Innovation Policies in Germany: An Analysis of Tools and Impacts

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Abstract. This work proposes an analysis of the main financial and political instruments adopted in 2012–2019 in Germany to support the various forms of innovation (startups, clusters, technology transfer, university-industry partnerships, etc.). In this way, we will try to understand whether these examples of industrial innovation policy have managed to play a crucial role in reducing the development gaps between West Germany and East Germany, thus facilitating acceleration of convergence between these two territorial areas.

Keywords: startup · technology transfer · entrepreneurship · cluster

1 Introduction

This paper, descriptive in nature, intends to offer a review of the main policies and tools adopted by Germany to support innovation, above all the digitization of production activities, and the creation of new entrepreneurship.

To satisfy this objective the paper proposes an analysis of the reports of the German Federal Government in recent years (2012–2019) with particular reference to innovation policies.

Through this analysis we will try to provide an answer to the following questions:

- What was the role of the Central Government in the management of these policies? and what was that of the individual regional governments?
- Was there an equal distribution of these initiatives in the territories of West Germany and East Germany?
- Which sectors benefited most from these initiatives?

The main objective of these policies should have been to reduce the development discrepancy between the two areas of Germany (East and West) by making the entire territory more cohesive. This convergence process initially witnessed marked acceleration, starting from the 1990s thanks to the increasing role of the industrial sector as a driving force of economic growth. On the other hand, since the end of the 1990s, this convergence process has slowed down considerably.

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The theme of innovation and digitalization of the economy has assumed central importance in the context of the PNRR (National Recovery and Resilience Plan) presented on April 27, 2021, in Germany. The composition of the German PNRR and the percentage incidence of the different strategic areas are described in detail in the Table 1 and Figs. 1, 2. However, it is much smaller than in other EU countries (27.9 billion euros).

Over 50% of the planned resources, or 14 billion, were allocated to the challenge of digitization, while 11.3 billion to the challenge of the environmental and energy transition. The government plans to spend over 90% of NGEU (NextGenerationEU) resources on digitization and ecological policies. A part of the resources allocated for digitization will benefit schools (overall 1.3 billion) and health facilities (overall 3 billion).

A significant portion of the resources will be allocated to the strengthening of the public administration to eliminate all the bureaucratic constraints that slow it down and often prevent it from meeting the needs of citizens. In this way, all public and private investments will be made faster. To this end, 3 billion will be allocated to finance the Online Access Act project, a centralized system designed to offer administrative services quickly and make it easier for citizens and businesses to access public administration documents.

According to the economic research institute DIW, 61.7% of the resources will be used to finance public investments and incentives for private investments. The latter will cover almost half of the total resources disbursed. The remainder is made up of current expenditure (20.5%), subsidies to businesses (15.3%), and transfers to households (2.5%). The use of resources will be highest in 2021, and about half of the expenditure will be concentrated in the two years 2021–22.

Table 1. PNRR and strategic areas. Source: Bundesfinanzministerium

Elements	Billion	Quote for digital (Billion)	Quote for envinroment (Billion)
Environmental and energy transition policies	11.26		11.26
Digitization of the economy	5.90	5.90	
Instruction	1.44	1.44	
Incentives to participate in social life	1.26	0.03	
Modernization of public administration and incentives for private investments	3.52	3.81	
Health	4.56	3.47	
Total	27.95	14.65	11.26

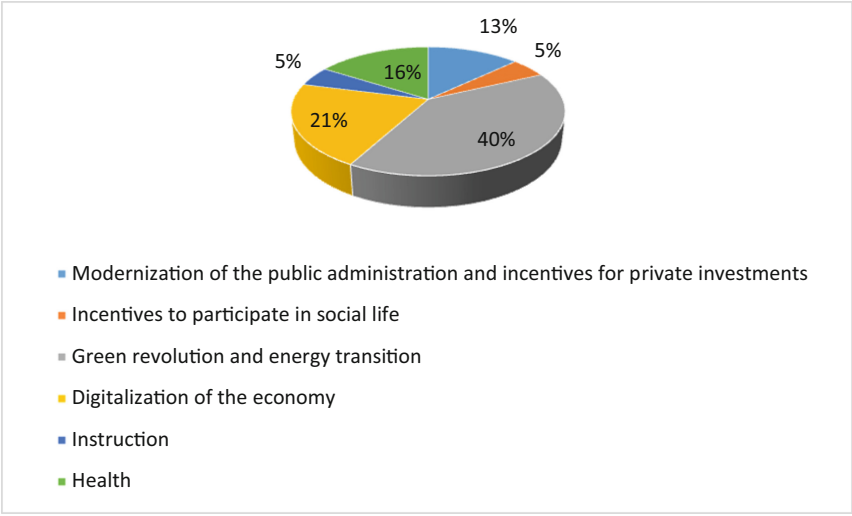

Fig. 1. Distribution of funds between EU strategic areas. Source: Authors elaboration based on PNRR data

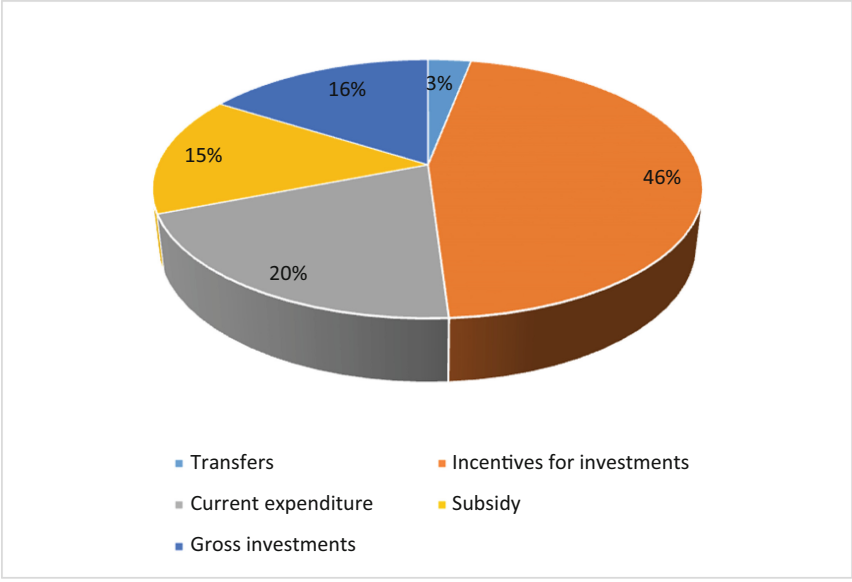

Fig. 2. Distribution of resources among expenditure components (estimated values)

In addition to previous resources, Germany has received € 12 million from the REACT-EU (Recovery Assistance for Cohesion and the Territories of Europe) program to support those most affected by the coronavirus pandemic, for example by

hiring additional teaching and assistance staff in early childhood education in financially weaker municipalities. The additional REACT-EU funds are primarily channeled through the European Regional Development Fund (ERDF) and the European Social Fund (ESF) (including the Youth Employment Initiative - YEI). Some of the new resources will also be used to top-up the European Fund for Aid to the Most Deprived.

At 31 May 2022, the headline figures on the volume of REACT-EU resources mobilized are as follows;

- EUR 42.2 billion total EU amount allocated through ERDF and ESF (with a further EUR 512 million allocated to FEAD)

This amount includes the thematic investments below:

- EUR 6.4 billion of ERDF allocated in support of the green transition, of which EUR 5.6 billion specifically target climate action;
- EUR 3 billion of ERDF allocated for digital economy;
- EUR 7.2 billion of ERDF allocated in support of enterprises and business development;
- EUR 7 billion of ERDF allocated in support of healthcare systems;
- EUR 15.3 billion of ESF allocated in support of labor market measures, social inclusion and education and training.

The new funds provided to Germany will also support the vocational training of 700 people aimed at improving skills for the digital and green transformation of the economy. They will also support the exchange between universities and SMEs to apply research results in enterprises to contribute to the digital transformation of the economy.

The issue of ecological transition has also been an essential focus in the context of the NRP in Germany. Other financial resources earmarked for this issue come from the Deutscher Aufbau- und Resilienzplan-Darp recovery plan, financed by the Recovery and Resilience Facility (RRF), also part of the EU Next Generation aid package. Green policies attracted 39% (11 billion out of a total of 28 billion) of the resources provided through the Recovery and Resilience Plan. This percentage gives Germany primacy in the promotion of green initiatives, surpassing Italy (31%) but maintaining an evident detachment from Spain (44%) and France, with over 50% of its "Plan de reliance" dedicated to green investments. By evaluating the amounts disbursed, in absolute terms, Germany is positioned in last place compared to Italy, France, and Spain. Italy is the country that has received the most significant amount of resources to be allocated to green investments, over 59 billion, against Spain (31 billion), France (21 billion), and Germany (11 billion).

Concerning energy transition, Germany is implementing a series of initiatives aimed at modernizing the industry by making it less dependent on greenhouse gas emissions and also massive interventions on the transport front, both public and private. Among the most significant investments, 3.3 billion has been set aside to decarbonize the economy, promoting the introduction of new hydrogen technologies to be implemented in production chains. Another 5.4 billion will be used for the construction of hybrid and electric means of transport, as well as the purchase of sustainable buses and trains, in line with the climate objectives of the Paris agreement. Germany, together with Spain, is the country that has invested the most in electric transport (respectively (5.4 and 13.2

billion). In addition, 2.5 billion will be invested in sustainable construction to increase the energy efficiency of new or existing buildings. Germany and Spain are focusing heavily on energy production from hydrogen (investing 3.2 and 2 billion respectively), trying to reduce as much as possible the production of electricity from nuclear power plants and to decommission coal-fired plants.

Thanks to the analysis conducted in this paper, it emerges that the economic structure of East Germany is rather fragmented, representing an essential constraint for the growth of investments in R&D by industry. The entrepreneurial fabric of Germany is made up of large companies operating mainly in the medium-high technology manufacturing sector (automotive and chemical) and some small, highly specialized companies characterized by a high degree of openness to international markets.

Creating new companies (spinoffs and startups) of both university and a non-university matrix is particularly widespread in Germany. In this regard, Daimer et al. [1] underline that, in recent years, there has been a shift from individual cooperation projects towards more strategic forms of cooperation with long-term interactions between business management and university researchers. These partnerships are prevalent in the high-tech sectors, but the humanities and social sciences sectors represent a potential future that is still not fully explored.

Germany can be considered a best practice case in the context of policies to support the creation of startups. Its startup ecosystem has therefore become a qualitatively unique model in Europe. Almost 10% of the founders of German startups and 22% of employees come from abroad. From a study conducted by I-COM [2], Germany is one of the European countries considered as having the highest market capitalization of successful innovative startups (about 7% of the 150 companies evaluated on the stock exchanges of Frankfurt and Xetra).

Furthermore, public financing in Germany is highly diversified and is essentially structured on four pillars: direct grants, public loans, public guarantees, and equity. In Germany, the relevant venture capital partners (VC) can be targeted through the Bundesverband Deutscher Kapitalbeteiligungsgesellschaften. e.V. (BVK - German Private Equity and Venture). Conferences and special events such as The German Equity Forum provide many opportunities for young companies to contact potential VC partners directly. Honttenrott and Richstein [3] demonstrated that joint funding consisting of government subsidies and soft loans positively impacted the startup of startups specializing in knowledge-intensive sectors.

The University of Lüneburg has set up an incubator concept, awarded over € 80 million in funding from the European Structural Funds and regional financing of Lower Saxony.

The paper is divided into three sections. The first section proposes a review of the literature to highlight how the way of thinking about industrial policy has changed over the years. In the second, a longitudinal analysis is proposed of the main initiatives adopted to guarantee support for innovation in all its forms (business creation, technology transfer, business-university partnerships, research clusters, and innovation poles) trying to define the objectives, the instruments adopted, and the significant repercussions at the national level and, where possible, at the regional level. The third section concludes the work.

2 Changes in the Conception of Industrial Policy: A Review of the Literature

Writing a literature review on the effects of industrial policy in advanced and developing economies is a rather daunting task for several reasons. First of all, there has been no sharing of the crucial role that industrial policy can play in territorial development processes. The manifestation of the repercussions of industrial processes has been highly heterogeneous globally. Furthermore, there is a problem of a lack of information on good performance and, above all, on the criticalities that may condition the success of any industrial policy both in its design and implementation phase. The lack of these data hinders the identification of best practices as models to follow to identify the changes to be made, especially for the benefit of the territorial areas falling furthest behind. It also makes it more problematic to conduct solid empirical checks. Among the countries that may be considered successful models to follow in implementing industrial policies, we may certainly include China.

The lack of data, making it difficult to carry out qualitative analyses, i.e., according to a case study approach, has also hindered over the years the conduct of econometric analyses aimed at investigating the impact of industrial policies. This criticality has diminished in intensity in recent years, and there have been many empirical analyzes. Lane [4] analyzed the fallout of the industrial policy known as "Heavy Chemical Industry (HCI)" under the Chung-Hee dictatorship (1973–1979). The economic activity of South Korea towards capital-intensive industry, generated an increase in productivity of 80% (compared to the manufacturing industries not affected by this policy). Furthermore, there are strong positive long-term effects of this industrial initiative on other sectors linked to those targeted, and weak adverse effects on industries with backlinks to the sectors targeted by HCI.

There has been a succession of empirical investigations that focused on the economy of China as a geographical area. For example, Nunn and Treffer [5], analyzing the tariff structures of 63 countries, identify a positive correlation between this protection mechanism of knowledge-intensive industrial sectors and the GDP growth rate over the long term. Concerning the economy of China, public subsidies are among the most investigated industrial policy instruments. The attention given to these tools can be explained by the fact that subsidies can significantly reduce the incidence of the barriers to innovation built by leading companies to the detriment of potential competing followers ([6–8]). Thanks to the first-mover advantage, leading companies have a whole range of skills that allow them to benefit more from the revenues associated with innovation. First of all, these companies, which have greater knowledge of the genesis of innovation and the factors necessary to develop it, exploit a more accentuated division of labor in order to manage production costs more efficiently, and may decide whether they need to transfer low-skilled tasks to another developing country willing to offer better conditions. Since the emerging industries globally are all high-tech, enterprises in China have more potential for productivity growth than enterprises in catching-up or maturing domestic industries. These tangible and intangible assets, which represent the strengths of Chinese companies in the management of innovation and in addition, their greater propensity to invest in R&D, are not sufficient to guarantee the success of innovation policies. The

probability of successful innovation for companies in emerging sectors on a global level is always strongly conditioned by the existence of market demand ([9–12]).

The development of market demand could be slowed down by the existence of information asymmetries between leading companies anticipating innovation and potential buyers. To reduce such asymmetries and avoid market failure on the demand side, several industrial policy instruments on the demand side, such as demand subsidies and tax reliefs and direct public tools for the procurement of innovation, can play a crucial role. Therefore, the joint action of supply-side subsidies and instruments to stimulate market demand would allow companies operating in emerging high-tech industrial sectors and located in developing countries to overcome the critical issues, which characterize these sectors for competing firms from OECD countries ([13]). Among the most recent studies are those by Guo et al. [14] and Boeing [15]. The former estimates the impacts of the INNOFUND government program supporting small and medium-sized enterprises, finding a positive correlation between the subsidies provided through this fund and the ability to produce innovation. For Boeing (2016), the subsidies granted by the Government to research and development produce a displacement effect in the sense that, in the short term, they replace (and do not add to) the corporate investments in research and development, and this effect tends to disappear over the long term. For Boeing et al. [16], this displacement effect is not prevalent for companies that repeatedly benefit from subsidies, companies specializing in high-tech sectors, and companies with minority state participation. Howell [17] examines the effect of public subsidies on different levels of innovation by businesses, and concludes that public subsidies promote innovation in higher-tech industries but hinder economic performance in both lower and higher-tech industries. Kalouptsidi [18] also investigates government subsidies as an instrument of industrial policy, limiting his attention exclusively to the shipbuilding industry. Thanks to disbursements of between 1.5 and 4.5 billion dollars (in 2006–2012), the Chinese shipbuilding industry achieved significant market shares from Japan and South Korea. Chen et al. [19] analyzed the cut in income taxes allocated to investments in research and development by companies as an industrial policy tool. Firms that benefited from this cut and thus double their real income for R&D could increase productivity by 9%. Aghion et al. [20] mainly focuses on trade policies such as tariffs, export subsidies, FDI policies, and tax exemptions.

A relatively recent definition of industrial policy is that provided by Schot and Steinmuller [21] and by Warwick [22]. The former introduced the expression "transformative innovation policies," those whose effects must be evaluated with respect to the ability to solve specific problems, primarily the fight against poverty, the aging of the population and climate change, rather than producing more innovation. According to Warwick, industrial policy is “any kind of government intervention or policy that attempts to improve the business environment or to alter the structure of economic activity towards sectors, technologies or tasks that should offer better prospects for economic growth or social well-being compared to what would occur in the absence of such an intervention.“ This definition is broader and shows greater horizontal impacts than the definitions previously provided by other authors, for example, Chang [23] and more recently Mao et al. [24], who prefer a vertical approach. For Chang, the effects of industrial policy

are not vertical, and fall exclusively on specific sectors. Also, for Mao et al., industrial policy intends to achieve objectives that identify a specific sector, for example, the expansion of entrepreneurial capacity, support for internationalization, technological change, strengthening of investments in research and development, increased productivity, etc. This heterogeneity of objectives is perfectly consistent with this broad definition of industrial policy, which includes all interventions supporting science and technology (tax breaks, tariffs, subsidies, export credits, FDI, and technology transfer) as strategic levers for greater competitiveness in targeted sectors.

This extension, proposed with a view to strengthening the possible synergies between industrial policy and S&T policies, represents a step forward compared to previous studies that investigated traditional and new types of industrial policies separately ([25–27]). For Mao et al., the productivity growth of an industrial sector depends on three factors: (1) the timing of a policy, (2) the attributes of a policy, and (3) industry attributes. The starting point for this argument is found in the reflections proposed by Lee and Malerba [28] and Pellegrino and Savona [11]. The former pointed out that within each specific sector, three sets of factors (technological, demand, and institutional/political) influence its recovery cycles. At the same time, the latter argued that both financial and non-financial factors played a role such as, for example, knowledge and factors on the demand side. Technological limitation is perhaps the most obvious non-financial factor limiting innovation, and the three types of industries in developing countries such as China face different incentive-related and technological constraints.

The difficulty of understanding the nature of the problem to be solved and the urgency with which solutions must be offered represent some of the causes of the failure of any industrial policy, regardless of how it is interpreted. In this regard, no socially desirable goal is the same for all territories ([29, 30]). Actors implementing policies "on the ground" are also more likely to possess the skills and practical knowledge necessary to understand specific problems of the place and context in which their solution is to be implemented ([31, 32]). All of this suggests the need for a more bottom-up or place-sensitive approach to innovation policy, something generally missing from the challenge-oriented innovation policy agenda. ([33]).

The attention to local specificities, as a starting point in the promotion of technological diversification strategies, is also taken up by the agenda of the European Commission with its smart specialization strategy ([34]). In this perspective, innovation policies should be selectively based on a place's unique and specific characteristics and resources ([35]). As tools for implementing the smart specialization strategy, many scholars have focused on public procurement, illustrating examples of procurement-driven innovation and providing estimates of the relationship between innovation outcomes and procurement ([36–41]). However, their effectiveness is severely weakened by several problems, primarily the lack of technical expertise on the part of the contracting authorities, poor coordination, and poor incentives. Innovation through public procurement requires policy change, in particular new meaningful capabilities and institutional change ([42–44]).

Despite a Great Deal of Interest in the Barriers and Challenges Associated with the Use of Procurement ([45]), Little Attention Has Been Paid to the Impacts that Public Procurement-Driven Innovation Can Produce at the Regional Level ([46]) and the

Institutionalization and Mainstreaming of This Political Innovation. There is a Lack of Practices that Can Be Considered *Best* Practices. Uyarra et Al. [47], Considering the Case of the Spanish Region of Galicia, Question the Effectiveness of Procurement as an Innovation Policy Tool.

3 Policies for Innovation

This section aims to analyze policies implemented in Germany to encourage business creation, the greater digitization of production activities, and the supply of broadband.

The management of policies and financial instruments in support of businesses and innovation is highly centralized and does not involve private entities outside the Federal Government. The two main actors which formulate the innovation policy are the Ministry of Education and Research and the Ministry of Economy and Energy. In particular, the latter has gradually seen the strengthening of its competency relating to programs supporting businesses, especially start-ups and small and medium-sized enterprises, and policies for promoting more excellent applied research.

Coordination between federal and national government decisions has also been ensured through the Joint Science Conference (Gemein-same Wissenschaftskonferenz-GWK) established in 2007 and made up of federal and state finance and research ministers. A particularly significant role in achieving greater cooperation between the federal government and local governments was played by the signing of three pacts. The first, the Hochschul pact for Higher Education, was signed in 2007, with financial coverage until 2020, and aimed to promote an expansion of the educational offer of German universities and to increase the propensity to internationalize their research activities. The second pact, the Pakt fur Forschung und Innovation - Research and Innovation, was signed in 2005 and funded until 2020 to strengthen the main research institutions. The third pact, the Exzellenzi (Excellence) initiative, was signed in 2007 to channel financial resources in favor of clusters and universities of excellence.

Since 2006, the Federal Government has been supported by institutions with a federal structure, made up of illustrious players from the worlds of economy and science, such as the Council for Innovation and Growth and the Union for Research between Science and Economics. More recently (2015), two other important groups of experts were set up: the High-Tech forum and the Platform for Industry 4.0. The first was made up of twenty exponents from the world of science and business, while the second represented a virtual platform aimed at facilitating multidisciplinary interaction and the greater sharing and dissemination of knowledge, especially in the digitization of business processes.

All these institutions working alongside the Federal Government to simplify bureaucratic and administrative issues that could hinder the implementation of innovation policies take the legal form of partnerships ("Projekttrager") of a public, semi-public or private nature.

The instruments described in this section are direct financing instruments since Germany differs from France, for example, in its absence of indirect financing for businesses through tax incentives.

As highlighted by Eickelpasch [48] and by Sofka [49], the areas of intervention of these various financial initiatives are essentially attributable to three categories: support

for technology startups, strengthening innovation in small and medium-sized enterprises, and business advisory services. As we will see from the description of these tools, the second area of intervention is characterized by a much more diversified offer of financial instruments and initiatives.

Table 2 summarizes the projects and financial allocations of the INNOKOM project since its launch (2009) in East Germany.

Table 2. The INNOKOM project in East Germany

	2009–2014	2009–2015	2009–2017
Projects	1,080	1,434	1,789
Amounts (million euros)	312	421	522

At the end of 2014, as part of the "Business Regions" initiatives, more than 170 "Innovation Forums" had received or would receive funding of up to € 85,000. By May 2017, out of 181 projects, 45 had been approved. At the end of 2018, the projects financed by non-profit research bodies reached 2,002 with funds of approximately 578 million euros. The share of East German forums was disproportionate, over 40%. The portfolio of topics ranged from technological development (e.g., flexible electronics or cross-reality [XR]) and social innovation in nursing, to the environment and sustainability (including the development of plastic-free packaging and new types of foods created from algae).

Table 3 represents the total amounts granted to support the creation of startups in Eastern Germany provided by the various European Resource Planning (ERP) programs: the ERP Start-Up Loan - Start-up Money program, the ERP Start-up Loan - Universal program, and the ERP Capital for Start-up program. In 2017, the total amount allocated by ERP to startups was 528 million euros, divided as follows: 43 million (approximately 18%) by ERP Start-Up Money, 459 million euros (approximately 13%) by ERP Universal, and 26 million euros (about 23%) by ERP Capital for Start-up. At the end of 2016, around 53 million euros (and therefore around 20% of the volume of commitments) had been granted by the ERP Start-up Loan - Start Money program, around 352 million euros (11%) by the ERP Start-up Loan - Universal Program, and 24 million euros by the ERP Capital for Start-up program (approximately 20%). As a demonstration of the growing interest in the startup phenomenon, this figure was far superior to that disbursed by the end of 2015, of approximately 51 million euros (approximately 19% of the volume of commitments) to enterprises in East Germany. The ERP startup loan-universal program was about 360 million euros (about 11%), and the ERP capital for the startup program about 35 million euros (about 26%).

Table 3. The project Enterprise Resource Planning for startup (ERP) in East Germany

	2016	2017	2018
Amounts (million euros)	429	528	483

The ERP Fund, specifically dedicated to the digitalization of businesses, expanded its budget in 2017 by financing 47 loans, amounting to resources of approximately 135 million euros to the new federal states. To benefit from these resources, companies had to qualify as "digital" or "Innovative" and to have been present on the market for at least two years.

About 31% of the young and innovative companies, which between 2013 and June 2016 were classified as eligible for support by the INVEST program, were based in the new federal states, with 21.9% in Berlin. In 2016 alone, 108 innovative companies from the new federal states received funding. This program was subsequently extended until 2017.

During the years 2014–2016, the EXIST program (Existenzgründungen aus der Wissenschaft), created in 1998 and consolidated in 2014 to fund the start-up of businesses and the process of transferring research, saw a redefinition of the prerequisites for funding. Above all, the primary intent of this program was to alleviate the start-up costs of academic spin-offs for a maximum period of 12 months.

In recent years, the section of the EXIST business start-up program has disbursed over 17 million euros, while the area of the EXIST program dedicated to the transfer of research accounts for over 23 million euros. About 20% of the total resources was granted to start-up teams in universities in East Germany. In 2017, the EXIST Start-up Grant and EXIST Research Transfer programs maintained and in some areas expanded the high level recorded the previous year. This is reflected in the number of projects, with 348 in the EXIST Start-up Grant program and 151 in the EXIST Research Transfer program (1 + 2 programs). For both the EXIST Start-up Grant (over 22 million euros) and the EXIST Research Transfer (over 30 million euros), approximately 18% of the total volume was awarded to start-up teams in East German universities.

Since 2015 the High-tech Founder Fund (HTGF), a seed-stage investor, has been operational, providing 21 loans for a total of around 10 million euros in the eastern federal states. This corresponded to commitments of around 54% of HTGF's 40 overall first-time financing commitments in 2015. In 2018, this amount was lower but still constituted a significant form of financial support for companies in East Germany (6.5 million euros, corresponding to commitments of approximately 15% of the 59 loan commitments). In 2017, € 3.65 million had been granted, or approximately 19% of the 34 loan commitments.

The 2,661 participations provided by the Micro-Mezzanine Fund from its inception in autumn 2013 to the end of 2018, amounted to approx. 107.8 million euros. Of this, 989 investments (959 at the end of 2017 and 917 at the end of 2016) for a value of approx. 39.8 million euros (38.4 million euros in 2017 and 37.7 million euros in 2016) went to the new federal states. This fund also disbursed 88 individual loans in 2018 to companies specializing in the ICT sectors operating in the new federal states for a total of approximately 264 million euros.

Smaller businesses, especially micro-businesses, were the preferred target of the new Microloan Fund, which disbursed 2,360 loans of approximately 15.04 million euros from 2010 to 2015 in the new federal states (excluding Berlin), and from May 2015 to February 2018, 811 loans of approximately € 7.3 million in East Germany (excluding

Berlin). This corresponded to 22% of the total funds for microloans. In 2018, 303 micro-enterprises (330 in 2017) in the new federal states (including Berlin) received loans for a total of over 2.8 million euros (3 million euros in 2017). This corresponded to 26% of all micro-entities receiving support.

Micro and small enterprises are also the subjects of another "SME-NetC" initiative, launched in August 2016 with a budget of approximately 18 million euros, particularly focusing on R&D in their innovation processes. Among the sectors most concerned are biotechnology, maritime technology, energy, environmental technology, and information and communication technology.

From 2001 to 2022, over 50 growth centers and 39 growth potential centers were supported with over 484 million euros thanks to the Innovative Regional Growth Cores or Growth Core Potential Program. A significant share of these funds (120 million euros) went to projects in Saxony. As part of this program in Lusatia, 15 partners set up a network to build the "house on the Bergheider See", a futuristic houseboat capable of satisfying its own needs for electricity, heating, and drinking water.

The budget for the "Centers for Innovation Competence" program up to 2021 amounted to at least 335 million euros. This budget continues to grow, and will reach 400 million euros by the end of 2022, with 14 Research Centers benefiting from these financial aids.

The "InnoProfile-Transfer" Program earmarked 123 million euros, with a deadline of 2019, to support 23 market-oriented collaborative projects, seven young research groups, and 21 research groups originating in university-business partnerships. In 2018, a total of around 300 million euros was approved. For the previous "InnoProfile" program, referring to the period 2006–2013, 157 million euros was allocated. Together with this previous project, 296 million euros would have been disbursed by 2019. One of these research groups was the FunGene ZIK of the University of Greifswald, which led to the foundation of an interdisciplinary center for genome research and the creation of the Northern Germany center for microbial genomics.

The "Priority for SMEs" Program, since it was launched in 2007, has supported over 1,500 individual and collaborative projects, granting a total of over € 1 billion and involving over 2,300 small and medium-sized enterprises across Germany. About a quarter of these funds have gone to research stakeholders in the eastern federal states.

The "Research Campus" initiative has allocated approximately 45 million euros in funding (from 2013 to 2020) for research and development projects in the new federal states and Berlin. Overall, the initiative is involved in 183 cooperation projects across nine research campuses, and 89 of these are participating in research campuses in eastern Germany. These partnerships can play a crucial role in revitalizing the East German regions, since more than half of the partners involved are SMEs. Among the most emblematic examples are the Berlin MODAL and Mobility2Grid campuses, researching new methods of mathematical optimization and coupling of mobility solutions with intelligent power grids, and the campuses in Magdeburg, focusing on medical technology (STIMULATE), as well as in Jena, with a focus on the diagnosis of infections and pathogens (InfectoGnostics).

The central innovation program for SMEs, "ZENTRALES INNOVATIONS PROGRAM MITTELSTAND-ZIM," launched in 2008, intends to promote the development

of technologies (of any kind) and leaner bureaucratic processes. Loans of up to 350,000 euros can be granted to companies with 500 employees. To meet this aim, support for all forms of cooperation between research and businesses and the increase in technology transfer is essential. The companies' projects are mainly focused on the technologies of the future: digitalization, energy and resource efficiency, health research and medical technology, smart mobility, and renewable energy. This program has been providing support for ambitious research and technology development projects by SMEs since July 2008, resulting in new products, processes, or technical services. It is significant for the regions of East Germany to which it has earmarked about 40% of the funding.

The Federal Government has repeatedly increased its budget for the ZIM program in recent years, which rose to 543 million euros in 2016 and 548 million in 2018. The planned budget for 2019 was approximately 555 million euros. From 2008 to 2014, over 31,000 loan applications were approved for over 4.2 billion euros to stimulate investments of over 8.4 billion euros in research and development.

As of 2016, as part of the Industry 4.0 Program, ten PMI 4.0 centers of excellence were established throughout Germany within the PMI 4.0 - Digital Production and Work Processes initiative. These centers offer companies practice-oriented digitization know-how and specific demonstration and testing opportunities to meet their regional priorities. Two centers of excellence in Berlin and Chemnitz are already operational. A third center will start operations in Ilmenau in autumn. In 2017, additional centers of excellence opened their doors, with the aim of filling regional and thematic gaps and providing assistance for economically less developed and industrially weak regions in East Germany.

Another key tool to assist SMEs and businesses in digital transformation is the Federal Mittelstand-Digital Program (digital SMEs), which in mid-2019 established a network of 26 SME 4.0 competence centers. Each of the nine federal states has 18 regional competence centers, which provide digitalization knowledge at different sites with various practical, and accessible demonstrators that SMEs can test for themselves.

Thanks to the "Go Digital" Program at the end of 2018, 113 consulting companies on innovative technologies were certified and located in the new federal states. More than a third of all project funding (38.4%) was paid to SMEs and specialist operators in East Germany.

Technological innovation received extensive financial support from the Federal Government during these years: 450 million euros in 2018 to East Germany, of which about 350 million euros for assistance in implementing projects that used innovative technologies and about 100 million euros within the scope of institutional funding. Six university-research centers-business alliances were completed by 2018, involving over 60 partners from the business world and the scientific/academic community. The eastern federal states benefited most from funding for information and communication technology (290 million euros for East Germany, or 57% of the funds provided nationally for this area), for nanotechnologies and materials (almost 60 million euros, 45% of the national funding), as well as optical technologies (for a total of 46 million euros, 38% of the total funding).

Also, in support of the development of new technologies, approximately 400 million euros were disbursed by the Federal Government in 2017, and of these, 250 million euros

in the form of research grants to finance research projects in Eastern Germany. The new federal states received 36% of federal government technology funding in 2017. Grants focused on information and communication technologies (44%), nanotechnology and materials technologies (35%), and optical technologies (38%).

In 2018, the Max Planck Schools program was launched, a joint initiative of the Max Planck Society, German universities, and non-university research organizations. Its aim is to concentrate scientific excellence in Germany and optimize doctoral programs internationally. Three pilot programs will initially be funded for five years, for a total of € 9 million per year. Primary responsibility for two of these networks, some of them at a European level, rests with institutes in the new federal states: the Max Planck School of Cognition is run by the Max Planck Institute for Human Cognitive and Brain Sciences, and the Max Planck School of Photonics is managed by the Fraunhofer Institute for Applied Optics and Precision Engineering (IOF) in Jena. In addition, three of the nine major project universities are located in East Germany: Friedrich-Schiller- Universität of Jena (MPS Photonics), University of Leipzig (MPS Cognition), and Humboldt- University of Berlin (MPS Cognition). The Otto-von-Guericke University of Magdeburg and the Dresden University of Technology also participate in MPS Cognition.

4 Conclusions

The description of Germany's instruments for financing innovation allows us to state that public spending on applied research and innovation by small and medium-sized enterprises has been marked by a certain balance between private and public contributions. Private spending has accounted for two-thirds of total expenditure on research and development. The federal government has managed to ensure a significant increase in public resources, and the supply of resources by the state has remained stably heterogeneous.

After this analysis of the main initiatives taken to accelerate the process of economic convergence between West Germany and East Germany, it must certainly be said that the objective of reducing the research and innovation gaps between these two areas has been achieved. In particular, from 2006 to date, spending on research and development has grown by over 3% of the GDP target set by the Euro-pa 2020 strategy. This objective has been raised to 3.5% of GDP by the strategy for technological innovation by 2025.

To accelerate the process of economic convergence, the major contribution that the Structural Funds (European Regional Development Fund-ERDF, European Social Fund-ESF, and European Agricultural Fund for Rural Development-EAFRD) are making should be highlighted. In particular, in 2005–2019, recalling the Solidarity Pact II, East Germany obtained various forms of significant financial aid (over 200 billion euros) divided among the infrastructure, transport, and urban development sector (156) and other sectors, primarily innovation, research and development, education, environmental protection, and sporting activities (51). For the following programming period (2021–2027), the European Commission has proposed for Germany a sum of 17.7 billion euros at current prices (15.7 billion euros at 2018 prices) from EU structural funds. In this way, an attempt is made not to extend funding to regions of Germany with a GDP between 75% and 100% compared to the EU average also to areas of East Germany (in transition).

In addition to the structural funds, the penultimate federal government, as part of the Solidarity Pact II, devised a new national financing system for structurally weaker

regions through a series of financial projects active from 2020: the BMWi INNO-KOM, the Joint Task To improve the regional economic structure and the WIR! (Wandel durch Innovation in der Region) of the Federal Ministry of Education and Research (BMBF). WIR! is a financial project, which became operational in 2017 and which, in a pilot phase, allocated 150 million euros for 32 initiatives in East Germany.

The way of thinking about the financial system is changing, increasingly favoring an open and systemic approach to financing that considers both technological and social innovation. The main idea of the new funding system is to expand, through an additional 22 funding programs, the Joint Task Improving Regional Economic Structure, currently limited to East Germany. These new programs include funding for innovation provided by the Innovative Skills Funding Program (INNO-KOM), the Central Innovation Program for SMEs (ZIM), and Funding for Innovation and Structural Change, funding for broadband coverage and programs for rural development, urban development, and the provision of essential community services.

As part of the High Technology Strategy, Germany has succeeded in responding to the demand for incremental innovation and investment in research and development that is developing above all thanks to relations between the public sector, large companies and research centers. These relations have been facilitated by the stability of the political system.

In the governance systems of innovation strategies, a central role is played by public development banks (KfW), and evaluation bodies (EFI) have been introduced. The presence of these evaluation agencies, totally independent from the central government, has made the evaluation system of innovation policies in Europe more effective (Borras and Laatsit 2019).

Innovation in universities has been facilitated by multilevel coordination between the federal government and the Länder.

Supporting the demand for innovation requires a revision of legislation as a necessary condition to ensure the effectiveness of the tools to support innovation. Better regulation translates not only into simplifying the procedures for disbursing loans to businesses but also into strengthening consultation practices and evaluating the effects of the measures introduced. Germany appears to have made significant progress towards this goal by shifting the focus from incremental entrepreneurial innovation to radical innovation through the adoption of the "transformative change" paradigm.

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References

1. Daimer, S., Dehio, J., Rothgang, M.: Knowledge triangle policies and practices in Germany-Research RWI Materialien, No. 119 (2017)
2. I-COM, Presenza ed impatto economico delle "start up" innovative di successo: un confronto internazionale (2013)

3. Honttenrott, H., Richstein, R.: Start-up subsidies: Does the policy instrument matter? Res. Policy **49**, 1–21 (2020)
4. Lane, N.: Manufacturing revolutions: industrial policy and networks in South Korea. Institute for International Economic Studies. Working Paper (2019)
5. Nunn, N., Treffer, D.: The structure of tariffs and long-term growth. AEJ: Macroecon **2**(4), 158–194 (2010)
6. Geref, G., Humphrey, J., Sturgeon, T.: The governance of global value chains. Rev. Int. Polit. Econ. **12**(1), 78–104 (2005)
7. Phillips, N.: Power and inequality in the global political economy. Int Aff **93**(2), 429–444 (2017)
8. Lema, R., Rabellotti, R., Sampath, P.G.: Innovation trajectories in developing countries: co-evolution of global value chains and innovation systems. Eur. J. Dev. Res. **30**(3), 345–363 (2018)
9. Canepa, A., Stoneman, P.: Financial constraints to innovation in the UK: evidence from CIS2 and CIS3. Oxford Econ. Papers **60**(4), 711–730 (2008)
10. Gao, X., Rai, V.: Local demand-pull policy and energy innovation: evidence from the solar photovoltaic market in China. Energy Policy **128**, 364–376 (2019)
11. Pellegrino, G., Savona, M.: No money, no honey? Financial versus knowledge and demand constraints on innovation. Res. Policy **46**(2), 510–521 (2017)
12. Boon, W., Edler, J.: Demand, challenges, and innovation. Making sense of new trends in innovation policy. Sci. Public Policy 45 (4), 435–447 (2018)
13. Perez, C., Soete, L.: Catching-up in technology: entry barriers and windows of opportunity. In: Dosi, G., Freeman, C., Nelson, R., Silverberg, G., Soete, L. (eds.), Technical Change and Economic Theory. Pinter Publishers, London (1998)
14. Guo, D., Guo, Y., Jiang, K.: Government-subsidized R&D and rm innovation: evidence from China. Res. Policy **45**(6), 1129–1144 (2016)
15. Boeing, P.: The Allocation and effectiveness of China's R&D subsidies - evidence from listed rms. Res. Policy **45**(9), 1774–1789 (2016)
16. Boeing, P., Mueller, E., Sandner, P.: China's R&D explosion—Analyzing productivity effects across ownership types and over time. Res. Policy **45**(1), 159–176 (2016)
17. Howell, A.: Picking 'Winners' in China: do Subsidies Matter for Indigenous Innovation and Firm Productivity? China Econ. Rev. **44**, 154–165 (2017)
18. Kalouptsidi, M.: Detection and impact of industrial subsidies: the case of Chinese shipbuilding. Rev. Econ. Stud. **85**(2), 1111–1158 (2018)
19. Chen, Z., Liu, Z., Serrato, J.C.S., Xu, D.Y.: Notching R&D Investment with Corporate Income Tax Cuts in China, NBER Working Paper w24749, Cambridge, MA (2020)
20. Aghion, P., Cai, J., Dewatripont, M., Du, L., Harrison, A., Legros, P.: Industrial policy and competition. Am. Econ. J. Macroecon. **7**(4), 1–32 (2015)
21. Schot, J., Steinmueller, W.E.: Three frames for innovation policy: R&D, systems of innovation and transformative change. Res. Policy **47**(9), 1554–1567 (2018)
22. Warwick, K.: Beyond industrial policy: emerging issues and new trends. OECD Science, Technology and Industry Policy Papers 2. OECD Publishing (2013)
23. Chang, H.J.: The Political Economy of Industrial Policy. Macmillan Press, London and Basingstoke (1994)
24. Mao, J., Tang, S., Hiao, Z., Zhi, Q.: Industrial policy intensity, technological change, and productivity growth: Evidence from China. Res. Policy **50**, 104287 (2021)
25. Chen, L., Naughton, B.: An institutionalized policy-making mechanism: china's return to techno-industrial policy. Res. Policy **45**(10), 2138–2152 (2016)
26. Zhi, Q., Suttmeier, R.P.: China's national S&T programs and industrial innovation: the role of the 863 program in the telecom and power sectors. In: Paper Presented at the Conference

on Policy, Regulation, and Innovation in Chinese Industry. Pittsburgh, PA, May 3–4, 2014 (2014)
27. Zhi, Q., Pearson, M.M.: China's hybrid adaptive bureaucracy: the case of the 863 program for science and technology. Governance **30**(3), 407–424 (2017)
28. Lee, K., Malerba, F.: Catch-up cycles and changes in industrial leadership: windows of opportunity and responses of firms and countries in the evolution of sectoral systems. Res. Policy **46**(2), 338–351 (2017)
29. Fitjar, R., Benneworth, P., Asheim, P.: Towards regional responsible research and innovation? Sci. Public Policy. https://doi.org/10.1093/scipol/scz029. in press (2019)
30. Wanzenböck, I., Frenken, K.: The Subsidiarity principle: Turning Challenge- Orientated Innovation Policy on Its Head (No. 1806). Utrecht University, Department of Human Geography and Spatial Planning, Group Economic Geography (2018)
31. Ansell, C., Sørensen, E., Torfing, J.: Improving policy implementation through collaborative policymaking. Policy Polit. **45**(3), 467–486 (2017)
32. Flanagan, K., Uyarra, E.: Four dangers in innovation policy studies—and how to avoid them. Ind. Innov. **23**(2), 177–188 (2016)
33. Coenen, L., Hansen, T., Rekers, J.V.: Innovation policy for grand challenges. An economic geography perspective. Geogr. Compass **9**(9), 483–496 (2015)
34. Foray, D.: Smart specialization strategies as a case of mission-orientated policy—a case study on the emergence of new policy practices. Ind. Corp. Change **27**(5), 817–832 (2018)
35. McCann, P., Ortega-Argilés, R.: Modern regional innovation policy. Camb. J. Reg. Econ. Soc. **6**(2), 187–216 (2013)
36. Edquist, C., Hommen, L., Tsipouri, L.: Public Technology Procurement and Innovation. Kluwer Academic Publishers, Dordrecht (2000)
37. Edquist, C., Vonortas, N.S., Zabala-Iturriagagoitia, J.M., Edler, J.: Public Procurement for Innovation. Edward Elgar, Cheltenham (2015)
38. Aschho, B., Sofka, W.: Innovation on demand—can public procurement drive market success of innovations? Res. Policy **38**, 1235–1247 (2009)
39. Guerzoni, M., Raiteri, E.: Demand-side vs. supply-side technology policies: hidden treatment and new empirical evidence on the policy mix. Res. Policy 44 (3), 726–747 (2015)
40. Georghiou, L., Edler, J., Uyarra, E., Yeow, J.: Policy instruments for public procurement of innovation: choice, design and assessment. Technol. Forecast. Soc. Change **86**, 1–12 (2014)
41. Raiteri, E.: A time to nourish? Evaluating the impact of public procurement on technological generality through patent data. Res. Policy **47**(5), 936–952 (2018)
42. Rolfstam, M.: Public Procurement and Innovation. Edward Elgar Publishing, Cheltenham (2013)
43. Lember, V., Kattel, R., Kalvet, T.: Quo vadis public procurement of innovation? Innovation **28**(3), 403–421 (2015)
44. Flanagan, K., Uyarra, E., Laranja, M.: Reconceptualising the 'policy mix' for innovation. Res. Policy **40**(5), 702–713 (2011)
45. Uyarra, E., Edler, J., Garcia-Estevez, J., Georghiou, L., Yeow, J.: Barriers to innovation through public procurement: a supplier perspective. Technovation **34**(10), 631–645 (2014)
46. Sánchez-Carreira, M.C., Peñate-Valentín, M.C., Varela-Vázquez, P.: Public procurement of innovation and regional development in peripheral areas. Innovation **32**(1), 119–147 (2019)
47. Uyarra, E., Zabala-Iturriagagoitiac, J.M., Flanagana, K., Magro, E.: Public procurement, innovation and industrial policy: Rationales, roles, capabilities and implementation. Res. Policy **49**, 103844 (2020)
48. Eickelpasch, A.: Innovation policy in Germany, Firenze, IRPET (2013)
49. Sofka W.: RIO Country report 2014: Germany, Lussemburgo Joint Research Centre of the European Commission (2015)