

Executive summary

Germany's science, technology and innovation system must rise to the challenges posed by global shocks and the digital and green transitions

The socio-economic consequences of the COVID-19 pandemic and the impact of Russia's war in Ukraine have revealed vulnerabilities in Germany's export-orientated economic model: an over-reliance on energy from Russia, a continued dependence upon fossil fuels, delayed digitalisation, as well as concentrated supply chains for German industry which are liable to disruption. The result is an increasing awareness in policy and in business that science, technology and innovation (STI) needs to adapt how they innovate and recalibrate the goals of innovation and innovation policy. However, there is a risk that, in attending to the series of crises that has buffeted Germany, insufficient action is taken to address these longer-term issues. Addressing these longer-term issues is essential, as innovation is the cornerstone of the country's socio-economic wellbeing, underpinning employment, investment, and job creation.

The German economy does not operate in a stable, predictable environment, and, just as in many countries around the world, the processes of digitalisation and the green transition are upturning many assumptions about the long-term viability of the German socio-economic model. Digital technologies are changing innovation in terms of what it can produce, how innovation occurs, and providing opportunities for entirely new business models across all sectors of the economy. The emergence of firms such as Tesla in the premium segment of the global automotive industry, long an area dominated by German firms, has demonstrated the disruptive impact of both new business models and digital technologies in areas of strategic importance to Germany. Almost a million people are directly employed in the German automotive industry, with many more employed in the thousands of SMEs that comprise the industry's supply chains – significant disruption to Germany's leadership in these areas would have profound implications for competitiveness as well as socio-economic wellbeing.

The processes of the digital and green transitions, and the structural changes they are engendering in the global economy, are challenging a number of the fundamental pillars upon which German economic competitiveness rests. While German firms and research organisations, and the human capital that powers them, are well-placed to meet these challenges and lead the global response to climate change, doing so will require a new approach to STI policy to raise the resilience of German STI in a context of repeated shocks and better prepare for future transitions.

German policymakers should not lose sight of the importance of how structural economic changes are affecting the pillars of the German economy, and the important role that STI must play in ensuring the future socio-economic wellbeing. Uncertainty will be a recurring theme in STI policymaking in the years ahead, and preserving German STI leadership will invariably involve risk and stepping into unknown areas of science and technology. If Germany is to lead in its core industries – automotive, machinery and chemicals, pharmaceuticals – as well as in new sectors in the future, then the government must adopt a more risk-tolerant and creative approach to STI policy.

The green and digital transitions are actively reshaping Germany's innovative industries

Manufacturing is the locum of the country's innovation system. The dynamics that support innovation are often a virtuous cycle, with success breeding success. Innovation in the German business sector is no different. Investment in education, skills, technology and intangible capital have helped underpin continuous innovative success in a wide range of industries, notably the automotive and machinery industries. This innovation has enabled decades of international competitiveness, which in turn has locked the economy into a self-reinforcing relationship between trade and domestic socio-economic wellbeing. The importance of industry for investment, jobs and innovation has invariably shaped German STI policy, orientating programmes and instruments towards firms that are active in these areas. Yet, while success has historically begot success, past performance is no guarantor of future competitiveness, particularly in a context where Germany's innovative industries are undergoing a process of radical change.

Whilst the benefits that Germany's economic model have been clear, it is less clear whether the predominance of extant industries in German STI has come at the expense of capabilities elsewhere, notably in digital technologies, advanced ICTs, and enabling technologies for the green transition. There is a clear lag in firm-level digitalisation in Germany relative to other advanced economies, in part due to a slow roll-out of high-quality broadband infrastructure, relatively low levels of public investment, and difficulties at the firm-level in investing in the intangible capital – firm know-how, software, intellectual property, data and management capacities – necessary to harness the innovative potential of the digital transformation. The result is that the German economy, perhaps one of the greatest sources of industrial data in the world, is under-utilising a key input for innovation. In addition to the challenge of redirecting existing competencies away from mechanical engineering towards digital areas, there is also the difficulty of fostering new types of business models that are based on digital technologies.

Lagging German digitalisation and the development of competencies in key enabling technologies takes place in a context where Germany's most innovative industries and the markets they serve are being reshaped. This creates challenges for how Germany innovates, as much as it does for what it innovates, and to what end. The growing importance of technologies such as quantum computing and artificial intelligence, as well as the microelectronics that power such technologies, requires capabilities that differ from those – such as mechanical engineering – where Germany has historically excelled.

In line with Paris Agreement on achieving global carbon neutrality in the second half of the 21st century, Germany is working towards securing greenhouse gas (GHG) neutrality by 2050. Achieving this goal will require radically reducing the GHG footprint of major emitters, such as industry and transport, by moving to more sustainable modes of production; increasing the use of renewable energy for electricity generation; and in some instances – such as with individual mobility – changing the behaviour of society and consumers. Not only do these transformational processes place new demands on how industry and society work, but they also fundamentally change the markets upon which some of Germany's most innovative industries rely.

In addition, the increasing importance of digital technologies and technologies that contribute to greener and less carbon-intensive production and products has implications for a number of Germany's highly internationalised industries. Manufacturing, for example, relies critically on intermediary inputs such as semi-conductors and other microelectronics to meet changing consumer expectations, but at present rely upon a small number of foreign suppliers for these items. Not only does this pose challenges for resilience, as shown during the COVID-19 pandemic, but it raises the question of whether this reliance comes at the expensive of acquiring capacities for innovation in core areas of future value-added for manufacturing.

There is a significant role for public policy to play in guiding this transition, mitigating short- and medium-term adjustment costs, and promoting the breakthrough innovations of markets of the future. There is also a need for policy to address the barriers that have to date led to a relative underdevelopment of German innovative competencies in areas of importance for the digital and green transitions, including issues around financing, risk-taking in public policy, inclusion and diversity in innovation, and the

commercialisation of high-impact research to the market. Programmes such as SPRIN-D and the BMWK's From the Idea to the Market initiative are important steps in this direction, but more needs to be done.

There are three major areas where Germany must act to ensure future success

Responding to the challenges that face STI policymakers in Germany requires action in two interlinking areas – the *how* and the *what* of the future of German innovation policy (Figure B).

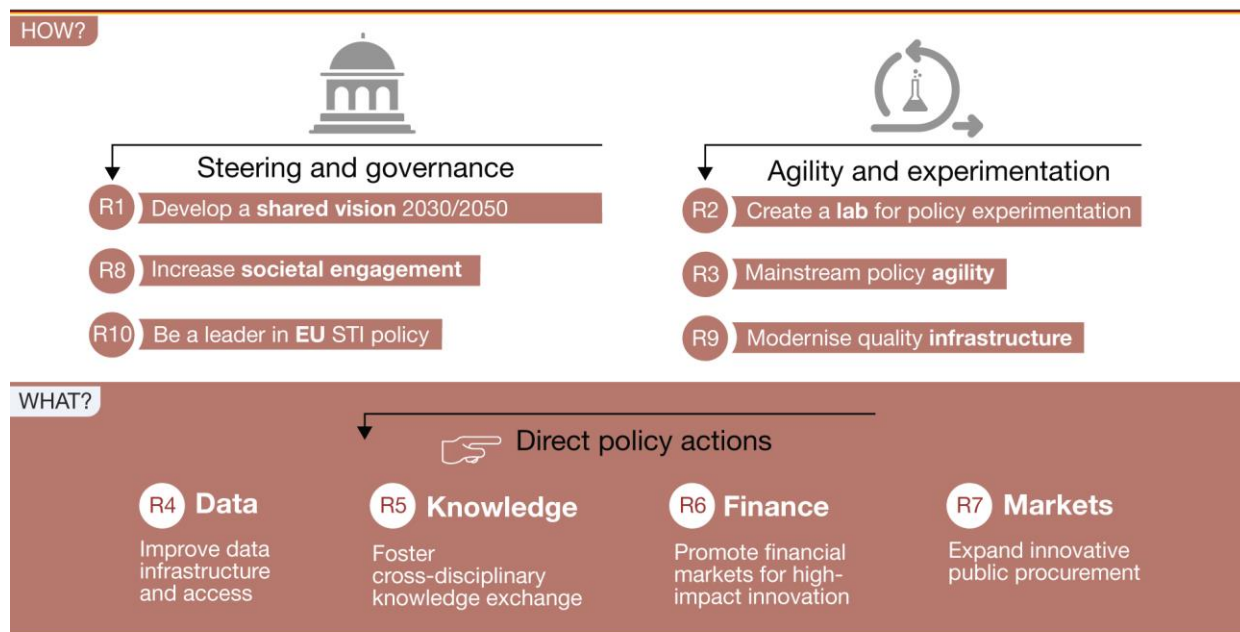
A new approach to STI policy in Germany

- **Steering and governing the German STI system:** Government should establish a clear vision for what success in the digital and green transitions looks like and how the STI system should contribute to this success. A core focus of governance should be to ensure inclusivity with a focus on engaging previously underrepresented groups in STI – for example, women and migrants – and on those who will be affected by the changes ahead. The nature of many core issues requires Germany takes a leading role internationally – at the EU level and beyond – in the governance and development of key technologies for the green transition.
- **Policy agility and experimentation to support private sector innovation:** Success in the transitional context will take place at the frontier of current knowledge and technological capabilities. Going beyond this frontier, and consolidating Germany's global innovative leadership, requires a new level of agility and experimentation, and a willingness from policymakers to creatively provide regulatory certainty to the country's innovators. The policy laboratory proposed by the review could be a key platform for driving policy experimentation and scaling the most promising of approaches.

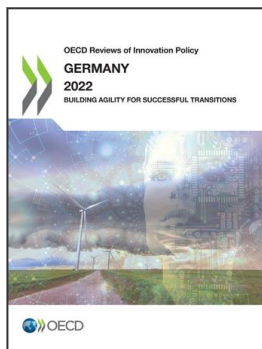
Key policy actions for supporting innovation in the digital and green transitions

- **Policy levers that can support market creation and breakthrough innovation:** A more risk-tolerant approach from government to supporting breakthrough innovation could accelerate the commercialisation of impactful innovations and support the creation of the markets of tomorrow. Policy also has a role to play in ensuring firms have the data they need to innovate, the necessary skills to use new inputs such as data, the infrastructure necessary for doing so, and that impactful ideas and research can be transferred across sectoral and disciplinary boundaries.

Figure B. Overview of Recommendations



It is normal that in times of crisis, where governments have had to undertake large and unexpected expenditures, that public budgets can come under pressure, with legitimate social concerns taking priority over other support for STI. Importantly, this Review places emphasis on focussing on new processes and approaches that do not claim additional financial resources – the *how* of STI policy – in areas such as experimental and flexible regulation and using public procurement more for innovation. The recommendations are actionable and impactful regardless of uncertainties in the coming years over public budgets.



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