Market failure

In the first half of the twentieth century STI became an area of explicit and active policymaking. A strong concern about *market failures* – that the unhindered interactions of firms and consumers in markets would under-produce and under-consume technology relative to some projected social optimum – provided the justification for financing research and development (R&D) as government policy. STI policy tended to focus on investment in R&D and on efforts to achieve an efficient transformation of subsidized R&D into commercial products and services.

At the time, three sources of *market failures* were recognized: externalities, uncertainty and indivisibilities.

Externalities. The main reason for the existence of externalities in STI is the difficulty to exclusively own the outcome of one's research investment. Knowledge developed through R&D in one firm will spread to others in informal communication as employees change jobs, during communication with and among entrepreneurs and investors, at conferences, and through publications in media or academic journals. Because competitors can benefit from such spillovers without paying, firms will hesitate to invest in R&D and technological progress will therefore be restrained.

Uncertainty. Uncertainty, which is a natural part of any innovation process, results in a market failure because it produces information asymmetries. Uneven information will result in difficulties in developing a common view between firms and financiers about the risks and returns of an innovative business proposition. This may result in under-investment in R&D as firms fail to access and secure external financing. Understanding uncertainty in innovation is important for good policymaking and will be discussed in the section 1.3.

Indivisibility. As for the problem of indivisibility, economies of scale are often needed to justify investment in R&D. However, there may be questions as to the required scale of production for commercializing an innovation and whether individual firms have the appropriate financial capacity. This acts as a disincentive mainly when there are doubts that production and sales volumes are insufficient to justify the R&D expenses, or when firms and financiers may be too small or unwilling to support innovation with investment in sufficiently large production facilities.

Systemic failure

During the late '90s, and with the development of innovation systems theory, *systemic failures* were recognized as a major impediment to innovation, in addition to *market failures*. There are several possible systemic failures that can be discussed when reviews or revisions of STI policy are conducted. Some examples are listed below. (Woolthuis et al., 2005)

- Infrastructural failures. IT, telecommunications, ports, roads, energy infrastructures, etc. fail to enable or support STI-led social and economic development.
- Transition failures, capabilities failures, lock-in and path dependency failures. Firms and organizations fail to adapt to new technological developments. Firms, especially SMEs, may lack capacity to learn and innovate. Society, as a whole, is unable to adapt to new technological paradigms.
- Hard institutional failure. Regulations and the legal system fail to support STI, in particular regarding new and frontier technologies.
- Soft institutional failure. Social institutions, such as entrepreneurial culture and social attitudes towards failure and risk-taking, impede innovation.
- Network failures. A lack of linkages between STI stakeholders results in missed innovation prospects and unexploited learning opportunities.

Transformative failure

Transformative failure (Lindner, Ralf et al., 2016) denotes the inability of a country to succeed on specific goal-oriented challenges that require fundamental changes to how goods and services are produced and consumed and require a specific innovation effort. Many societal challenges come to mind, including the SDGs. Stakeholders in a certain challenge, say energy production and consumption and the need to decarbonize the sector, will come from private firms, public organisations, and citizens and citizen associations. The technological and innovative capacities may be uneven and the incentives for collaborative action may be weak or even contradictory.

Transformative failure can be divided into two types of failure: directionality failure and reflexivity failure. Regarding directionality failure, it would describe an economy that has notable innovation capacity and outcomes but is missing direction of transformative change, in terms of overwhelming societal needs and goals. It is a result of an inability to develop a shared national – or even global – vision and coordinating mechanism regarding socio-economic challenges at hand. Reflexivity failure refers to a lack of continuous monitoring on the progress of transformational change. Reflexivity failure may be thought of as a poorly performing macro monitoring and evaluation system which fails to provide inputs for adjusting policy and, consequently, fails to reduce the uncertainty of innovation and transformative change.