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A measurement framework and proposed questionnaire

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Note

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This series of publications seeks to contribute to exploring current issues in science, technology, and innovation, with particular emphasis on their impact on developing countries.

The term "country" as used in this study also refers, as appropriate, to territories or areas. In addition, the designations of country groups are intended solely for statistical or analytical convenience and do not necessarily express a judgment about the stage of development reached by a particular country or area.

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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 production and consumption patterns (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. However, taking advantage of this opportunity will require 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.[1] 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.[2] 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.[3]

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 the E-Commerce in Enterprises and the Statistics Canada (StatCan) survey of Digital Technologies and Internet Use.[4] 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.[5]

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.