establishments.[22] Frontier technologies under the 4IR appear to present unique challenges and opportunities for SMEs, and especially to those in developing countries.

The readiness of SMEs in developing countries to "embrace" the 4IR has been largely questioned, and they are often portrayed at a higher risk of not being able to benefit from the upcoming revolution. For the 4IR to result in equitable and sustainable growth, it must take place not only in the minority of large enterprises but also in SMEs. With SMEs being the backbone of developing economies, it becomes essential to develop tools that help better assess their readiness, propensity, and prospects of adopting frontier technologies. Some of that relates to (a) the propensity of firms to adapt and innovate - not only in terms of their products, but also in terms of their production practices, and (b) the nature of different 4IR technologies and their applications in the operations of firms with different sizes.

Regarding (a) the propensity of SMEs in developing countries to innovate – small businesses in developing countries have been described as highly innovative and increasingly proactive in improving their business operations (Muchie et al, 2015; Kraemer-Mbula and Wunsch-Vincent, 2016; Kraemer-Mbula et al. 2019). This is a good starting point for introducing new frontier technologies. However, it is important to note that technological innovations are often concentrated in specific sectors (particularly high-tech manufacturing), scarce in a developing country context. The vast majority of small businesses in developing countries engage in non-technological innovation, although they are increasingly adopting digital technologies.

Regarding the nature of different 4IR technologies and their applications in firms' operations, as discussed above in section 3.1 on internal drivers and constraints, some technologies are more likely to be adopted by larger businesses due to the sizeable capital investment required (such as the case of industrial robots) and their application in a context of large-batch/mass production. Other 4IR technologies are more easily applied in the context of smaller firms. However, some basic technological and infrastructural requirements are necessary for those technologies to be adopted at the firm level.

[21] The aggregate results from the EU's Community Survey on ICT and e-Commerce in Enterprises identify significantly lower adoption rates for small firms. See: https://ec.europa.eu/eurostat/data/database

[22] See the Annex for a review of these surveys. For an overview report on the 5 UNIDO surveys, see Kupfer et al. (2019).

In order to assure the relevance of the survey framework to SMEs in developing countries, we recommend including indicators of several digital technologies linked in general to having access to the Internet as described in Table 1 below.

Table 1: Overview of 4IR technologies and their application by sector and firm size

Technology	Definition	Applications	Sectoral presence	Application in small firms
Robots/Cobots	Robots are programmable machines which are usually able to carry out a series of actions autonomously, or semi-autonomously	• Industrial Robot: automatically controlled, reprogrammable multipurpose manipulator programmable in three or more axes, which can be either fixed in place or mobile for use in industrial automation applications • Cobots or collaborative robots, are robots intended for direct human-robot interaction within a shared space, or where humans and robots are in close proximity.	Industrial Robots are concentrated in a few sectors, namely automotive, electronics, metal manufacturing, chemicals, and food production. Cobots are used in a wide range of industries, from processing to manufacturing, construction to retail, healthcare, the chemical industry, the textile, the petroleum industry, pharmaceutic to the hospitality industry.	Application of industrial robots in small firms is limited, due to capital investment, maintenance costs, and physical space requirements. Cobots have broader applicability in small firms, due to their: affordability, flexible deployment, fast set-up, and simplicity to use.
3D Printing/ additive manufacturing	The 3D printing process builds a three-dimensional object from a computer-aided design (CAD) model, usually by successively adding material layer by layer	• Prototyping - quick and efficient creation of prototypes. • Low-volume manufacturing • Development of project-specific mechanical parts Custom-made biomedical devices	One of the early adopters of 3D printing was the aerospace and defense industry, where highly complex parts are produced in low volumes. 3D printing allows creating complex geometries can be created without having to invest in expensive tooling equipment. 3D printing offers new opportunities for “Mass-customisation”.	With 3D printers and 3D printing services becoming more affordable, this technology is increasingly accessible to smaller firms. Small firms are making use of 3D printing for proof of concept and rapid prototyping, for R&D towards the development of new products, and to customise products for their customers efficiently and quickly.

Technology	Definition	Applications	Sectoral presence	Application in small firms
Big data analysis	Big data refers to vast amounts of data in different possibly unstructured formats (e.g. text, video, voice, sensor data, activity logs, coordinates). Big data analysis refers to the use of technologies or software tools such as machine learning and data or text mining for analysing big data extracted from the firm's own data sources or other data sources.	Applications of big data analysis are wide. Example include: • In banking for trade analytics used in high-frequency trading • In media and communication to create content for target audience and recommend content on demand • In manufacturing for for integrated business planning. • In logistics for real-time shipment tracking. • In retail and wholesale timely inventory analysis fraud detection • Automated Customer Communications (Chatbot)	While big data analysis can be applied in any sector for extracting sales related insights from data or for integrated business planning an management it is expected to predominate in data-intensive industries as banking, financial services and insurance (BFSI) sector; media, publishing and advertising industries; and healthcare and pharmaceuticals. These sectors typically comprise large businesses.	The gradual advancement and development of cost-effective standardized software packages for processing big data including predictive analytics and data mining has made big data analysis more accessible to smaller businesses, for example for extracting sales-related insights from customer data.
Machine learning	Machine learning (deep learning), a branch of artificial intelligence, is one the core methods used to process big data. Machine learning uses vast amounts of labelled data (big data) to give computers the ability to 'learn' and perform tasks without being explicitly programmed.	Machine learning is a technology used in big data analytics. Important applications, which are overlapping with those of big data analysis, include: • customer service management • next to buy individualised offering • customer acquisition • predictive maintenance	Machine learning has application in all sector for marketing and for hiring and recruitment. It has wide application in manufacturing and logistics for predictive maintenance and quality control. As with big data analytics, with which it is closely tied, it is used extensive in data-intensive industries and sectors.	Machine learning is used less by small firms because of its substantial in-house data and skills requirements. Exceptions are applications using cost effective standardized packages available on the market that are within the reach of smaller business. These are typically offered over digital platforms and are a type of cloud computing service accessible to smaller firms. Examples include marketing and customer

Technology	Definition	Applications	Sectoral presence	Application in small firms
	representation or to identify words and phrases in spoken language and convert them to a machine-readable format.	• yield optimisation and inventory and parts optimisation, • analytic driven hiring and analytic drive HR		relationship management (CRM) tools.
Internet of Things (IoT)	IoT refers to interconnected devices or systems, often called "smart" devices or "smart" systems. They collect and exchange data and can be monitored or remotely controlled via the Internet, through software on computers or smartphones.	• Wearables • IoT (smart) sensors • Geolocation applications • Network monitoring and control • Maintenance management • Autonomous vehicles • Mobile point-of-sale (mPOS) devices	The automobile industry is one of the most active in IoT adoption – e.g. car GPS system and self-driven cars. Agriculture/agro-tech, hospitality, manufacturing and losgistics/transportation are also some of the fast adopters. IoT also increasingly present in the retail sector – for example, retail stores are using Bluetooth beacons that enable them to provide location-based services to their customers.	With smart devices such as sensors, wearables and cameras becoming more affordable, small business are increasingly incorporating IoT applications, such as "smart locks" to control physical access to work premises, connected cameras, sensor-based inventory and stock control; and supply chain data monitoring (allowing businesses to verify the quality of deliveries). Mobile point-of-sale (mPOS) devices have revolutionised small-scale retail.
Virtual reality/ Augmented reality	Virtual reality (VR) refers to a computer-generated simulation in which a person can interact within an artificial three-dimensional environment using electronic devices, such as special goggles with a screen or gloves fitted with sensors. Augmented reality (AR) is the real-time use of information in the form of text, graphics,	• Retail – using the smartphone or tablet as an AR platform to create a shopping environment for customers. • Industrial field services – providing access to real-time remote help from experts or vendors located anywhere in the world	Some industries are already making use of virtual reality/ augmented reality. Its adoption is still very much confined to the realm of large businesses, in auto manufacturing (used for prototyping), retail (IKEA, and large fashion retailers for instance), real estate, tourism (e.g. museums and galleries) and healthcare.	The context of COVID-19 has pushed small businesses to start incorporating augmented reality (AR) and virtual reality (VR) into their businesses to help connect with employees and customers while still honouring social distancing. Popular social media platforms such as Facebook, Snapchat and Instagram are offering augmented reality online tools, either free or

Technology	Definition	Applications	Sectoral presence	Application in small firms
	audio, and other virtual enhancements integrated with real-world objects."	• Design and modelling – producing product mock-ups at scale • Training and education • Repair and maintenance – providing enhanced customer support to consumers related to repairs, maintenance, etc.		at little charge. These AR tools encourage customer engagement and boost marketing efforts.
Cloud computing	ICT services that are used over the Internet to access software, computing power, storage capacity etc. The services are delivered from servers of service providers, can be easily scaled up or down (e.g. number of users or change of storage capacity), can be used on-demand by the user, and are paid for, either per user, by capacity used, or they are pre-paid.	• Software-as-a-Service (SaaS) • Infrastructure-as-a-Service (IaaS) • Platform-as-a-Service (PaaS) • Disaster Recovery as a Service (DRaaS) • File sharing and data storage • Data governance and cybersecurity	Traditionally large firms were reluctant to use cloud computing due to security concerns. However, as security in cloud services has improved, many large businesses have migrated to the cloud. Cloud services are becoming more industry-specific – as more industries adopt the cloud into their infrastructure, providers have developed tools and solutions designed specifically for those industries to take advantage of. Healthcare, finance, education, automotive and manufacturing are some of the industries that are adopting cloud computing more intensively.	Cloud computing is equally accessible to large and smaller businesses. Cloud computing offers expanded data storage at a reduced cost (as compared to buying hardware for data storage), increases flexibility and mobility of the business, and facilitates collaboration among members of the organisation. These features make it particularly fit for a small business environment. Currently the use of shared data storage applications (such as Dropbox), and tools such as Zoom, Slack and others is widespread among small businesses.
E-commerce	Sale or purchase of goods or services conducted over computer networks by methods specifically designed for the purpose of receiving or	• Online store (web shop) • Web forms • Extranet	E-commerce has ramped up in almost all sectors. However, some of the industries that engage with e-commerce more intensively are: Fashion and	E-commerce is booming and since it has become relatively easy to set up an online store, small businesses only need an internet connection to run various e-

Technology	Definition	Applications	Sectoral presence	Application in small firms
	placing of orders. The payment and the delivery of the goods or services do not have to be conducted online. E-commerce transactions exclude orders made by manually typed e-mail messages.	• Bookings and binding/fulfilled reservations are considered • Sales via apps for mobile devices or computers • Sales via external e-commerce marketplace • websites or apps	Apparel, Beauty and Personal Care, Entertainment, Household Goods and Electronics.	commerce solutions and a shipping process.
Social media	Applications based on internet technology or communication platforms and the use of Web 2.0 technologies and tools for connecting, conversing and creating content online, with customers, suppliers, or other partners, or within the enterprise. Social media includes social networks or communities, blogs, and content communities.	• Marketing research • Communication: company-to-consumer (in which a company may establish a connection to a consumer based on its location and provide reviews about locations nearby) and user-generated content. • Sales promotions and discounts • Relationship development and loyalty programs • Informal employee learning/organisational development – Blogs, wiki pages, web forums, social networks and others can act as Technology Enhanced Learning (TEL) tools • Customer service and support • e-Commerce	Social media is currently used in all industries where brand matters.	Due to its low cost and accessibility, social media is widely used by small businesses.

Technology	Definition	Applications	Sectoral presence	Application in small firms
Fintech & mobile money	Financial technology (Fintech) refers to software and other modern technologies used by businesses that provide automated and improved financial services. Mobile money or mobile wallet refers to financial payment services that are conducted using a mobile phone, where value is stored virtually (e-money) in an account associated with a SIM card. A bank account is not required to use mobile money services—the only pre-requisite is a basic mobile phone.	• Cryptocurrency and digital cash • Blockchain technology • Smart contracts, which utilise computer programs (often utilising the blockchain) to automatically execute contracts between buyers and sellers. • Open banking • Insurtech, which seeks to use technology to simplify and streamline the insurance industry • Robo-advisors, such as Betterment, utilise algorithms to automate investment advice to lower its cost and increase accessibility. • Unbanked/underbanked, services that seek to serve disadvantaged or low-income individuals who are ignored or underserved by traditional banks or mainstream financial services companies	Fintech is largely adopted by the financial sector, but also has a growing presence in sectors such as education, retail banking, fundraising and non-profit, and investment management.	Trends toward mobile banking, increased information, data, and more accurate analytics and decentralisation of access create opportunities for small firms to utilise fintech for making and receiving payments. In a developing country context mobile money platform may be used to access micro-credit (e.g. M-Shwari).

6. Survey Methods

6.1 Developing harmonized surveys

Appropriate survey methods designed to the extent possible to form a representative sample of the target population of establishments are of central importance both for purposes of research and for policy. This presents several challenges related to the quality of available sample frames but also to problems of coordination across countries. There is value in assuring that surveys carried out in different countries of the same region are comparable so that valid comparisons can be made for the purpose of policy making at the regional level. This objective underlies, for example, the development of the Bogota Manual[23] on guidelines for carrying out surveys on innovation in the Latin America region, and it underlies the use by the World Bank of a common methodology for carrying out its enterprise survey in different regions of the world. Although such harmonization might be achieved through an agreement among countries within a region, we believe that the most reliable way to achieve this will be for UNCTAD to coordinate the process centrally, either by contracting out for the surveys with private service providers or by working in collaboration with the NSOs. The latter approach has the advantage of facilitating access to adequate business registers for purposes of developing the sample frame and may bring to the table statistical skills and competences in carrying out the survey to assure quality. Possible drawbacks include the obstacles that may be encountered in reaching an agreement on survey methods and questionnaire design and, as noted in the Bogota Manual (2001, p. 41), the fact that statistical agencies may take several years to process the information collected, making it less relevant for policy purposes. Our recommendation is, where possible, to carry out joint surveys with government agencies or NSOs, which is the most reliable way to assure surveys of high quality and representativeness.

6.2 Target population and sample frames

Surveys of technology adoption may use the enterprise or the establishment as the primary sampling unit (PSU). We recommend using the establishment which can be defined as a physical location where business is carried out and where industrial operations take place or services are provided. Enterprises may be composed of several establishments, and enterprise groups may be comprised of several enterprises. The choice of the establishment or business unit at a particular location is proposed as the PSU because this is the level at which the new technology will be used and the characteristic of the establishment in terms of product mix and workflows will bear directly on the choice of technology and its effects as discussed above in Section 3.1. For example, a large brewery may be composed of several establishments, including a production site, a site for warehousing, and a site for sales. The types of technology used at each site will vary in accordance with the function or type of activity within the enterprise. In the case of SMEs, the large majority will be single-unit businesses so that the establishment and enterprise are identical. Establishments may, of course, be part of a multi-plant

[23] See: http://www.ricyt.org/wp-content/uploads/2019/09/bogota_manual.pdf

enterprise and they may also be owned or owned in part by multinational companies; and in such cases, we recommend including questions on whether the decisions to invest and adopt new technologies are made locally or at the enterprise or MNC levels.

The choice of PSU bears on the availability of sampling frames, and there is variability across counties as regards the unit adopted in the official business registers that are maintained by NSOs or other government agencies such as tax or business licensing authorities. Annual industrial surveys are usually carried out at the establishment level, and where such surveys have been carried out recently, these sample frames should be used. A recent UN-DESA assessment (UNDESA, 2014, p. 14) on the global status of business statical registers found that the most used statistical unit in the business registers among developing countries is the "establishment". In cases where the only available official frames are at the enterprise level one option is to contact the population of multi-unit enterprises to identify all their establishments and to include them in the frame. Alternatively, it may be possible to use available commercial registers of establishments at a cost. In cases where no suitable frames are available, an option is to manually construct a sample frame.[24] Budgetary consideration will necessarily bear whether this option, generally the most expensive, is pursued.

We recommend sampling establishments with 5 or more employees if possible and excluding micro-enterprises and the self-employed. One practical reason for this is that most national business registers apply a size cut-off based on the firm's number of employees or turnover. This can also be justified on budgetary grounds since a large number of such micro-businesses would require a substantial increase in the sample size to assure representativeness and an adequate level of precision in statistical estimates. For similar budgetary reasons, we do not recommend including non-registered firms in the target population since covering such establishments would require the 'manual' construction of sample frames in most cases.

6.3 Sampling methods and sample size and precision

Random sampling should be used, and we recommend stratified random sampling to increase the precision of statistical estimates for the relatively small population of larger establishments and for specific sectors of activity that may be of interest for strategic policy proposes. We recommend as an objective a sample of 1000 establishments. In the case of simple random sampling for a technology with an expected adoption rate of 50% and given a 95% confidence interval, the margin of error with a sample of 1000 would be 3.10% or a 95% chance that the real value is within ±3.10% of the measured/surveyed value.[25] For smaller countries, the sample size can be reduced to 600. Under the

[24] This is done is a few cases for the World Bank Enterprise survey with the sample frame is created via block enumeration, where the World Bank ,constructs a list of eligible firms by first partitioning a country's cities of major economic activity into clusters and blocks and then randomly selecting a subset of blocks to be enumerated. See:

[25] The margin of error will decrease for instances with a lower or higher adoption rate with the margin of error being 1.86% in the case of an expected 10% or 90% rate of adoption

same parameter assumptions for a country where the target population is composed of 15,000 firms, a sample of 600 gives a margin of error or 3.92%.

We recommend stratification into 4 employment size groups (5-10; 10-49, 50-100 and >100) and depending on the size of the economy 3 or 4 ISIS sectors of activity. For smaller economies, we suggest stratification into manufacturing, including mining and construction, business services, and other services. For larger economies, one or two specific activity areas of strategic interest could be separated out as separate stratum. The number of establishments per stratum should preferably be between 50 and 100 in order to permit minimal statistical analyses by sector and/or size.

6.4 Data collection methods

Data collection methods can be divided between self-administered surveys and interview methods. Self-administered survey can, in turn, be divided between postal surveys in which printed questionnaires are mailed or faxed to the respondent, electronic methods where the questionnaire is embedded in an email or available as an attachment to an email, and web-based methods where the questionnaire is completed on-line. In all cases, the questions have to be simple and easily understandable as there will be not be guidance from a person carrying out an interview. Independently of the implications for questionnaire design these methods in general are not suitable for representative surveys in developing countries. Postal systems may be slow and unreliable while a large share of the population of firms targeted will not have business fax or email address, and there is unlikely to be a listing of addresses or fax numbers for those that do.

Interview methods can be divided into face-to-face interviews carried out at the site of the establishment and telephone interviews. Telephone interviews which are more taxing for respondents, need to be shorter than face-face interviews and a good rule of thumb is to limit a telephone interview to half an hour and face-to-face to no more than an hour. Questions have to be phrased differently for telephone interviews, avoiding a long list of responses since the respondent will have difficulty in remembering the different response categories (Blaire, Czaja and Blair 2013). Telephone methods are in general unsuitable for developing countries for similar reasons identified for self-administered questionnaires sent by fax or email. A large share SMEs in developing countries will not have a business telephone and there will not be a complete listing of telephone numbers for those that do. This leads to the recommendation of using face-to-face interview methods. While these methods are the most expensive of those referred to, they have the important advantages of allowing for a longer interview than any of the others and they share the advantage of telephone methods of the interviewer being able to clarify the meaning questions in the event that a respondent is unsure. For those firms that do have telephones or email addresses, these can be recorded at the time of the interview, and this will allow for relatively inexpensive follow-up procedures to address possible problems of item non-response for this subset of the sample.

6.5 Cognitive testing and the pilot test

Cognitive testing is an important step in the process of preparing a survey and the failure to undertake proper cognitive testing can result in both unacceptably high non-item response and the low reliability of the survey results. The main purposes of cognitive testing are to assure high content validity in the sense that the responses to question measure what the researcher intended that they should measure, and high reliability in the sense that the responses are accurate ad are unaffected by differences in the type of respondent.[26] The target population of the survey proposed here calls for a questionnaire that crosses two main dimensions, the size of the establishment and the sector of activity, including manufacturing and services. Cognitive testing can help assure that the questions are understood in the same way by respondents from each dimension. To the extent that a cross-country study is proposed covering multiple cultural and language groups, cognitive testing will help assure that results are comparable across countries, thus providing the basis for collecting harmonized data at the level of larger geographical regions. Cognitive testing does not need to be undertaken on a large scale, but it should seek to cover the different types of respondents across the main dimensions of the target population. We recommend undertaking 50 cognitive tests per country.

Cognitive testing should not be confused with the pilot test. The pilot test serves as a trial run for the actual survey and is used to test the entire survey process in actual field conditions.[27] A pilot test allows the research to evaluate and make changes to the survey design and methods based on an assessment of the resources that will be needed for undertaking the survey, possible difficulties encountered in recruiting respondents and the adequacy of the training given to interviewers. It also can be used for a preliminary assessment of the data entry and data analysis methods envisaged even if the results cannot be used for making statistical inferences. We recommend carrying out a pilot test on a minimum of 200 establishments covering the main size and sector dimensions of the target population.

[26] For a discussion of these points and illustrations of common problems encountered in questionnaire design, see the Meadow Guidelines (2010, pp. 329-41).
[27] For a discussion, see Ruel et al. (2015, Ch. 6).

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Annex A

A review of exiting surveys on the adoption and use of new and emerging technologies[28]

As we observed in the introduction to the report, there is a lack of quantitative survey-based data on the adoption and use of new and emerging technologies by firms in developing countries. Developing countries around the world have increasingly been concerned to put in place polices to promote the adoption of new and emerging technologies while at the same taking the necessary steps to mitigate possible negative social and environmental outcomes. Developing appropriate polices is hindered by the lack of information on the adoption of these technologies, on the factors which affect their diffusion and on their economic and social impacts. There is more information on the adoption and impacts of new technologies in developed countries than there is in developing ones. The only firm level surveys carried out in developing countries that we are aware of are those coordinated by UNIDO between 2017 and 2019 in Argentina, Brazil, Ghana, Thailand, and Vietnam. This annex provides an overview of the UNIDO surveys which are described in the 2020 Industrial development Report (UNIDO, 2019). The annex also reviews the following surveys carried out in developed countries that may provide model questions for a survey in developing questions: the European Union (EU) Survey on Enterprise ICT usage and e-commerce, the European Manufacturing Survey (EMS), the Japanese Survey of Corporate Management and Economic Policy and the Canadian Survey of Digital Technology and Internet Use (SDTIU). Apart from the EMS, the developed country surveys reviewed cover both manufacturing and services. The UNIDO surveys are limited to the manufacturing sector. This is an important limitation not only because employment in service sectors is more important than that in manufacturing in most developing counties but also because of way new digital technologies are transforming the provision of service including logistics.

As the purpose of the overview is provide useful information for the design of a survey to be carried out by UNCTAD, we focus on issues of survey design and methodology and provide only limited information on the survey findings. Table A.1 provides and overview. The reader is referred to reports and publications that present the main finding of the surveys.

1. UNIDO Adoption of Digital Technologies by Industrial Firms

1.1 Objectives and scope of the survey

The aim of the UNIDO survey is to provide evidence on the current and prospective adoption of digital technologies by manufacturing firms in developing countries with a special focus on the capabilities necessary to make the best use of these technologies. The survey focuses on what are termed Advanced Digital Production (ADP) technologies. These are defined as, "technologies that combine hardware (advanced robots and 3D printers), software (big data analytics, cloud computing and

[28] This annex was prepared with the assistance of Sibusiso Mpungose, College of Business and Economics, University of Johannesburg.

artificial intelligence) and connectivity (the Internet of Things). Advanced digital production technologies are the latest evolution of digital technologies applied to production; a core technological domain associated with the fourth industrial revolution"[29].

Section A of the questionnaire asks background information on the firm. The questionnaire does not distinguish between single unit and multi-unit enterprises. Following the section on firmographics, the survey is divided into 4 sections. Section B investigates the use of ADP technologies in relation the firm's relations with its suppliers and clients, its current product development activities and as a support to business management. What is covered under the term 'business management' is not defined. For each area of use the survey asks what steps are currently being taken towards adopting ADP technologies in the next 5 to 10 years. Section B also asks about a set of possible obstacles to the adoption of ADPs including lack of capital, lack of skills or talent, inadequate infrastructure, and a lack of awareness. Section C of the survey focuses on the expected impact on employment and skills, Section D on the location of the firm in the value chain including the share of sales exported, and Section E on the relation of the adoption of ADP technologies to energy use and environmental sustainability.

1.2 Concepts and definitions

The survey design is based on a clear conceptual frame and is designed to identify the firm's stage of development of ADPs with respect to predefined generations of digital technology development. Following analogy production (generation 0.0) defined by the absence of use of digital production technologies (DPT), 4 generations are defined (UNIDO, 2019, p. 7). These are Rigid Production (generation 1.0) defined as the use of DPT limited to an individual function, Lean Production (generation 2.0) defined as the use of DPT use to connect several functions in the firm, Integrated Production (generation 3.0) defined as the use of DPT to integrate and connect the entire production process in the use of Enterprise Resource Planning, (ERP) and Smart Production (generation 4.0) where information flows across operations and generates real-time feedback to support decision-making (such as use of smart sensors and machine-to-machine communication. Generation 4.0 corresponds to the idea of a cyber physical system.

The generational approach adopted reflects in part the recognition that there will be considerable heterogeneity in technology adoption across firms and that within a developing country context only a minority of firms can be expected to be using the most advanced digital technologies. It is also designed to capture possible within firm heterogeneity with the coexistence of different generations of technology across the functions of supplier relations, client relation, product and process development and business management processes. A background report on the surveys carried out in Argentina and Brazil observes:

> *"First, digital technologies are available and have been used by industrial firms across all sectors for at least 30 years. Consequently, any analysis should include the possibility that companies are using digital technologies of different generations. Secondly, regardless of the generation of technology being used at firm level, digital technologies are being used in all business- functions such as client and supplier relations, product development or*

[29] UNIDO. 2019b. Industrial Development Report 2020: Industrializing in the digital age. UNIDO: Vienna.

production management. Thirdly, as digital technologies are being used in every industrial activity, the proposed questions on adoption must be specified in a way to allow for any firm to respond them, regardless of their level of knowledge about these technologies." (UNIDO, 2019a)

While definitions of the technologies are not embedded in the individual questions, the questionnaire has an Annex with a glossary of definitions. The glossary includes definitions for additive manufacturing, advanced manufacturing, use of artificial intelligence in business process and customer services, big data, cloud computing, computer-aided design and manufacturing, internet of things, robots and the smart factory. While the glossary refers to AI in terms of the use of neural nets and machine learning it is notable that no attempt is made to define these terms or how they differ from more convention AI based on computer coding by a programmer.

1.3 Survey methods

The UNIDO surveys were carried out independently in each country starting with Brazil in 2017, followed by Argentina in 2018 and then in Ghana, Thailand and Vietnam in 2019.[30] All of the surveys included the same set of core questions from Section B on the current and expected use of DPT allowing to map their use according to the digital generation and in relation to the different functions of the firm as described above. The Brazilian survey excluded sections C, D and E of the master questionnaire on location in the value chain, employment and skills, and energy and environmental sustainability. The Argentinian survey excluded section C on location while it included section E on energy and the environmental sustainability. Only the UNIDO coordinated surveys in Ghana, Thailand and Vietnam included all five sections of the master questionnaire.

The overview report of the five surveys by Kupfer et al (2019) provides information on the survey populations and samples. The quality of the sample frames used is not discussed in the report nor is it made clear whether the PSU is the enterprise or the establishment in a specific physical location. There is some diversity in terms of the sector coverage and considerable diversity in terms of firm size. In the case of the Brazilian survey, which was initiated by the Brazilian National Confederation of Industry (CNI) and implemented by the Euvaldo Lodi Institute (IEL/NC et al., 2018), the sample consisted of 711 firms with a minimum of 100 employees selected randomly from a population 1,250 firms operating in the agroindustry, automobile, basic metals, capital goods, chemicals, consumer goods and ICT and other sectors. The sample was stratified by sector and by size with size divided into medium (100-250 employees), medium-large (250-500) and large firms (> 500).

The Argentine survey was conducted in 2018 at the initiative of the Institute for the Integration of Latin America and the Caribbean (INTAL-IADB) in cooperation with the Center for the Implementation of Public Policies Promoting Equity and Growth (CIPPEC). The size of the population from which a sample of 293 firms was selected is not specified in the description of the survey given by Albrieu et al. (2019) and there is no information on the margin of error. The sample covered six manufacturing sectors:

[30] For an overview of the 5 surveys see, Kupfer et al. (2019)

processed foods products, steel, light vehicles and parts and accessories, textile, agricultural machinery, and biopharmaceuticals with an objective of including 50 firms per sector.

The Ghanaian, Thai and Vietnamese surveys were UNIDO initiatives each conducted in 2019. The sample size was 200 in Ghana selected from a population of 534 firms with a minimum of 20 employees. In Thailand the sample was also set at 200 selected from a population of 523 firms with a minimum of 50 employees. In Vietnam a sample of 250 was selected from a population of 5,470 firms with a minimum of 20 employees. The surveys covered 4 or 5 industrial sectors in each country and the samples were stratified by sector, size, and region.

Data collection for the Argentinian and Brazilian surveys relied on a combination of telephone interviews and on-line questionnaires. This implies that those firms doing the survey on-line would have to refer to the Annex in order to consult definitions of terms. In Ghana, Thailand and Vietnam face-to-face interviews were conducted by trained enumerators. Since each country survey has unique sector and size specifications, a direct comparison of the results is not possible. To make some cross-country comparisons Kupfer et al (2019) constructed a dataset using just those firms with common sectoral and size classifications. Given that the Brazilian survey was limited to firms with 100 or more employee this required eliminating smaller firms in all countries and restricting the size categories to firms with 100 to 250 employees and to those with over 250 employees.

1.4 Strengths and weaknesses

The UNIDO survey has the merit of developing a measurement frame based on a clear conception of the nature of new digital technologies and their process of adoption and diffusion in an economy. The survey results point to considerable firm heterogeneity within and across countries and finds that only a small share of firms have adopted the more advanced forms of digital production technologies (generation 3.0 and 4.0) in the countries investigated. While basing the survey's measurement frame on a conception of stages or generations of digital technology development allows for the direct classification of firms along a scale of readiness, it also limits the user's ability to use the survey for exploring alternative conceptions of the process of technology adoption. For this reason, the survey may be limited in terms of the extent to which it meets the needs of a diverse range of users. Moreover, since the questionnaire asks the respondent about the use of particular digital systems for different functions, such as managing supplier or client relations, the results do not allow for estimating the adoption rates at the sector of national level for specific technologies that may be of interest such as the adoption of industrial robots or artificial intelligence. Industrial and trade policies for example can more easily target the adoption of specific technologies than they can integrated systems of technologies.

In terms of methods, an important limitation of the UNIDO surveys is the lack of harmonisation across countries according to sector and size classifications. This precludes making cross country comparisons on the entire sample and as noted above in order to make such a comparison Kupfer et al. (2019) were obliged to eliminate all small firms and those medium firms with less than 100 employees from the data set. These firms constitute the majority in terms of numbers and account for large share of total manufacturing employment in each country. This restriction necessarily reduces the relevance of the comparative findings for policy purposes.

The differences in the sampling methods used in the surveys point to the kinds of problems that are often encountered in gaining access to good quality sample frames in developing countries. While the 5,470 firms used for constructing the sample of 250 firms for the Vietnamese survey may appear reasonable given the cut-off at 20 employees or more, the population sizes of 534 and 523 firms for the samples of 200 firms in Ghana and Thailand are clearly too small to make the claim of adequately covering the target population. While the decision of UNIDO to only cover firms with 20 employees in Ghana, Thailand, and Vietnam may be justified on budgetary grounds it nonetheless leaves unexplored the technology adoption behaviour of the majority of small businesses.

2. European Manufacturing Survey (EMS)

2.1 Objective and scope of the survey

The European Manufacturing Survey (EMS) investigates product, process, and organisational innovation in European manufacturing. The EMS is organized by a consortium of research institutes and universities co-ordinated by the Fraunhofer Institute for Systems and Innovation Research (ISI) in Germany. The consortium includes member organisations from Austria, Croatia, the Czech Republic, Denmark, Finland, Lithuania, the Netherlands, Norway, Portugal, Serbia, Slovenia, Slovakia Spain, Sweden and Switzerland. The survey was carried out on a triennial basis since 2001 with the latest round being in 2018. It targets a random sample of manufacturing establishments with more than 20 employees belonging to NACE Rev. 1.1 sectors 15-37. [31]

The survey is described as including a core of indicators on the innovation fields of: "technical modernisation of value adding processes", "introduction of innovative organisational concepts and processes", and "new business models for complementing the product portfolio with innovative services". Successive rounds of the survey maintain a common set of questions while allowing for the introduction of new questions in accordance with current problems. Furthermore, allowance is given for some country or project specific topics. There has been a strong focus on ICTs in recent rounds of the EMS survey. Topics such as automation and robotics, additive manufacturing technologies, as well as the digital factory, have become more prominent in recent years.

With respect to digital technologies, the EMS focuses on the drivers of technology and their relation to the characteristics of the firm products. The questionnaire distinguishes between firms' products and production processes according to batch size, complexity and whether products are produced to the customer's orders or in advance to stock. The questionnaire also includes questions on annual turnover and the number of employee's which allows for productivity estimates. Retrospective questions are included which allows for an assessment of employment and sales impacts over a two-year period.

2.2 Concepts and definitions

The survey covers a broader range of topics related to manufacturing technologies and methods and the available reports on the website of Fraunhofer ISI do not make explicit reference to a

[31] See: https://www.isi.fraunhofer.de/en/themen/industrielle-wettbewerbsfaehigkeit/fems.html#367861728

measurement framework designed to studying the 4th Industrial Revolution or Industry 4.0.[32] The individual technologies that are measured are not given precise definitions in the questionnaire and given that the survey is self-administered this may be a limitation on the quality of responses. The questions do include illustrative types of uses for each technology and this may help achieve high content validity in the sense of being sure that the responses measure what the researchers want to measure. The core survey covers the adoption and use of industrial robots, technologies such as nanotechnology and biotechnologies for processing new materials, additive manufacturing, a set of 'smart factory' technologies including the use of ERP software, digital exchange of product/process data with suppliers or customers, systems for automation and management of internal logistics, product-lifecycle-management-systems (PLM) and technologies for safe human-machine interaction such as collaborative robots (cobots).

2.3 Survey methods

The unit of analysis for the EMS is the establishment or production site and the size cut-off is 20 employees or more. The survey covers the entire manufacturing sector defined as NACE Rev.2 codes 10-33. The sample size varies considerably across countries and the entire sample is weighted towards Germany. A 2015 report for the European Commission on the use of robots based on the results of the 2009 survey that covered a total of about 3,200 manufacturing firms located in Germany, Austria, France, Spain, Denmark, the Netherlands shows that slightly less than 50% of the establishments were located in Germany while the smallest sample was for Spain with 114 firms followed by France with 158 (Jäger et. al. 2015, p. 19) The survey uses simple random sampling making use of what are described as, "the best available data bases in each country" and applies a standardized follow-up procedure with a minimum of reminders to help assures consistency in data gathering. The core questionnaire was translated into the respective language of the country and tested to allow for cross-country analyses based on comparable indicators. Although the survey design did not use stratified random sampling, post survey weights are applied based on National Statistics data in each country to align the country sample with the actual firm sizes and industry structures in the respective countries.

2.4 Strengths and Weaknesses

The EMS to our knowledge is the only large-scale employer survey in Europe that analyses the determinants of the use of advanced production technologies. A strength of the survey design is that it includes both measures of the adoption new technologies and types of organisational practices and management systems and so provides the basis for exploring possible relations between the adoption of these technologies and how the firm is organised internally. While the survey is not a panel it has been carried out periodically since 2001 and this provides the basis for estimates of changes in the frequency of adoption of new technologies over time at the sector and national levels.

Methodologically a weakness of the survey is the large differences in sample sizes across member countries. In several cases the country sample sizes are too small to allow for even minimal statistical analyses by sector or size within a country. Without appropriate weighting at the national level the results of any econometric estimates for the entire sample will necessarily be weighted towards the

[32] For an overview of the survey design, see Jäger et al. (2015)

results for Germany. In terms of dissemination, the webpage devoted to the survey on the website of Fraunhofer Institute for Systems and Innovation Research (ISI) contains a list of publications based on the results of different rounds of the survey. Our impression, however, is that the results of this important survey are not widely known amongst members of the research and academic communities both within and outside of Europe. One possible avenue for enhancing its visibility would be to set up procedures for general access to the micro data for prior rounds of the survey.[33]

3. Survey of Corporate Management and Economic Policy (Japan)

3.1 Objectives and Scope

The Survey of Corporate Management and Economic Policy (SCMEP) was conducted by the Research Institute of Economy, Trade, and Industry (RIETI) in in Japan in 2019. The questionnaire-based survey was conducted on 15,000 Japanese firms operating in both manufacturing and service industries between January and February 2019. The survey is designed to collect information on corporate management practices and strategy and is divided between three main section on market competition and management-labour relations, Innovation, and the firm's view of government regulation and polices. The section on innovation includes questions on management's use and attitudes towards three new technologies: AI, big data, and robotics. There is no explicit reference to the 4th Industrial Revolution, or a measurement framework designed to measure the adoption of new technology.

The SCMEP does not identify or measure the drivers of the adoption of new technologies even though it contains questions on a range of factors affecting strategic management decisions more generally, such as profitability, market share, competition, globalisation, and regulation. It des consider whether the use of AI and robotics is expected to have a positive or negative effect on employment and the firm's business activities. The new technologies at the core of the SCMEP Survey, namely, AI, big data and robotics, are not defined in the survey questionnaire.

3.2 Survey methods and dissemination

The questionnaire was sent to 15 000 Japanese firms in manufacturing and service industries. The firms were randomly sampled from about 30,000 firms registered in the Basic Survey of Japanese Business Structure and Activities (BSJBSA) conducted by the Ministry of Economy, Trade and Industry since 2017. The BSJBSA is an official firm survey in Japan that accumulates annual statistics for all Japanese firms with 50 or more employees engaged in mining, manufacturing, electricity and gas, wholesale, retail, and several service industries. The SCMEP collected responses from 2,535 firms (response rate of 16.9%), with 52.7%, 5.4%, 18.0%, 10.6%, 9.3%, and 3.3% firms engaged in manufacturing, ICT, wholesale, retail, services, other industries, respectively[34].

[33] This might be done through the UK Data Archives at the University of Essex which provides controlled access to the micro data of EU surveys including the European Company Survey and the European Working Conditions Survey.

[34] About 0.7% of the respondent firms did not state their industry affiliation.

The survey report does not indicate whether there was any cognitive testing of the questionnaire. All indications are that the survey is originally mail-based although online submissions have been made possible since 2014[35]. The response rate for this survey is reported at 16.9%. No information is reported on efforts taken to improve the response rate. The survey is conducted annually across Japan as part of an official initiative. A report focusing on the automation technologies component was published as an official discussion paper of RIETI[36]. The research is supported by The Japan Society for the Promotion of Science (JSPS) Grants-in-Aid for Scientific Research.

3.3 Strengths and weaknesses

The survey has the strength of going beyond standard questions on the introducing of new products and processes and providing evidence on the adoption three new technologies that are widely discuses by policy maker ad researchers and about which little is known. From the point of view of designing a servery for the purposes of collecting and interpreting information on the adoption of new and emerging technologies, however, the limitations stand out. The survey does not define the technologies it seeks to measure, and in particular it does not make any effort to define what is meant by artificial intelligence or whether the focus in on measuring the adoption of industrial or service robots. This, combined with the fact that there is no evidence of the questions being cognitively tested, raises the possibility of there being problems of low content validity and low reliability.

4. EU Community Survey on ICT Usage and e-Commerce in Enterprises

4.1 Objective and scope of the survey

The purpose of the above survey is to measure the development of the Information Society within the European Union (EU) using relevant statistics on society, business processes and the digital economy. The questionnaire has 63 mandatory and 25 optional questions distributed across various aspects of ICT applications and technologies as follows:

Table 4.1: Scope of the Community Survey on ICT and e-Commerce in Enterprises

Module	Description	Mandatory questions	Optional questions
A	Access and use of the internet	13	2
B	E-commerce	7	2
C	Invoicing	3	1
D	Use of cloud computing services	8	0
E	Big data analysis	10	10
F	ICT specialists and skills	7	4

[35] https://www.meti.go.jp/english/statistics/tyo/kikatu/pdf/Notes_on_Use_2020.pdf

[36] Morikawa, M. 2020. Heterogeneous Relationships between Automation Technologies and Skilled Labor: Evidence from a Firm Survey. RIETI Discussion Paper Series, 20-E-004 January 2020.

G	Internet of Things	0	6
H	Use of 3D printing technologies	6	0
I	Use of robotics	9	0
	Total	**63**	**25**

The survey is carried out for benchmarking purposes in the context of monitoring Europe's eAction Plans as specified under the terms of the EC Regulation No 808/2004 of the European parliament and of the Spring Council of 21 April 2004 concerning Community statistics on the information society. The need for collecting these statistics is justified in the regulation in terms of "The rapidly changing nature of the information society domain requires that the statistics that are produced adapted to new developments.

Except for the case of big data analysis, the questions focus on the extent of adoption of the technologies and there is no attempt to determine the factors that that may hinder adoption. In the case of the section on big data, questions are asked to determine whether such factors as high costs, lack of skilled personnel, inadequate infrastructure and privacy laws are reasons for not using big data. The survey does not measure impacts though in countries where there is scope for linking the survey to the annual enterprise surveys it would be possible to carry out this analysis. The survey does include a module on ICT skills to determine whether the firm undertook any training of specialists and has encountered any problems in recruiting skilled ICT specialists.

4.2 Concepts and Definitions

In the Methodological Manual for the survey there is no explicit measurement framework or a conceptual discussion that serves to justify the choice of indicators that are being measured. The manual does provide very detailed definitions and explanations for the design of the questionnaire and for the phrasing of the questions. As an illustration, the guidelines in the module on big data analysis and the use of machine learning methods states (Eurostat, 2020, pp; 47-55):

> *Big data analysis*
>
> *"The purpose of the following questions is to make a first attempt to collect information for enterprises that use big data analysis. The use of a filter question was not recommended. Firstly because responding enterprises might not be fully aware of the terms "data analysis", "big data" or "big data analytics" and secondly because it would require a lengthy and detailed introduction/definition that would be rarely read by respondents. Respondents are requested to identify any of the following three sources of big data."*
>
> *Machine learning*
>
> *"Machine learning (e.g. deep learning) involves 'training' a computer model to better perform an automated task, e.g. pattern recognition. Machine learning uses algorithms*

whose performance improves as they are exposed to more data over time. Deep learning is a subset of machine learning in which multi-layered neural networks learn from vast amounts of data. Neural networks (Artificial neural networks (ANN) or connectionist systems) are computing systems vaguely inspired by the biological neural networks. The neural network itself is not an algorithm, but rather a framework for many different machine learning algorithms to work together and process complex data inputs. Such systems "learn" to perform tasks by considering examples, generally without being programmed with any task-specific rules. Although neural networks are not explicitly mentioned in this answer option, they are in scope of this item."

As can be seen in the above extract, great care is taken to achieve clarity in the key terms of the survey. Taken comprehensively, all the terms covered constitute many of the key technologies of the 4IR without directly referencing it directly as an organising theme.

4.3 Survey methods and questionnaire development

The unit of analysis for this survey is the enterprise, which defined as "the smallest combination of legal units that is an organisational unit producing goods or services, which benefits from a certain degree of autonomy in decision-making, especially for the allocation of its current resources"[37]. The target population consists of all enterprises with 10 or more employees the EU countries though in several cases the survey covered enterprise with 2 or more employees. The respondent enterprises cover a wide range of economic sectors.

The target respondent is a decision maker with major responsibility for ICT-related issues in the enterprise (the ICT manager or a senior professional in the ICT department). In smaller enterprises, the respondent should be someone at the level of managing director or the owner.

The Eurostat guidelines requires that the sample size should be sufficient for obtaining accurate, reliable, and representative results on the variables and items in the model questionnaire. For the 2019 round samples sizes ranged from a low 1790 in Slovenia to a high of 64,923 in Germany. Response rates were generally over 60% expect it the case of Germany with a response rate of 30% which given the large gross sample size corresponding to a net sample size of about 20,000. The surveys were carried out with stratified random sampling according to size class and sector of activity except the cases of Turkey and Cyprus where simple random sampling was used.

4.4 Strengths and weaknesses

The strengthen of the survey are in the use of careful definitions of the technologies measured and in the attention given to the phrasing of question so that they are understandable to the respondent. Although there is no available quality report, the initial Methodology Manual refer to the use of pre-

[37] Eurostat. 2020. Methodological Manual for statistics on the Information Society, March 2020.

testing and the up-dated manuals refer to on-going testing of new questions. Although there are some minor differences across member countries a clear strength of the survey is the central coordination carried out by Eurostat to assure harmonized survey methods and the comparability of results. Thus, the survey can be reliably used for purposes of comparing differences in adoption rates across EU member countries.

From the perspective of providing a model for carrying out surveys of the adoption of new and emerging technologies in developing countries a limitation of the survey design is the lack of information collected on the factors promoting and the obstacles firms face to technology adoption. Further there is little relevant information collected on other dimension of the firm's activity and organization that might as a bearing on the use of new technology such as the nature of the products or the way workflows are organized. While the ability to link the survey to other surveys in some EU counties potentially allows researchers to overcome these limitations, this sort of linkage is not possible in most developing countries. For this reason, in a developing country context it is important to develop a self-contained survey questionnaire that allows for an investigating of those aspects needed for interpreting technology adoption decision.

5. Canadian Survey of Digital Technology and Internet Use

5.1 Objectives and Scope of the Survey

The Canadian Survey of Digital Technology and Internet Use (SDTIU) is designed to measure the impact of digital technologies on the operations of Canadian enterprises. It is a revised version of the former Electronic Commerce and Technology Survey carried out annually between 2001 and 2007. It has been carried out three times, in 2012, 2013 and 2019. [38]

The survey is designed to gather information that helps to better understand how enterprises use the internet, including their online presence, involvement in e-commerce, use of specific information and communication technologies (ICTs) and interaction with federal government online services. The survey also examines skills and employment in ICT-related jobs. The data from this survey are used by government departments to develop policies and programs that help improve Canada's innovation system and strengthen the overall economy.

The survey is divided into several modules focusing on the use of what are referred to as ICT technologies. The emphasis is on technologies that depend on internet connectivity and involve data exchange. These include sections asking the firm to identify the means it use to gain access to the internet followed by sections on its use of: a business website, e-government services, e-commerce, cloud computing, the Internet of Things, artificial intelligence, big data analysis, and blockchain. In each case the enterprise is asked to identify the reasons for adopting the technology and the obstacles to adopting it if the technology is not used. The firm is also asked whether it used robotics and 3d_printing, Enterprises resource Planning (ERP) software ad Customer management Relations ((CMR) software but in these cases, there is not assessment of the reasons for of for not adopting.

[38] See https://www23.statcan.gc.ca/imdb/p3Instr.pl?Function=getInstrumentList&Item_Id=1250755&UL=1V

There is also a section on skills and employment including a question on the difficulties the firm may have experience in recruiting ICT specialists.

5.2 Concepts and definitions

There is no document attached to the survey's webpage at Statistics Canada presenting the conceptual underpinning for the survey or an explicit measurement framework. The definitions for some of digital technologies covered in the survey are included in the questionnaire. These are in some case quite short. For example, artificial intelligence (AI) is simply defined as referring, "to systems that display intelligent behaviour by analysing their environment and taking actions - with some degree autonomy - to achieve specific goals. AI-based systems can be purely software-based or embedded in a device." Other technologies measured, including cloud computing, ERP and CRM software, robotics, 3D-printing, are not defined.

5.3 Survey methods and questionnaire design

The sample frame was derived from Statistics Canada's Business Register (BR). The BR is an information database on the Canadian business population and serves as a frame for all Statistics Canada business surveys. It is a structured list of businesses engaged in the production of goods and services in Canada. This survey covers enterprises with 5 or more employees operating in Canada in almost all industrial sectors excluding government entities; agriculture, forestry, fishing, and hunting; private households; and public administration. he final sample size was 14,127 enterprises. The survey is mandatory, and the response rate is reported at 77%. The survey was administered electronically either by email or on-line after an initial telephone contact to identify an appropriate person to respond. Cognitive testing of the questionnaire content was carried with the Questionnaire Design Resource Centre based at Statistics Canada in both official languages and concentrated on validating respondents' understanding of concepts, questions, terminology, the appropriateness of response categories and the availability of requested information. Stratified random sampling was used.

5.4 Strengths and weaknesses

The survey, as would be expected given the reputation of Statistics Canada, appears to be methodological very strong terms of sampling frames and sampling methods. Data collection was preceded by contact procedures to identify an appropriate respondent and follow up procedures were used to increase item response rate and correct possible errors. A possible weakness in the questionnaire design is the lack of detailed definitions for many of the technologies covered. The questionnaire was self-administered and even though the questionnaire went through cognitive testing it seems possible given the complexity of the technical language used that some of the questions were poorly understood or not understood in the same way by all respondents. These sorts of problems can be best handled through face-to-face interview methods which we recommend for several reason in the case of surveys carried out in developing countries.

A strength of the survey is that it does include for selected technologies questions asking what the main reasons are for their adoption or for not adopting them. These questions focus on what we have referred to as internal drivers and constraints and the survey does not explore external drivers or constraints such as inadequate infrastructure, the impact of market demand and competition, or of the regulatory environment. While the survey goes beyond the EU ICT Enterprise usage survey in terms of providing elements for interpreting adoption decision, it nonetheless remains limited in this respect.

Table A.1 on Survey Methods

Survey	Target population National Regional Multi-country Other	Target population Specify sector coverage and whether PSU is establishment or enterprise	Sample frame Specify if an official register or commercial register.	Sample size	Sampling methods Specify if simple or stratified random sampling or other	Data collection Postal/Fax Questionnaire, Face-to- face, CATI, On-line, Multi-mode	Dissemination Specify if open access to micro data	Response rate Give response rate and specify if weighting for non-response
EMS		Manufacturing. Establishment level	Official registers	Ranges across countries from about 1600 in Germany to 114 in Spain in 2009 round	Simple random sampling	Online	Closed	NS
EU ICT Usage	EU Member countries and Turkey and	Manufacturing. Enterprise level	Official registers		Stratified random sampling in most countries	Multi-mode	Restricted access to anonymized data	Generally over 60%
UNIDO	Brazil, Argentina, Ghana, Vietnam and Thailand	Manufacturing. PSU not specified	Commercial registers	Either 200 or 250	Probability Proportional sampling	Multi-mode in Brazil and Argentina. Face-to-face in Ghana, Vietnam, and Thailand	NS	NS
Japan SCMEP	National	Manufacturing & services. Enterprise level	Official register	15 000	Simple random sampling	Multi-mode	NS	16.9%
Canada STDIU	National	Manufacturing and service. Enterprise level	Official register		Stratified random sampling	Electronic	Restricted access to anonymized	77%

NS = Not Specified

Annex B

Draft Model Questionnaire

A. Profile of the firm

1. Is the establishment
a. A single independent establishment
b. One of a number of establishments belonging to a larger firm or organisation

2. What percentage of the establishment is owned by the following?
a. Private domestic individuals, companies, or organisations _____ %
b. Private foreign individual, companies, or organisations _____ %
c. Government or state _____ %

3. What is this establishment's main production activity, that is, the activity that represented the largest proportion of annual sales?
(INTERVIEWER : PROBE IN SUFFICIENT DETAIL TO DETERMINE THE 2-DIGIT ISIC CODE)

4. Regarding your main activity, is this establishment mainly:
a. A producer of finished goods or services for final consumption
b. A supplier of inputs (goods or services) for other businesses

5. What is the main market in which this establishment sells its main product or service?
Local …….
National ……..
International ……

6. In what year was this establishment formally registered. Year ……
Never registered …….
7. At the end of fiscal year 2020/21, how many permanent, full-time individuals worked in this establishment? Please include all employees and managers
Number ……..

8. Three fiscal years ago, at the end of fiscal year 2017/2018, how many permanent, full-time individuals work in this establishment? Please include all employees and managers
Number ……..

9. Approximately what percentage of the workforce at this establishment belongs to each of the following occupational groups?
a. Managers
b. Professionals and skilled technicians
c. Skilled craft workers and machine operators
d. Skilled clerical and sales workers
e. Laborers and unskilled workers
(INTERVIWER: CHECK IF THE SUM OF a+b+c+d+e = 100%)

10. In fiscal year 2020/2021, what were this establishment's total annual sales for ALL products and services?
Total sales ……

11. In fiscal year 2017/2018, what were this establishment's total annual sales for ALL products and services?
Total sales 3 years ago ……

12. What share of the firm's sales in the fiscal year 2020/21 were:

a. National sales _____ %
b. Indirect exports sold to domestic third parties for export _____ %
c. Direct exports _____ %

13. In the fiscal year 2020/21, approximately what share of this firm's export revenues were to countries in the following regions:

a. Asia (excluding Japan and Korea) _____ %
b. Sub Saharan Africa _____ %
c. Latin America and Caribbean _____ %
d. Middle East and North Africa _____ %
e. Developed countries _____ %

14. In fiscal year 2020/21 what share of your supplies and inputs were purchased from

d. Domestically owned firms or producers _____ %
e. Foreign owned firms located in this country _____ %
f. Imported from foreign suppliers _____ %

15. Have you imported technologies through any of the following routes over the last 3 financial years (FY2017/17 to FY2020/21)? (tick all that apply)

a. Licensing agreement
b. Purchase of patent and/or trademark
c. Franchise agreement
d. Joint venture agreement
e. Technical assistance/know-how
f. Import of equipment/ machinery Import of software
g. Turn-key agreement
h. Cooperation with foreign experts/consultants
i. Other (please specify)

16. What three types of skills would you say are most needed in your business? From this list please select the three most needed skills in your business.
Describe

1. Skill 1
2. Skill 2
3. Skill 3

INTERVIEWER PRESENT THE LIST TO RESPONDENT:

- Communication skills (e.g. internal, clients, suppliers etc.)
- Marketing skills

- Negotiation skills
- Financial knowledge & budgetary skills
- Business planning skills
- Computer use
- Coding and Programming
- Technical skills
- Complex problem-solving skills
- "Community skills" (knowing of the community, personal networks, etc)
- Creative skills (i.e. come up with creative ideas and solutions)

17. In your opinion, is this business generally open to the incorporation of new technologies?
-To a great extent
-To a moderate extent
-To a small extent
-Not at all

B. Innovation and Competition

1. During the last three years, has this establishment introduced new or significantly improved products or services?

Yes ……..

No …….

2. Were any of the new or significantly improved products or services also new for the establishment's main market?

Yes …….

No ……..

3. During the last three years, has this establishment introduced new or significantly improved marketing methods?

Yes ……..

No ……

4. During the last three years, did this establishment give employees some time to develop or try out a new approach or new idea about products or services, business process, firm management, or marketing

Yes …….

No ……

5. How competitive would you say the market for the main products or services provided by this establishment is?

☐ Not at all competitive ☐ Not very competitive ☐ Fairly competitive ☐ Very competitive

6. How important are the following factors for the competitive success of this establishment? (INTERVIEWER: PLEASE ORDER THEM FROM MOST TO LEAST IMPORTANT, ENTERING 1 FOR THE MOST IMPORTANT DOWN TO 3 FOR THE LEAST IMPORTANT.)

Offering products or services at lower prices than the competition

Offering products or services that are of better quality than those offered by the competition

Regularly developing products, services or processes that are new to the market

7. Does this establishment have an internationally-recognized quality certification?
(INTERVIEWER: SOME EXAMPLES ARE ISO 9000 or 14000, or HACCP)
Yes ……..
No ……
Still in process ……..

C. Products and Internal Organisation

Products
1. Which of the following best describes this firm's products or services?
[INTERVIEWER: THE RESPONDENT CAN CHOOSE ONE ONLY]
a. Products or services that are developed according to the customers specification
b. Standardized products or services into which customer specific options are inserted
c. Standardized products or services from which the customer can select

2. If your enterprise's main product is a physical good, which of the following best describes its fabrication:
a. Single unit or one-off production
b. Small or medium batch or lot
c Large batch production

Internal organisation

3. For how many employees in this establishment does their job include independently organising their own time and scheduling their own tasks? Your best estimate is good enough.
☐ Less than 25%
☐ 25% to 49%
☐ 50% to 74%
☐ over 74%

4. For how many employees in this establishment does their job entail finding solutions to unfamiliar problems they are confronted with? Your best estimate is good enough.
☐ Less than 25%
☐ 25% to 49%
☐ 50% to 74%
☐ over 74%

5. How quickly do the knowledge and skills needed from the employees in this establishment change?
☐ No change at all ☐ Not very quickly ☐ Fairly quickly ☐ Very quickly

6. Who normally decides on the planning and execution of the daily work tasks of the employees at this establishment?
[INTERVIEWER: ONLY ONE ANSWER IS POSSIBLE]
a. The employee undertaking the tasks .....

b. Managers or supervisors .....
c. Both employees and managers or supervisors .....

7. How many employees in this establishment are in jobs that require continuous training? Your best estimate is good enough.
(INTERVIEWER: CONTINUOUS TRAINING: TRAINING THAT IS RECEIVED AT A FREQUENT, REGULAR BASIS, AND THAT IS REQUIRED TO KEEP UP WITH CHANGES IN THE EQUIPMENT THAT IS BEING USED, OR CHANGES IN THE PRODUCTS OR SERVICES THAT THE ENTERPRISE PRODUCES AND MARKETS.)

☐ Less than 25%
☐ 25% to 49%
☐ 50% to 74%
☐ over 74%

A team is a group of people working together with a shared responsibility for the execution of allocated tasks, within or across units of the establishment.

8. How many employees in this enterprise work in teams. Your best estimate is good enough
☐ Less than 25%
☐ 25% to 49%
☐ 50% to 74%
☐ over 74%

9. If you think about the tasks to be performed by the teams: Do the team members decide among themselves by whom the tasks are to be performed, or is there usually a superior distributing the tasks within the team?
(INTERVIEWER: CHECH ONE RESPONSE)

a. Team members decide among themselves .....
b. Tasks are usually distributed by a superior .....

D. New Technology Adoption

An industrial robot is defined as an automatically controlled, reprogrammable multipurpose manipulator programmable in three or more axes, which can be either fixed in place or mobile for use in industrial automation applications.

1. Does this establishment currently use industrial robots for manufacturing processes:
Yes No
(INTERVIEWER: IF THE RESPONSE TO C.1 IS NO, PLEASE GO TO QUESTION C.6)

2. What is the year in which this technology was first used: …….
(INTERVIEWER: IF UNCERTAIN PLEASE ESTIMATE THE YEAR)

3. How important are the following objectives for using this technology

a. Industrial robots are used at this enterprise to substitute for the skills of the establishment's existing employees on existing tasks and reduce labor requirements

☐ Very important ☐ Moderately important ☐ Slightly important ☐ Not at all important

b. Industrial robots are used at this enterprise to complement the skills of the establishment's existing employees on existing tasks and increase productivity or quality of work

☐ Very important ☐ Moderately important ☐ Slightly important ☐ Not at all important

c. Industrial robots are used at this enterprise to undertake entirely new tasks requiring new skills development on the part of the establishment's employees

☐ Very important ☐ Moderately important ☐ Slightly important ☐ Not at all important

4. Was the establishment motivated to adopt industrial robots for any of the following reasons:
(INTERVIEWER: CHECK ALL THAT APPLY)

a. Knowledge of the technology acquired from the main client or clients
b. Direct pressure to adopt from the main client or clients
c. Competitive pressure
d. To meet standards for export
e. Government support programmes
f. Support from professional or industry associations
g. To improve working conditions
h. Other

5. How did the establishment acquire/develop this technology:
(INTERVIEWER CHECK ONE OF THE FOLLOWING)

a. The technology was purchased or paid for from a domestic supplier
b. The technology was purchased or paid for from a foreign supplier or a foreign owned supplier located in this country
c. The technology was developed and implemented in-house by this firm
d. The technology was developed and implemented in collaboration with a domestic firm
e. The technology was developed and implemented in collaboration with a foreign firm or a foreign owned firm located in this country

6. For which of the following reasons does this firm not use industrial robots:
(INTERVIEWER: CHECK ALL THAT APPLY)

f. Lack of capital or funds for investment
g. Lack of knowledge/awareness of the technology
h. Lack of skills for using the technology
i. Lack of competition in the market
j. Inadequate power or ICT infrastructure
k. Too restrictive regulations
l. The technology is not adapted to my business activity
m. Other

Collaborative robots (Cobots) are designed to perform tasks in collaboration with workers in industrial sectors. Human-industrial robot collaboration can range from a shared workspace with no direct human-robot contact or task synchronisation, to a robot that adjusts its motion in real-time to the motion of an individual human worker

7. Does this establishment currently use cobots in its manufacturing processes:
Yes No
(INTERVIEWER: IF THE RESPONSE TO C.7 IS NO, PLEASE GO TO QUESTION C.12)

8. What is the year in which this technology was first used: …….
(INTERVIEWER: IF UNCERTAIN PLEASE ESTIMATE THE YEAR)

9. How important are the following objectives for using this technology
(INTERVIEWER: PLEASE ORDER THEM FROM MOST TO LEAST IMPORTANT, ENTERING 1 FOR THE MOST IMPORTANT DOWN TO 3 FOR THE LEAST IMPORTANT.)

a. Cobots are used at this enterprise to substitute for the skills of the establishment's existing employees on existing tasks and reduce labor requirements
☐ Very important ☐ Moderately important ☐ Slightly important ☐ Not at all important

b. Cobots are used at this enterprise to complement the skills of the establishment's existing employees on existing tasks and increase productivity or quality of work
☐ Very important ☐ Moderately important ☐ Slightly important ☐ Not at all important

c. Cobots are used at this enterprise to undertake entirely new tasks requiring new skills development on the part of the establishment's employees
☐ Very important ☐ Moderately important ☐ Slightly important ☐ Not at all important

10. Was the establishment motivated to adopt cobots for any of the following reasons:
(INTERVIEWER: CHECK ALL THAT APPLY)

a. Knowledge of the technology acquired from main client or clients
b. Pressure from the main client or clients
c. Pressure from competitors
d. To meet standards for export
e. Government subsidies or tax advantages
f. Support from professional or industry associations
g. Improve working conditions
h. Other

11. How did the establishment acquire/develop this technology:
(INTERVIEWER CHECK ONE OF THE FOLLOWING)

n. The technology was purchased or paid for from a domestic supplier
o. The technology was purchased or paid for from a foreign supplier or a foreign owned supplier located in this country
p. The technology was developed and implemented in-house by this firm
q. The technology was developed and implemented in collaboration with a domestic firm

r. The technology was developed and implemented in collaboration with a foreign firm or a foreign owned firm located in this country

12. For which of the following reasons does this firm not use cobots:
(INTERVIEWER: CHECK ALL THAT APPLY)

s. Lack of capital or funds for investment
t. Lack of knowledge/awareness of the technology
u. Lack of skills for using the technology
v. Lack of competition in the market
w. Inadequate power or ICT infrastructure
x. Too restrictive regulations
y. The technology is not adapted to my business activity
z. Other

3D-Printing/Additive manufacturing builds a three-dimensional object from a computer-aided design (CAD) model, by successively adding thin layers of material. 3D printing is the opposite of subtractive manufacturing which is cutting out / hollowing out a piece of metal or plastic with for instance a milling machine.

13. Does this establishment currently use 3D-Printing:
Yes No
(INTERVIEWER: IF THE RESPONSE TO C.13 IS NO, PLEASE GO TO QUESTION C.18)

14. What is the year in which this technology was first used: …….
(INTERVIEWER: IF UNCERTAIN PLEASE ESTIMATE THE YEAR)

15. How important are the following objectives for using this technology
(INTERVIEWER: PLEASE ORDER THEM FROM MOST TO LEAST IMPORTANT, ENTERING 1 FOR THE MOST IMPORTANT DOWN TO 3 FOR THE LEAST IMPORTANT.)

a. 3D-printing is used at this enterprise to substitute for the skills of the establishment's existing employees on existing tasks and reduce labor requirements
☐ Very important ☐ Moderately important ☐ Slightly important ☐ Not at all important

b. 3D-printing is used at this enterprise to complement the skills of the establishment's existing employees on existing tasks and increase productivity or quality of work
☐ Very important ☐ Moderately important ☐ Slightly important ☐ Not at all important

c. 3D-printing is used at this enterprise to undertake entirely new tasks requiring new skills development on the part of the establishment's employees
☐ Very important ☐ Moderately important ☐ Slightly important ☐ Not at all important

16. Was the establishment motivated to adopt 3D-Printing for any of the following reasons:
(INTERVIEWER: CHECK ALL THAT APPLY)

a. Knowledge of the technology acquired from main client or clients
b. Pressure from the main client or clients
c. Pressure from competitors
d. To meet standards for export
i. Government subsidies or tax advantages
j. Support from professional or industry associations
k. Improve working conditions
l. Other

17. How did the establishment acquire/develop this technology:
(INTERVIEWER CHECK ONE OF THE FOLLOWING)
a. The technology was purchased or paid for from a domestic supplier
b. The technology was purchased or paid for from a foreign supplier or a foreign owned supplier located in this country
c. The technology was developed and implemented in-house by this firm
d. The technology was developed and implemented in collaboration with a domestic firm
e. The technology was developed and implemented in collaboration with a foreign firm or a foreign owned firm located in this country

18. For which of the following reasons does this firm not use 3D-Printing:
(INTERVIEWER: CHECK ALL THAT APPLY)
a. Lack of capital or funds for investment
b. Lack of knowledge/awareness of the technology
c. Lack of skills for using the technology
d. Lack of competition in the market
e. Inadequate power or ICT infrastructure
f. Too restrictive regulations
g. The technology is not adapted to my business activity
h. Other

Big data refers to vast amounts of data in different possibly unstructured formats (e.g. text, video, voice, sensor data, activity logs, coordinates). Big data analysis refers to the use of software tools such as data mining, predictive analytics and machine learning for analysing big data extracted from your own firm's data sources or other data sources

19. Does this establishment currently use big data analysis:
Yes No
(INTERVIEWER: IF THE RESPONSE TO C.19 IS NO, PLEASE GO TO QUESTION C.24)

20. What is the year in which this technology was first used: …….
(INTERVIEWER: IF UNCERTAIN PLEASE ESTIMATE THE YEAR)

21. How important are the following objectives for using this technology:

a. Big data analytics is used at this enterprise to substitute for the skills of the establishment's existing employees on existing tasks and reduce labor requirements
☐ Very important ☐ Moderately important ☐ Slightly important ☐ Not at all important

b. Big data analytics is used at this enterprise to complement the skills of the establishment's existing employees on existing tasks and increase productivity or quality of work
☐ Very important ☐ Moderately important ☐ Slightly important ☐ Not at all important

c. Big data analytics is used at this enterprise to undertake entirely new tasks requiring new skills development on the part of the establishment's employees
☐ Very important ☐ Moderately important ☐ Slightly important ☐ Not at all important

22. Was the establishment motivated to adopt big data analysis for any of the following reasons: (INTERVIEWER: CHECK ALL THAT APPLY)

a. Knowledge of the technology acquired from main client or clients
b. Pressure from the main client or clients
c. Pressure from competitors
d. To meet standards for export
m. Government subsidies or tax advantages
n. Support from professional or industry associations
o. Improve working conditions
p. Other

23. How did the establishment acquire/develop this technology:
(INTERVIEWER CHECK ONE OF THE FOLLOWING)

a. The technology was purchased or paid for from a domestic supplier
b. The technology was purchased or paid for from a foreign supplier or a foreign owned supplier located in this country
c. The technology was developed and implemented in-house by this firm
d. The technology was developed and implemented in collaboration with a domestic firm
e. The technology was developed and implemented in collaboration with a foreign firm or a foreign owned firm located in this country

24. For which of the following reasons does this firm not use big data analysis:
(INTERVIEWER: CHECK ALL THAT APPLY)

a. Lack of capital or funds for investment
b. Lack of knowledge/awareness of the technology
c. Lack of skills for using the technology
d. Lack of competition in the market
e. Inadequate power or ICT infrastructure
f. Too restrictive regulations
g. The technology is not adapted to my business activity
h. Other

Machine learning (deep learning) is a branch of artificial intelligence that uses vast amounts of labelled data (big data) to give computers the ability to learn and perform tasks without being explicitly programmed. Examples are predictive maintenance and next to buy individualised offering

25. Does this establishment currently use machine learning:
Yes No
(INTERVIEWER:IF THE RESPONSE TO C.25 IS NO, PLEASE GO TO QUESTION C.30)

26. What is the year in which this technology was first used: …….
(INTERVIEWER: IF UNCERTAIN PLEASE ESTIMATE THE YEAR)

27. How important are the following objectives for using this technology
a. Machine learning is used at this enterprise to substitute for the skills of the establishment's existing employees on existing tasks and reduce labor requirements
☐ Very important ☐ Moderately important ☐ Slightly important ☐ Not at all important

b. Machine learning is used at this enterprise to complement the skills of the establishment's existing employees on existing tasks and increase productivity or quality of work
☐ Very important ☐ Moderately important ☐ Slightly important ☐ Not at all important

c. Machine learning is used at this enterprise to undertake entirely new tasks requiring new skills development on the part of the establishment's employees
☐ Very important ☐ Moderately important ☐ Slightly important ☐ Not at all important

28. Was the establishment motivated to adopt machine learning for any of the following reasons:
(INTERVIEWER: CHECK ALL THAT APPLY)
a. Knowledge of the technology acquired from main client or clients
b. Pressure from the main client or clients
c. Competitive pressure
d. To meet standards for export
q. Government subsidies or tax advantages
r. Support from professional or industry associations
s. Improve working conditions
t. Other

29. How did the establishment acquire/develop this technology:
(INTERVIEWER CHECK ONE OF THE FOLLOWING)
a. The technology was purchased or paid for from a domestic supplier
b. The technology was purchased or paid for from a foreign supplier or a foreign owned supplier located in this country
c. The technology was developed and implemented in-house by this firm
d. The technology was developed and implemented in collaboration with a domestic firm
e. The technology was developed and implemented in collaboration with a foreign firm or a foreign owned firm located in this country

30. For which of the following reasons does this firm not use machine learning :
(INTERVIEWER: CHECK ALL THAT APPLY)

a. Lack of capital or funds for investment
b. Lack of knowledge/awareness of the technology
c. Lack of skills for using the technology
d. Lack of competition in the market
e. Inadequate power or ICT infrastructure
f. Too restrictive regulations
g. The technology is not adapted to my business activity
h. Other

The Internet of Things (IoT) refers to interconnected devices or systems, often called "smart" devices or "smart" systems. They collect and exchange data and can be monitored or remotely controlled via the Internet, through software on computers or smartphones.

31. Does this establishment currently use the Internet of Things:
Yes No
(INTERVIEWER: IF THE RESPONSE TO C.31 IS NO, PLEASE GO TO QUESTION C.36)

32. What is the year in which this technology was first used: …….
(INTERVIEWER: IF UNCERTAIN PLEASE ESTIMATE THE YEAR)

33. How important are the following objectives for using this technology
a. The Internet of Things is used at this enterprise to substitute for the skills of the establishment's existing employees on existing tasks and reduce labor requirements
☐ Very important ☐ Moderately important ☐ Slightly important ☐ Not at all important

b. The Internet of Things is used at this enterprise to complement the skills of the establishment's existing employees on existing tasks and increase productivity or quality of work
☐ Very important ☐ Moderately important ☐ Slightly important ☐ Not at all important

c. The Internet of Things is used at this enterprise to undertake entirely new tasks requiring new skills development on the part of the establishment's employees
☐ Very important ☐ Moderately important ☐ Slightly important ☐ Not at all important

34. Was the establishment motivated to use the Internet of Things for any of the following reasons:
(INTERVIEWER: CHECK ALL THAT APPLY)

a. Knowledge of the technology acquired from main client or clients
b. Pressure from the main client or clients
c. Pressure from competitors
d. To meet standards for export
u. Government subsidies or tax advantages
v. Support from professional or industry associations

w. Improve working conditions
x. Other

35. How did the establishment acquire/develop this technology:
(INTERVIEWER CHECK ONE OF THE FOLLOWING)
a. The technology was purchased or paid for from a domestic supplier
b. The technology was purchased or paid for from a foreign supplier or a foreign owned supplier located in this country
c. The technology was developed and implemented in-house by this firm
d. The technology was developed and implemented in collaboration with a domestic firm
e. The technology was developed and implemented and implemented in collaboration with a foreign firm or a foreign owned firm located in this country

36. For which of the following reasons does this firm not use the Internet of Things:
(INTERVIEWER: CHECK ALL THAT APPLY)
a. Lack of capital or funds for investment
b. Lack of knowledge/awareness of the technology
c. Lack of skills for using the technology
d. Lack of competition in the market
e. Inadequate power or ICT infrastructure
f. Too restrictive regulations
g. The technology is not adapted to my business activity
h. Other

Virtual reality/ Augmented reality (VR) refers to a computer-generated simulation in which a person can interact within an artificial three-dimensional environment using electronic devices, such as special goggles with a screen or gloves fitted with sensors. Augmented reality (AR) is the real-time use of information in the form of text, graphics, audio, and other virtual enhancements integrated with real-world objects.

37. Does this establishment currently use the Virtual reality/Augmented reality:
Yes No
(INTERVIEWER: IF THE RESPONSE TO C.37 IS NO, PLEASE GO TO QUESTION C.42.)

38. What is the year in which this technology was first used: …….
(INTERVIEWER: IF UNCERTAIN PLEASE ESTIMATE THE YEAR)

39. How important are the following objectives for using this technology
a. Virtual/augmented reality is used at this enterprise to substitute for the skills of the establishment's existing employees on existing tasks and reduce labor requirements
☐ Very important ☐ Moderately important ☐ Slightly important ☐ Not at all important

b. Virtual/augmented reality is used at this enterprise to complement the skills of the establishment's existing employees on existing tasks and increase productivity or quality of work
☐ Very important ☐ Moderately important ☐ Slightly important ☐ Not at all important

c. Virtual/augmented reality is used at this enterprise to undertake entirely new tasks

☐ Very important ☐ Moderately important ☐ Slightly important ☐ Not at all important

40. Was the establishment motivated to use Virtual reality/ Augmented reality for any of the following reasons:

(INTERVIEWER: CHECK ALL THAT APPLY)

a. Knowledge of the technology acquired from main client or clients
b. Pressure from the main client or clients
c. Pressure from competitors
d. To meet standards for export
y. Government subsidies or tax advantages
z. Support from professional or industry associations
aa. Improve working conditions
bb. Other

41. How did the establishment acquire/develop this technology:

(INTERVIEWER CHECK ONE OF THE FOLLOWING)

a. The technology was purchased or paid for from a domestic supplier
b. The technology was purchased or paid for from a foreign supplier or a foreign owned supplier located in this country
c. The technology was developed and implemented in-house by this firm
d. The technology was developed and implemented in collaboration with a domestic firm
e. The technology was developed and implemented in collaboration with a foreign firm or a foreign owned firm located in this country

42. For which of the following reasons does this firm not use virtual/augmented reality:

(INTERVIEWER: CHECK ALL THAT APPLY)

a. Lack of capital or funds for investment
b. Lack of knowledge/awareness of the technology
c. Lack of skills for using the technology
d. Lack of competition in the market
e. Inadequate power or ICT infrastructure
f. Too restrictive regulations
g. The technology is not adapted to my business activity
h. Other

Cloud computing refers to ICT services that are used over the Internet to access software, computing power, storage capacity etc. The services are delivered from servers of service providers, can be easily scaled up or down (e.g. number of users or change of storage capacity), can be used on-demand by the user, and are paid for, either per user, by capacity used, or they are pre-paid.

43. Does this establishment currently use cloud computing:

Yes No

(INTERVIEWER: IF THE RESPONSE TO C.43 IS NO, PLEASE GO TO QUESTION C.48)

44. What is the year in which this technology was first used: …….

(INTERVIEWER: IF UNCERTAIN PLEASE ESTIMATE THE YEAR)

45. How important are the following objectezives for using this technology

a. Cloud computing is used at this enterprise to substitute for the skills of the establishment's existing employees on existing tasks and reduce labor requirements

☐ Very important ☐ Moderately important ☐ Slightly important ☐ Not at all important

b. Cloud computing is used at this enterprise to complement the skills of the establishment's existing employees on existing tasks and increase productivity or quality of work

☐ Very important ☐ Moderately important ☐ Slightly important ☐ Not at all important

c. Cloud computing is used at this enterprise to undertake entirely new tasks

☐ Very important ☐ Moderately important ☐ Slightly important ☐ Not at all important

46. Was the establishment motivated to use cloud computing for any of the following reasons:
(INTERVIEWER: CHECK ALL THAT APPLY)

a. Knowledge of the technology acquired from main client or clients
b. Pressure from the main client or clients
c. Pressure from competitors
d. To meet standards for export
cc. Government subsidies or tax advantages
dd. Support from professional or industry associations
ee. Improve working conditions
ff. Other

47. How did the establishment acquire/develop this technology:
(INTERVIEWER CHECK ONE OF THE FOLLOWING)

a. The technology was purchased or paid for from a domestic supplier
b. The technology was purchased or paid for from a foreign supplier or a foreign owned supplier located in this country
c. The technology was developed and implemented in-house by this firm
d. The technology was developed and implemented in collaboration with a domestic firm
e. The technology was developed and implemented in collaboration with a foreign firm or a foreign owned firm located in this country

48. For which of the following reasons does this firm not use cloud computing:
(INTERVIEWER: CHECK ALL THAT APPLY)

a. Lack of capital or funds for investment
b. Lack of knowledge/awareness of the technology
c. Lack of skills for using the technology
d. Lack of competition in the market
e. Inadequate power or ICT infrastructure
f. Too restrictive regulations
g. The technology is not adapted to my business activity
h. Other

E-Commerce can be defined as the sale or purchase of goods or services conducted over computer networks by methods specifically designed for the purpose of receiving or placing of orders. The payment and the delivery of the goods or services do not have to be conducted online. E-commerce transactions exclude orders made by manually typed e-mail messages.

49. Does this establishment currently use e-commerce:
Yes No
(INTERVIEWER: IF THE RESPONSE TO C.49 IS NO, PLEASE GO TO QUESTION C.54)

50. What is the year in which this technology was first used: …….
(INTERVIEWER: IF UNCERTAIN PLEASE ESTIMATE THE YEAR)

51. How important are the following objectives for using this technology
a. E-commerce is used at this enterprise to substitute for the skills of the establishment's existing employees on existing tasks and reduce labor requirements
☐ Very important ☐ Moderately important ☐ Slightly important ☐ Not at all important

b. E-commerce is used at this enterprise to complement the skills of the establishment's existing employees on existing tasks and increase productivity or quality of work
☐ Very important ☐ Moderately important ☐ Slightly important ☐ Not at all important

c. E-commerce is used at this enterprise to undertake entirely new tasks
☐ Very important ☐ Moderately important ☐ Slightly important ☐ Not at all important

52. Was the establishment motivated to use e-commerce for any of the following reasons:
(INTERVIEWER: CHECK ALL THAT APPLY)
a. Knowledge of the technology acquired from main client or clients
b. Pressure from the main client or clients
c. Pressure from competitors
d. To meet standards for export
e. Government subsidies or tax advantages
f. Support from professional or industry associations
j. Improve working conditions
k. Other

53. How did the establishment acquire/develop this technology:
(INTERVIEWER CHECK ONE OF THE FOLLOWING)
a. The technology was purchased or paid for from a domestic supplier
b. The technology was purchased or paid for from a foreign supplier or a foreign owned supplier located in this country
c. The technology was developed and implemented in-house by this firm
d. The technology was developed and implemented in collaboration with a domestic firm
e. The technology was developed and implemented in collaboration with a foreign firm or a foreign owned firm located in this country

54. For which of the following reasons does this firm not use e-commerce:

(INTERVIEWER: CHECK ALL THAT APPLY)

a. Lack of capital or funds for investment
b. Lack of knowledge/awareness of the technology
c. Lack of skills for using the technology
d. Lack of competition in the market
e. Inadequate power or ICT infrastructure
f. Too restrictive regulations
g. The technology is not adapted to my business activity
h. Other

Social media refers to applications based on internet technology or communication platforms and the use of Web 2.0 technologies and tools for connecting, conversing and creating content online, with customers, suppliers, or other partners, or within the enterprise. Social media includes social networks or communities, blogs, and content communities.

55. Does this establishment currently use social media:

Yes No

(INTERVIEWER: IF THE RESPONSE TO C.55 IS NO, PLEASE GO TO QUESTION C.60)

56. What is the year in which this technology was first used: …….
(INTERVIEWER: IF UNCERTAIN PLEASE ESTIMATE THE YEAR)

57. How important are the following objectives for using this technology

a. Social media is used at this enterprise to substitute for the skills of the establishment's existing employees on existing tasks and reduce labor requirements

☐ Very important ☐ Moderately important ☐ Slightly important ☐ Not at all important

b. Social media is used at this enterprise to complement the skills of the establishment's existing employees on existing tasks and increase productivity or quality of work

☐ Very important ☐ Moderately important ☐ Slightly important ☐ Not at all important

c. E-commerce is used at this enterprise to undertake entirely new tasks

☐ Very important ☐ Moderately important ☐ Slightly important ☐ Not at all important

58. Was the establishment motivated to adopt social media for any of the following reasons:
(INTERVIEWER: CHECK ALL THAT APPLY)

a. Knowledge of the technology acquired from main client or clients
b. Pressure from the main client or clients
c. Pressure from competitors
d. To meet standards for export
e. Government subsidies or tax advantages
f. Support from professional or industry associations
g. Improve working conditions
h. Other

59. How did the establishment acquire/develop this technology:
(INTERVIEWER CHECK ONE OF THE FOLLOWING)
a. The technology was purchased or paid for from a domestic supplier
b. The technology was purchased or paid for from a foreign supplier or a foreign owned supplier located in this country
c. The technology was developed and implemented in-house by this firm
d. The technology was developed and implemented in collaboration with a domestic firm
e. The technology was developed and implemented in collaboration with a foreign firm or a foreign owned firm located in this country

60. For which of the following reasons does this firm not use social media:
(INTERVIEWER: CHECK ALL THAT APPLY)
a. Lack of capital or funds for investment
b. Lack of knowledge/awareness of the technology
c. Lack of skills for using the technology
d. Lack of competition in the market
e. Inadequate power or ICT infrastructure
f. Too restrictive regulations
g. The technology is not adapted to my business activity
h. Other

Fintech (Financial Technology) refers to software and other modern technologies used by businesses that provide automated and improved financial services. Mobile money or mobile wallet refers to a form of fintech for making payments using a mobile phone, where value is stored virtually (e-money) in an account associated with a SIM card. A bank account is not required to use mobile money services—the only pre-requisite is a basic mobile phone.

61. Does this establishment currently use Fintech:
Yes No

(INTERVIEWER: IF THE RESPONSE TO C.61 IS NO, PLEASE GO TO QUESTION C.66)

62. What is the year in which this technology was first used: …….
(INTERVIEWER: IF UNCERTAIN PLEASE ESTIMATE THE YEAR)

63. How important are the following objectives for using fintech:
a. Fintech is used at this enterprise to substitute for the skills of the establishment's existing employees on existing tasks and reduce labor requirements.
☐ Very important ☐ Moderately important ☐ Slightly important ☐ Not at all important

b. Fintech is used at this enterprise to complement the skills of the establishment's existing employees on existing tasks and increase productivity or quality of work
☐ Very important ☐ Moderately important ☐ Slightly important ☐ Not at all important

c. Fintech is used at this enterprise to undertake entirely new tasks
☐ Very important ☐ Moderately important ☐ Slightly important ☐ Not at all important

64. Was the establishment motivated to adopt fintech for any of the following reasons:
(INTERVIEWER: CHECK ALL THAT APPLY)

a. Knowledge of the technology acquired from main client or clients
b. Pressure from the main client or clients
c. Pressure from competitors
d. To meet standards for export
e. Government subsidies or tax advantages
f. Support from professional or industry associations
g. Improve working conditions
h. Other

65. How did the establishment acquire/develop this technology:
(INTERVIEWER CHECK ONE OF THE FOLLOWING)

a. The technology was purchased or paid for from a domestic supplier
b. The technology was purchased or paid for from a foreign supplier or a foreign owned supplier located in this country
c. The technology was developed and implemented in-house by this firm
d. The technology was developed and implemented in collaboration with a domestic firm
e. The technology was developed and implemented in collaboration with a foreign firm or a foreign owned firm located in this country

66. For which of the following reasons does this firm not use fintech:
(INTERVIEWER: CHECK ALL THAT APPLY)

a. Lack of capital or funds for investment
b. Lack of knowledge/awareness of the technology
c. Lack of skills for using the technology
d. Lack of competition in the market
e. Inadequate power or ICT infrastructure
f. Too restrictive regulations
g. The technology is not adapted to my business activity
h. Other