12 From incrementalism to breakthrough: New challenges and approaches to innovation

This chapter considers the potential role of breakthrough innovation in the German economy. It discusses the essential factors that will support its propensity for engaging – and succeeding – in breakthrough innovation in the context of the green and digital transitions.

Introduction

In 2019, the Federal Government of Germany created the Federal Agency for Disruptive Innovation (Agentur für Sprunginnovationen [SPRIND]) to better support breakthrough innovation. SPRIND adopts a different approach to policy support for such innovations – one that is more conducive to risk-taking, and acknowledges that their success and significance exceeds the traditional competitiveness rationale for science, technology and innovation (STI) policy interventions. Breakthrough innovation involves the creation of new markets, as well as market disruption and displacement, with profound societal implications. Such innovation has always happened, as illustrated by electricity or (more recently) the internet. However, it has often emerged organically (even randomly), rather than being deliberately cultivated.

The digital and green transitions have heightened the need for more of these innovations. For the world to meet the net-zero ambitions set in the Paris Agreement, technological solutions will need to be developed rapidly to drastically decarbonise the global economy. Many of these solutions will require innovative breakthroughs (i.e. entirely new technologies, the application of existing technologies to new areas, and the systematised use of certain technologies and processes in businesses' and citizens' lives and work) in the short- and medium-term future. Not achieving these breakthroughs could mean irreversible damage wrought by climate change, with profound implications for socio-economic well-being and stability.

The rise of the digital economy, and the ever-increasing use of data as an input in research and innovation, have created new opportunities for breakthrough innovation. Indeed, many breakthroughs stem from combinations of knowledge and data that are only possible thanks to advances in digital technologies and information and communication technology (ICT). The importance of breakthrough innovation has grown owing to the sustainability transition, along with the capacity of the STI system to act.

Policy intervention to support breakthrough innovation largely involves correcting market failures that may stop breakthroughs from occurring more frequently. For example, opportunities for investment may be lower because breakthrough innovation involves a higher degree of risk. If the cost of inaction is not factored into market and business operations, then technologically viable solutions for decarbonisation may not be generalised enough to be effective. If breakthroughs require new combinations of knowledge and experience, then the existing innovation orientation of the research base and private sector may not make these new connections, or make them quickly enough.

This chapter introduces some of the ways in which policy support for breakthrough innovation differs from traditional STI policy. It considers how policy interventions can overcome some challenges to accelerate the development and diffusion of new breakthroughs, drawing on a policy paper prepared for this review (Paunov, Einhoff and Mackle, Forthcoming[1]). The chapter discusses the justification for a policy focus on breakthrough innovation and provides some related evidence. It continues with a more detailed look at how support for breakthrough innovation differs from traditional STI support, and concludes with a series of open questions for policy makers in Germany.

12.1. Business as usual? The case for a new approach to innovation

Addressing some of the complex socio-economic and environmental challenges facing Germany requires combining previously disparate areas of science and industry – for example, data and energy technologies, or artificial intelligence and pharmaceutical research. This type of innovation is often referred to as "breakthrough" or "radical". In many cases, such innovation is considered "disruptive", insofar as it challenges the status quo of established sectors, from retail to network sectors (such as communications). A key departure from traditional modes of innovation (particularly in the manufacturing sector) is the growing importance of data, which have become a key input for innovation in general, and radical and

breakthrough innovation in particular. Recommendation 4 (Chapter 10) on access to data and data infrastructure is partly a response to this new reality.

12.1.1. The significance of breakthrough innovation in Germany's transitional context

The complexities facing large and industrialised economies, such as Germany's, in the context of the twin transitions of digitalisation and environmental sustainability are unprecedented. No major industrialised economy has ever had the very basis of its competitiveness and resilience so systematically challenged by changing social, environmental and regulatory pressures. Moreover, these pressures are profoundly complicated by the deep interconnections between the German economy and international markets.

If the German economy has historically been very innovative, then it might follow that it will continue to be so, regardless of what *type* of innovation is necessary for success. The reasons for which this may not be so straightforward, and historical success does not always guarantee future success, can be found at the firm level. Kodak, a global leader in photography whose entire business model was rendered obsolete by the technological leap to digital cameras, may be the most famous example. Other examples include Nokia, a world leader in mobile phones displaced by new entrants as smartphones took hold, and Blockbuster, the globally famous video rental service whose model was disrupted by the rise of online streaming.

These stories share a number of commonalities that are relevant to STI policy in Germany, even if it is necessary to take a theoretical leap to appreciate them. First, these firms were innovative leaders and at the cutting edge of their industries. In the case of Kodak, the firm was so innovative that it actually invented the world's first digital camera in 1975, but did not have the foresight to see how this could upend its business model. The second commonality is the importance of breakthrough innovation, and how easy it can be for large, innovative firms to slip into obsolescence when certain breakthroughs are made and begin to disseminate through an economy.

What does this mean for Germany? Many German firms are highly innovative, world leaders in R&D, and act as large employers. And yet, they have business models which could be fundamentally challenged by the digital and green transitions. The digital transition may engender a growing preference for connected and shared mobility, or for vehicles and machinery with embedded digital services. The sustainability transition will likely lead to a preference for electric vehicles, while decarbonisation may hamper the competitiveness of German industrial firms to the benefit of firms those located in countries with lower wage pressures.

The German economic model – and the innovative firms that power it – will likely not face obsolescence, but policy makers should nevertheless consider whether the current direction of STI policy will lead to the private sector's deep well of knowledge and innovative competencies being utilised in a way that secures the economy's future resilience, sustainability and competitiveness. For example, that the American car manufacturer Tesla, which focusses on electric vehicles and has particular competencies in battery technologies, had a market capitalisation of USD 1,074 billion in April 2022, a valuation USD 200 billion greater than the ten next firms *combined*. Yet, this valuation is in spite of the fact that Tesla was not even in the top ten automotive firms by annual earnings in 2021, and had a price-to-earnings ratio in April 2022 of 343, compared, for example, to Volkswagen, which had 2021 revenues of USD 241 billion and a price-to-earnings ratio of 4.49.

The gulf between the present valuation of Tesla compared to other automotive firms stems from the perceived likelihood that the American firm will deliver some of the breakthrough innovations that will underpin the automotive industry's future competitiveness in a net-zero future. The high valuation also shows that investors are looking forward to the creation of new markets, even if that involves some speculation. German automakers may well master the technologies needed to become global leaders in electric vehicle manufacturing, but Tesla's competencies in fields such as battery technology likely factor into investor sentiment.

12.1.2. Supporting breakthrough innovation in Germany: SPRIND

Created by the German government in 2019, SPRIND aims to identify and develop research ideas with the potential to produce radical or breakthrough innovation, as well as accelerate the commercialisation and diffusion of highly innovative ideas. The agency falls under the aegis of both the Ministry of Education and Research (BMBF) and the Ministry for Economic Affairs and Climate Action (BMWK). Its governing board comprises ten members from industry, academia and politics, as well as one representative each from the Ministry of Finance, BMBF and BMWK. Like the Defense Advanced Research Projects Agency in the United States (DARPA), SPRIND plans innovation challenges or competitions around specific themes. Such innovation incentives and initiatives became popular during the COVID-19 pandemic, but are already well-established in information technology sectors (such as coding).

The projects supported by SPRIND reflect the institution's technologically open nature, touching on areas ranging from a potential cure for Alzheimer's disease to water purification. As of June 2022, SPRIND had led three projects to completion and was supporting eight ongoing projects. The first three projects had a strong ICT focus, while the ongoing projects were more varied. The agency also runs two innovation challenges, focusing on decarbonisation and approaches to combatting viral infections. SPRIND selects a relatively small number of projects from a large pool of applicants: in 2021, the agency only selected 4 projects from among 440 proposals, with an initial funding of EUR 2-4 million (euros).

While they are not exact analogues, both SPRIND and DARPA have a similar purpose and model – lean, risk-tolerant institutions that aim to accelerate the development of breakthrough innovations. SPRIND remains at an early stage of development and has been allocated a EUR 1 billion budget for the initial ten-year period. The scale of the funding influences the number of projects the agency can support, both in terms of direct financing and institutional capacity. DARPA, which has operated for over 50 years, has a 2023 budget of EUR 3.9 billion (DARPA, 2022[2]). It numbers more than 200 government employees, including 100 project managers allocated across 6 technical programme offices (Congressional Research Service, 2021[3]).

The ability of SPRIND to support breakthroughs may be constrained by national and EU-level regulation, a point argued by the president of the National Academy of Sciences of Germany, Gerald Haug (Handelsblatt, 2021[4]). The director of SPRIND, Rafael Laguna, also voiced his concerns over regulatory constraints on the institution's ability to support breakthrough and disruptive innovation in a 2021 interview (Handelsblatt, 2021[5]). These constraints – particularly those relating to state aid and public procurement – have led to calls from within the institution for a "SPRIND law" that would lighten the regulatory burden on the agency and allow it to be more agile – and impactful – in its project selection and support. From a governance perspective, ministerial presence on SPRIND's supervisory board may also limit the agency's ability to act autonomously.

While it is too early to judge its successes, the establishment of SPRIND illustrates the kind of institutional development that will likely support the innovation activities sought by political and industrial leaders. However, the agency's current size and budget may not be large enough to support breakthrough and disruptive innovation at a systemic level. Complementary measures are also necessary, such as targeting rules and evaluation criteria for existing innovation programmes to support disruptive solutions and risk (including in public procurement); setting anticipatory regulation featuring the right standards and mechanisms; and promoting serious opportunities for scaling successful solutions.

12.2. Breakthrough innovation and its policy implications for Germany

The introduction to this chapter asked whether the German business sector can adapt and thrive in the context of the sustainability and digital transitions, or whether (at least in some of its largest and most innovative industries) there exists a risk of obsolescence in certain technological and innovative capacities.

Germany's strong STI system, which features diverse competencies and innovative know-how across a range of sectors and firm sizes – including the *Mittelstand* – should augur well for the sustainability transformation.

Compared to incremental innovation, breakthrough innovation is associated with the launch of new markets and the novel application of or new technologies (Ahuja, Yang and Shankar, 2009[6]).[1] Radical inventions combine previously unconnected knowledge domains, an uncertain and risky process (Castaldi, Frenken and Los, 2014[7]; Fleming, 2001[8]).

From a policy perspective, what can the government do to support breakthrough innovation, and how does such support differ from the already well-established policy programmes for STI that have consistently and effectively supported the private sector? While overlaps exist – firms and entrepreneurs still require investment, access to finance, support for R&D, access to skilled staff, etc. – the policy implications for breakthrough innovation as opposed to "incremental" innovation differ in important ways. These different needs reflect the logical conclusion of a breakthrough innovation – new markets and products, and disruption and displacement, often with socially important implications.

As discussed above, the establishment of SPRIND is a reflection of the need for a new approach to STI policy making that explicitly supports breakthroughs, with a number of policy implications (Table 12.1). For example, SPRIND can provide finance to riskier innovation endeavours. It can provide the research and physical infrastructure necessary to innovate. It can mitigate regulatory, legal and co-ordination challenges, in theory linking with other government policy areas (such as public procurement) to support publicly driven market creation. In fact, linking innovation support to pre-commercial procurement for specific challenges (such as energy) is a clear demonstration of how institutions such as SPRIND can help implement a more directional and explicit approach to STI policy and support for breakthrough innovation.

Table 12.1 Breakthrough innovation and policy implications

Type of challenge	Policy implications
Cost	1. Provide funding to produce and scale (increase the number of new business ideas), with less private funding potentially available for incremental innovations
Combination	2. Support collaborative projects across industries and policies to support industry-science-civil society collaborations even more than for incremental innovations 3. Support cross-disciplinary and cross-sectoral collaborations and innovation platforms
Market creation	4. Use public procurement to incentivise products with the potential to create new markets and be a frontrunner, which is not needed for established products 5. Expand civil society engagement in policy design and innovation processes, which is an advantage but not as essential for incremental innovations 6. Promote industry-government collaboration in shaping demand for more environmentally friendly products/transitions (e.g. mobility in cities)
Risks	7. Expand venture capital-type funding and support for riskier projects 8. Support firms with expertise in dealing with risks 9. Invest in research relevant to questions around key enabling technologies 10. Anticipate future tech forums, etc. 11. Provide incentives for public officials, firms (including start-ups and small and medium-sized enterprises [SMEs]) and science to take on riskier important research (including through prizes)
Infrastructure	12. Improve digital and other infrastructures necessary for disruptive innovation, especially where this may diverge from traditional innovation needs 13. Support dialogue between various areas of government and industrial and other stakeholders on infrastructure use
Regulatory and legal constraints	14. Expand regulatory sandboxes 15. Support regulatory and policy agility
Co-ordination failure	16. Devise strategies/visions for countries, industries and regions 17. Support cross-governmental collaboration around key challenges 18. Support ecosystem thinking involving adjustments across the entire value chain
Inclusivity	19. Design STI, education and social policies (including migration approaches) to respond explicitly to existing

	challenges
Skills and capabilities	20. Provide on-the-job training and skill training 21. Provide knowledge services and support for collaborations 22. Expand skilled migration policies

Source: Paunov, Einhoff and Mackle (Forthcoming[1])

The remainder of this section expands on some of these policy challenges and how they relate to Germany.

12.2.1. Co-ordination challenges in transition contexts

Whenever a country's industrial focus shifts, a number of complex co-ordination challenges arise. In the context of the sustainability transition, these challenges manifest themselves in an array of social and economic areas. While there may be benefits for all stakeholders to shift to an entirely new product/process or market, no stakeholder can do so alone, as this would be too expensive and inputs from all other stakeholders are required. For example, the shift from combustion engines to electric vehicles requires not only an adjustment of the entire supply chain to produce inputs for the new products, but also deep infrastructure changes. Electric vehicles can only be a viable alternative for German automotive manufacturers if the supportive infrastructure – i.e. charging stations and the necessary battery technology – is in place. These challenges require heightened co-ordination and joint action, as proposed in Recommendation 1 on the establishment of the forum.

12.2.2. Financing challenges

As discussed in Chapter 7, SMEs in Germany traditionally have good access to finance, which is a key strength of the STI system. Nevertheless, SMEs face difficulties in accessing finance when the investment is intended for intangible capital. Physical capital has sustained industrial investment and innovation for decades, but in a context where more widespread and quicker diffusion of digital technologies; greater use of data; and increased cross-disciplinarity, reskilling and upskilling, and experimentation are required for success, investment in intangible capital will become even more important. As long as SMEs struggle to access finance for these intangible investments (often owing to the impossibility of collateralising the asset), they may adapt more slowly to the sustainable transition and be less engaged in such innovations than their peers in other economies, compounding the issue of financing for innovation (see Recommendation 6).

Beyond investment in intangible capital, financing breakthrough innovation invariably involves higher risk – at least early on, even though the payoffs may be greater in the end. Furthermore, innovators may be start-ups or individuals with few assets they can collateralise or an underdeveloped business plan. In these important respects, financing for breakthrough innovation can differ significantly from financing "incremental" innovation, or innovation by established STI actors. Financing institutions may be ill-equipped to deal with the additional risk. They may not appreciate the implications of the innovation activity, or have misaligned incentives (expecting a return on investment that does not reflect the innovation's socially impactful nature). Public institutions that finance STI programmes may face similar problems. This implies a different approach to innovation financing if policy makers wish to see more breakthroughs (and greater systemic uptake thereof).

12.2.3. Management, skills and capabilities

One of the issues discussed in this section (and in the review more broadly) is the slow diffusion of ICT in the private sector and the impact on innovation – particularly the digital and data-driven innovation necessary for technological breakthroughs. One factor not mentioned so far is the issue of management, skills and capabilities. Recent studies have shown that one reason for the slow diffusion of technology in

German SMEs lies in their relatively weak management practices. Similarly, actors in the STI system (whether factory workers, procurement officers or academic researchers) must possess the technological and human-resource capabilities to innovate, recognise opportunities for innovation (e.g. in public procurement) and be empowered to make these decisions.

Given their critical role in boosting corporate productivity and the effective use of new technologies, upgrading management methods must be central to business-innovation strategies. Adopting advanced management practices, such as target setting, performance monitoring and providing incentives, is a key factor explaining differences in firm productivity both within firms and across countries (Bloom and Van Reenen, 2007[9]). These two interlinking questions – managing people within the STI system and the capabilities of actors within that system – apply equally to the public and private sectors.

In addition, identifying opportunities for breakthrough innovation, or seeing the potential impact of such breakthroughs, may require different management skills. A manager who appreciates the market implications of incremental improvements to a product may not appreciate the implications of a breakthrough, because it deviates from a previously planned course of action. Broadly speaking, the management capabilities for innovation in general may be misaligned with the requirements of more breakthrough innovations. In such cases, the ability to see across technological disciplines, factoring in the broader social implications of innovation activities – and feeling motivated by them – may be more important.

12.2.4. Service-sector contributions

The German economy's innovative strengths lie in the manufacturing sector. However, the digital transformation continues to generate significant opportunities for service innovations, because it is now much easier to interact with customers and assess their specific needs (e.g. for on-demand transportation services). Another consequence of the digital transformation is the servitisation of manufacturing (Guellec and Paunov, 2018[10]). Success in the sustainability transition may therefore entail increased attention to service-sector innovation and potential linkages across sectors to drive future transitions.

12.2.5. Increasing participation in policy programmes that help breakthrough innovation

A key challenge for STI policy makers is to increase the participation of SMEs in the programmes they design, and to garner policy support for breakthrough and radical innovation. The policy avenues for incremental innovation are relatively clear for many firms, particularly when they are already engaged in innovation activities. This is not necessarily true for firms engaged in breakthrough and radical innovation, which implies a departure from normal activities and the risk of taking a new direction. Support programmes for breakthrough and radical innovation face the same participation challenges as traditional policy support mechanisms, compounded by many firms' unfamiliarity with the concept, and the need to bring a greater diversity of firms and actors – often from outside the formal STI system – into the fold.

A related question is societal engagement in innovation activities with possible social implications. Transitions entail fundamental changes to markets, and consequently involve not only producers, but also customers and society at large. Engaging those stakeholders will therefore be critical in order to make the right choices and take joint actions (see Chapter 16).

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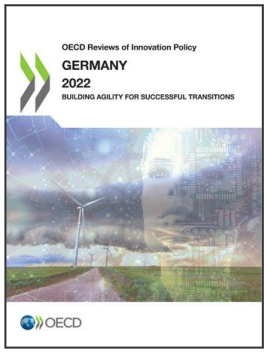
Endnote

[1] A close definition of radical innovation is disruptive innovation. In business theory, a disruptive innovation is an innovation that creates a new market and value network, eventually displacing established market-leading firms, products and alliances (Bower and Christensen, 1995[11]).



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