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Technology assessment in developing countries

A proposed methodology

Science
Technology
Innovation

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Notes

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Abbreviations

AI	Artificial intelligence
AvH	Alexander von Humboldt Stiftung
BIBB	Bundesinstitut für Berufsbildung
BMZ	German Federal Ministry for Economic Cooperation and Development
CGIAR	Consultative Group for International Agricultural Research
CIM	Centrum für Internationale Migration und Entwicklung
DAAD	Deutscher Akademischer Austauschdienst
ESIA	Economic and social impact assessment
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GMOs	Genetically modified organisms
IEEE	Institute of Electrical and Electronic Engineers
HST	Hypersonic spaceflight technology
LMOs	Living modified organisms
MoEF&CC	Ministry of Environment, Forestry and Climate Change
NGOs	Non-governmental organizations
NIS	National innovation system
TA	Technology assessment
TAB	Technology Assessment Bureau
SDG	Sustainable Development Goal
STI	Science, technology and innovation
PUB	Public understanding of biotechnology
UNCTAD	United Nations Conference on Trade and Development

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1. Introduction

Technology assessment (TA) is a well-established interdisciplinary methodology for assessing opportunities and risks of new technologies, mainly in developed countries. In many countries, its emergence was embedded in a somewhat sceptical or concerned attitude towards technologies, with possibly far-reaching impacts, such as the use of nuclear energy to generate electricity. However, new technologies also have huge potential to help reconcile economic, social and environmental development goals. Technological innovations can contribute to many of the United Nations Sustainable Development Goals (SDGs). One example is mini-grids fed by renewable energies; these can help provide quality electricity to the rural population in parts of Africa, contributing to SDG 7 (Affordable and clean energy) and also to SDG 13 (Climate action). Another example is precision agriculture, enabled by uncrewed aerial vehicles (drones) and artificial intelligence (AI), which can help stabilize yields of food crops in the context of climate change while reducing the environmental impacts of intensive farming. This contributes to SDG 2 (Zero hunger), SDG 6 (Clean water and sanitation) and SDG 15 (Life on land).

In many cases, innovation outcomes may have both positive and negative consequences. For example, AI in agriculture can enable the precise application of fertilizers and other chemical inputs. However, it can also lead to a loss of jobs due to advancements in agricultural robotics (as discussed in box 2). In some cases, the picture remains opaque regarding how exactly a technology will develop and the economic, social and environmental impacts its implementation may have in each country. One example is Cas,[1] a new technology for genome editing in agriculture and medicine with potentially positive effects on food security, but which raises a number of questions on risks and ethical issues (Stamm, 2021). One prominent and current case is "green hydrogen", which many see as a fundamental element of a global strategy for climate protection and socioeconomic development. However, it is unclear where and under what conditions green hydrogen will be produced and whether developing countries (often well-endowed with renewable energy sources) can benefit from it.

In all these cases, TA is a crucial tool that helps assess the pros and cons of a given technological development; informs policymakers; induces public dialogues and debates; and helps frame supportive policies and instruments. Developing countries need to know in advance about the features of new technologies and their possible impacts. However, in a globalized economy, the decision of whether a new technology should be employed widely is not purely in the hands of national actors. For instance, if a multinational company decides to automate harvesting activities in a host country, national regulation can usually do little to prevent this. However, by being informed as early as possible, governments and other actors can take appropriate measures to minimize risks and maximize benefits. In many cases, these accompanying measures will not have an immediate effect and may need years before they bear fruit. One example is the building up of human resources (e.g. vocational training, higher education) required to deal appropriately with a new technology.

It should be noted that TA, as described in this document, can be used to assess a selected technology very early in the innovation cycle when it is not yet fully adopted in a country. On the other hand, a standard impact assessment methodology is more suitable once a concrete implementation has already taken place in a given socio-environmental context. In either case, attention needs to be paid to mobilizing the local, indigenous and often tacit knowledge of the population groups that might benefit from a technology or suffer from its direct or indirect consequences (see section 7).

[1] Clustered regularly interspaced short palindromic repeats (CRISPR) associated protein (Cas).

This document summarizes the existing knowledge about TA processes and good practices and reflects on these in the context of the current conditions in African and other developing countries. The following observations are considered crucial to delimit the subject area:

- First, there is great diversity among developing countries' exposure to new technologies. This occurs mainly through acquiring technological goods and services (e.g. mobile phones, machinery and equipment, e-commerce), foreign direct investment, or integration in global value chains. In addition, international agreements – for instance, related to climate change mitigation and adaptation – also demand the implementation of new technologies (e.g. solar photovoltaics, wind turbines, and in the future, probably green hydrogen). This is true for most low- and lower-middle-income countries. In most cases, building up technological knowledge and capabilities is limited to a degree necessary for mastering the operation and maintenance of equipment and systems ("know-how") but does not help better understand the technologies and the science behind them ("know why"). In many upper-middle-income countries, the national innovation systems (NISs) host a relatively large number of scientific and technical experts who are able to assess the opportunities and risks that new technologies and innovations create. However, the NISs are not sufficiently advanced to offer such expertise in many developing countries.
- Second, in many high-income countries, deliberations about new technologies and (disruptive) innovations and their potential impacts on society are driven by the research and expert communities, other stakeholders (e.g. business organizations, trade unions, non-governmental organizations (NGOs)) and even the informed public (e.g. newspapers, journals, other media). In many developed countries, discussing the pros and cons of technologies is an essential part of the academic curricula at most vocational schools and universities. In most high-income countries, social conflicts relating to the assessment processes are possible. However, they are embedded in democratic traditions and participatory processes that allow all stakeholders to express their views and opinions without risk of repression or negative consequences. In parts of the developing world, this is not the case, whereby opposing the interests of dominant interest groups may be encountered with sanctions and even violence.

This paper proposes a step-by-step approach to TA. There is little experience with TA implementation in the context of sub-Saharan Africa and in developing countries in general. Therefore, the document is supported largely with analogies and experiences from other regions, especially Europe and North America. The approach will be tested, verified and possibly modified within the United Nations Conference on Trade and Development (UNCTAD)–United Nations Commission on Science and Technology for Development project. This TA project aims to assist countries in sub-Saharan Africa and other developing countries to achieve three objectives: (1) to focus on the issue of recent and emerging technologies that could be crucial for them; (2) to encourage discussion of economic, social and environmental impacts of the selected technologies; (3) to support the national public-sector efforts to access and master some priority technologies for the country. The paper is, therefore, to be understood as a living document. Researchers and practitioners in TA and closely related science, technology and innovation (STI) disciplines, especially from African and other developing countries, are welcome to contribute to future developments of the document by providing comments and documenting experiences. Even if there are overlaps between TA and some other concepts, TA should not be equated with "other methodological approaches or tools of technology management such as technology forecasting, technology foresight, technology needs assessment, and technology roadmaps" (UNCTAD, 2021 p.6ff):

- TA can be seen as "a form of policy research that examines short- and long-term consequences (e.g. societal, economic, ethical, legal) of the application of technology" (Banta, 2009 p.7).

Impacts of TA are expected to be threefold (Hahn and Ladikas, 2019 p.6): raising knowledge, forming opinion among policymakers, and initializing actions by them.

- **Technology forecasting** is often used to predict the future characteristics of useful technological machines, procedures or techniques. Thus, it applies to all purposeful and systematic attempts to anticipate and understand technological change's potential direction, rate, characteristics, and effects, especially invention, innovation, adoption and use (Firat et al., 2008). However, its aim is mainly to inform decision makers at the level of companies and other organizations, thus not concentrating on the broader societal effects of technological advancements and innovation. It is based mainly on quantitative techniques for prediction of the future.
- **Technology foresight** combines creative thinking, expert views and alternative scenarios to contribute to strategic planning. It represents a systematic exercise looking into the longer-term future of STI to make better-informed policy decisions (Pietrobelli and Puppato, 2016). Foresight is broader in focus than TA and applies foresight tools to STI policy (including research, technology and innovation) or other policy areas. Foresight is a long-term strategic planning tool that aims to inform and steer policy in directions that help move towards desirable future outcomes rather than purely an assessment tool.
- **Technology needs assessment** methodology has been developed since 2001 to identify, evaluate and prioritize technological means for achieving sustainable development in developing countries, increasing resilience to climate change, and avoiding dangerous anthropogenic climate change. Technology needs assessments are a set of country-driven activities that identify the technology priorities of partner countries and work towards producing a pipeline of investment projects (Haselip et al., 2019).
- **Technology roadmaps** combine foresight, horizon-scanning techniques and long-term strategic planning to develop future product development plans that include specific technological solutions. They traditionally represent a structured business planning approach to STI developments, originally used by industry and geared towards developing specific products (Phaal et al., 2004). Roadmaps have been adopted for use more widely, including by governments. The term “roadmap”, rather than “technology roadmap”, is also used and incorporates a broader focus that can include STI policy in a general sense. In addition, roadmaps can cover other areas, such as health, energy, agriculture, or the environment. Roadmaps generally set out an implementation plan to reach specified future objectives that have been selected for a product, for STI policy[2] or a specific sector or industry.
- **Responsible research and innovation** is an approach that anticipates and assesses potential implications and societal expectations concerning research and innovation, intending to foster inclusive and sustainable research and innovation design. In practice, the responsible research and innovation approach is implemented as a package that includes multi-actor and public engagement in research and innovation, enabling easier access to scientific results, the take-up of the gender perspective and ethics in the research and innovation content and process, and formal and informal science education (European Union, 2014). The approach builds its