



# Education and Technology for Industrial Power: The German Experience of Human Capital Accumulation

Liu Chunyang<sup>1</sup>, Gao Ke<sup>2</sup>, Yang Chen<sup>3</sup>

<sup>1</sup>School of Finance and Finance, Renmin University of China, Beijing, China

<sup>2</sup>School of Economics, Peking University, Beijing, China

<sup>3</sup>School of Shizhong District Party Committee of Jinan, Jinan, China

## Email address:

liuchunyang@ruc.edu.cn (Liu Chunyang), gkfly@126.com (Gao Ke), 342711198@qq.com (Yang Chen)

\*Corresponding author

## To cite this article:

Liu Chunyang, Gao Ke, Yang Chen. Education and Technology for Industrial Power: The German Experience of Human Capital Accumulation. *International Journal of Economics, Finance and Management Sciences*. Vol. 9, No. 4, 2021, pp. 128-133.

doi: 10.11648/j.ijefm.20210904.11

**Received:** June 1, 2021; **Accepted:** July 13, 2021; **Published:** July 15, 2021

---

**Abstract:** Germany is both an industrial powerhouse and a human capital powerhouse. The first accumulation and rapid development of Germany's human capital not only effectively promoted its industry and economy, but also greatly enhanced its military strength and comprehensive national strength, playing a leading, creating and promoting role in the rise of the country. This paper analyzes the experience of human capital accumulation in Germany from the perspectives of education and science and technology, and discusses the changes of economic and demographic structure, the characteristics of human capital and the investment of human capital. Germany's human capital has three characteristics: cumulative advantage, leading knowledge and career orientation. Germany increases the investment in human capital through policies, funds and innovations. From the experience of Germany, human capital has a fundamental impact on the rise of a country. The general logic is that the rise of a country requires a strong overall national strength and good social order. When a country's human capital accumulates to a considerable extent and forms a great advantage, the vigor of human capital will be fully released under the implementation of appropriate national strategies or even seemingly accidental historical opportunities, which will lead to the release of the creative potential of the society and the economic potential of the country, thus opening the way for the rise of the country. By summarizing the model and experience of human capital accumulation in Germany, this paper provides reference for human capital investment policies of various countries.

**Keywords:** Germany, Human Capital Investment, Human Capital Accumulation

---

## 1. Introduction

In the middle and late 19th century, Germany rapidly rose into a global industrial power, and national education and scientific and technological progress were the most important driving factors. For the rise of modern Germany, it is generally believed that national education and scientific and technological progress are the most important driving factors, and the quality of human capital plays a decisive role. The accumulation of human capital in Germany is characterized by government leading, knowledge leading and career oriented. Germany took the lead in implementing compulsory education for all, building a unique and systematic vocational

education, promoting the teaching reform of modern universities, and realizing the close integration of education and national spirit cultivation with national development and social needs. The first accumulation and rapid development of German human capital not only effectively promoted the industry and economy, but also greatly enhanced the military strength and comprehensive national strength, playing a leading, creative and promoting role in the rise of the country. His paper analyzes the experience of human capital accumulation in Germany from the perspectives of education and science and technology, and discusses the changes of

economic and demographic structure, the characteristics of human capital and the investment of human capital. It is intended to provide reference and reference for other countries by summarizing German experience.

## 2. Literature Review

Human capital is the stock of human skills and productive knowledge. The benefit or return on investment in human capital lies in improving one's skills and profitability, as well as in improving the efficiency of economic decision-making in and out of a market economy. *The Wealth of Nations* argues that it shows for the first time how investments in human capital and labor market skills affect individual income and wage structures, arguing that improving workers' skills is the fundamental source of economic progress and improved economic welfare. Alfred Lotka provided the first quantitative application of human capital. Theodore W. Schultz (1961) believed that the core of the concept of human capital was the long-term improvement of workers' skills based on education, training and literacy, but he also pointed to the improvement of health and longevity, the reduction of child mortality and the increase of family resources for children, and the improvement of educational attainment [12]. Gary Becker analyzed the important role of human capital in economic growth and increase of national income, demonstrated that investment in education is a productive investment, and used empirical data to illustrate the return rate of higher education and compare the gap between different levels of education. The income function designed by Mincer (1958, 1974) introduces in detail the development of Becker's on-the-job training theory and the optimization of the model, and introduces education into the on-the-job training theory [4-6].

There is a wealth of research on education, technology and human capital in Germany. Stein, Volker. concentrates on the German aspects of the HCM debate is aimed at systematizing this discourse by outlining the past and present HCM development in Germany as well as its future perspectives. It will result in a synoptic view, summing up the German state-of-the-art HCM [13]. Maurseth, P. B., & Frank, B.. study in 2019 is motivated by previous studies that have found that information and communication technology (ICT) industries seem to cluster geographically and having spatially clustered growth rates. In Germany, the production of ICT devices is concentrated in clusters of innovating regions (in terms of patents) [7]. Poelhekke, Steven Focus on highly skilled workers, by using metropolitan areas instead of administrative regions and correcting important biases, it is shown that the effect of the share of college graduates on growth is at least one-third smaller and closer to 0.5% employment growth for a 10% increase in human capital [9]. Roy, I., & D Consoli. employs a task-based approach to analyze structural changes in regional employment within a rich vocational education setting in West Germany during 1979 and 2012, findings show that unlike in the USA where employment growth in low-skilled service occupations has been the greatest, in Germany there is a greater trend toward occupational

upgrading and larger growth in managerial and professional occupations due to the operationalization of its apprenticeship system [11]. Scholl, T., et al. investigate the effects of attending a more advanced track in middle school on long-term education and labour market outcomes for Germany, a country with a rigorous early-age tracking system, where the risk of misallocating students is particularly high. Remarkably, we find no evidence that attending a more advanced track leads to more favourable long-term outcomes [14]. Bond, M., et al. puts forward different policies, initiatives and strategies for the innovation of educational technology in German Higher Education, and supports the wider application of educational technology in higher education institutions for the purpose of teaching and learning [2]. Moglie, M. L., Mencarini, L., & Rapallini, C. investigate company foundations in the German micro technology industry by means of a spatial-temporal micro-geographic analysis. We demonstrate that spatial proximity has a clear influence on where new companies are founded, the influence of proximity to different agents is not constant over times but evolves with the industry's life cycle [8]. Souza, W. D., & Gabriel, B. Applying an outlier robust extension of the data envelopment analysis (DEA) followed by a geoaddivitive regression analysis, this study identifies and decomposes the efficiency of 439 German regions in using infrastructure and human capital. Concrete regional funding schemes, shaped by best practice results, might not be appropriate for all regions, a more differentiated funding scheme that accounts for both spatial and structural factors seems more promising. Since the mid-1990s, German technology policy has undergone a typical shift from a standard funding scheme to a regionally oriented and competition-based R&D policy [15]. Based on the recent literature on heterogeneous firms and the life cycle of clusters, Vehrke, F. J.. analyzes a new policy experiment called inter-cluster competition, and investigates the firms in 21 winning cluster regions. The findings suggest that the new funding scheme takes into account insights from recent theoretical developments and addresses important barriers to the internationalization of firms and clusters [16]. Dittmar, J. E., & Meisenzahl, R. R. study public goods provision established through new laws in German cities during the 1500s. Cities that adopted the laws subsequently began to differentially produce and attract human capital and to grow faster [3]. Prantl, S., & Spitz-Oener, A. find that immigration can have negative effects on the wages of natives. These effects surface when product and labor markets are competitive but not under regulations that restrict the entry of firms and provide workers with a strong influence on firms' decision making [10]. Becker, S. O., et al. study the long-run effects of forced migration on investment in education, combine historical censuses with newly collected survey data to show that, while there were no pre-WWII differences in educational attainment, Poles with a family history of forced migration are significantly more educated today than other Poles, these results are driven by a shift in preferences away from material possessions toward investment in human capital [1].

### 3. The Economic and Demographic Changes in the Rise of Germany in Modern Times

After the reunification of Germany, it quickly entered the era of economic prosperity, and the industrial growth rate remained at a high level for 40 consecutive years. After two industrial revolutions, German steel output increased from 126000 tons in 1870 to 13 million tons in 1913; The output of coal increased from 5.1 million tons in 1850 to 191.5 million tons in 1913; The length of the railway increased from 18800 km in 1870 to 60500 km in 1912; The tonnage of steam powered ships increased from 820 million tons in 1871 to 43.8 billion tons in 1913. Along with the development of heavy industry, the German electrical industry and chemical industry also witnessed rapid development. Many large companies, such as Siemens, German Edison Electric, German central dyestuff and so on, have been established. By 1913, the share of German electrical products accounted for 34% of the world. In the middle of the 19th century, more than half of the guns produced by Krupp were exported to foreign countries, and Germany became one of the largest machine exporting countries in the world.

At this stage, German industrial technical workers gradually become the main body of employment. The structure of human capital has obvious characteristics of industrialization. First, the proportion of the employed population in the total population has been rising, of which the number and proportion of employees in industry, commerce and transportation have increased rapidly, while the number and proportion of employees in agriculture and forestry have decreased steadily. Second, after the improvement of social security mode, the birth rate is not high, but the lower mortality rate causes the rapid growth of the total population, the rapid growth of urban population becomes the main body of national residents, and the negative growth of rural population becomes a minority of residents. Third, the migration of the outflow population has decreased, the migration of the inbound population has gradually exceeded that of the outflow population, and a large number of foreign excellent technical talents have been gathered. The population of domestic agricultural areas is transferred to industrial areas.

Germany did not sacrifice agriculture in the process of industrialization. Although the total population of agriculture and forestry in Germany decreased by 1.5433 million from 1882 to 1907, the number of employees increased by 1.6468 million, indicating that agriculture maintained stable development, redundant population decreased, agricultural economic quality improved, and farmers gradually separated from rural areas and joined the urban employment army. At the same time, the traditional industrial guilds were powerful, and the status of craftsmen was not quickly replaced by industrial technical workers. By 1870, the proportion of craftsmen and industrial workers was roughly 1: 1, forming the characteristics of "dual economy". The composition of

urban industry is very complex, not a single modern industrial economy, which is conducive to the integration of Germany's traditional fine style into emerging industries.

### 4. Characteristics of Human Capital: Cumulative Advantage, Knowledge Leadership and Career Orientation

Compared with the catch-up stage of the economy, Germany's catch-up in human capital dates back nearly a century. As the economy catches up with Britain and France, Germany's cumulative advantage in human capital is already significant.

#### 4.1. Compulsory Education for All

Germany was the first country to implement compulsory education. In 1763, Prussia promulgated the first "General Compulsory Education Law" in the world, requiring all minors to receive education. Under Bismarck, education and military service were mandatory duties for Germans. "Education became a part of national activities in Germany after the 19th century. In 1809, Prussia established educational administrative institutions at all levels from the central government to provinces, counties and counties. Each county set up several school districts, and each school district set up at least one primary school. In basic education, general knowledge learning is used to replace single subject learning, Pestalozz teaching method is introduced, and students' personality is emphasized. Primary school enrollment in Prussia reached 60% in 1816 and 93% in 1864. By 1890, the illiteracy rate in Germany was about 0.51%, far lower than that of other European countries in the same period. At that time, the illiteracy rate in Switzerland was 0.8%, that in France was 9.5%, that in the Netherlands was 7.3%, that in Belgium was 13.6%, that in Austria was 30.8%, and that in Italy was 41.4%. The basic education in Germany was far ahead in Europe.

In order to improve the quality of education and teaching methods, Prussia and the whole of Germany paid close attention to the construction of teaching staff in the 19th century. They sent people to Switzerland many times to learn advanced educational concepts and establish various normal schools. By 1840, there were 38 normal schools in Prussia alone, forming a relatively complete way of education, scientific research and teacher training, and cultivating a large number of new teachers for German education.

#### 4.2. Highly Developed University Education

After Heidelberg University was founded in 1386, several universities were built in every century in Germany. Six were built in the 15th century, four in the 16th century, three in the 17th century, four in the 18th century, and nine in the 19th century. Since the 18th century, Germany has carried out three university reforms. Founded in 1809, the University of Berlin introduced the function of scientific research into the

University for the first time in the world, established the postgraduate system and set up research laboratories in the University, which made the university become a social center research institution, opened up the modern university model, and became a model for higher education in the world at that time. From the founding of Berlin University, Germany replaced France as the world science center in only 30 years, until it was replaced by the United States after the Second World War "From the establishment of the laboratory of Giessen University in 1826 to 1914, the organized work of academic research was extremely developed in Germany, far beyond the reach of other countries.

#### **4.3. The World'S Leading Scientific Research Talents**

In Germany, scientific research is as important as religion and is regarded as "the world conqueror of our time". Before 1920, Germany had 200 scientists and 279 scientific and technological achievements. During the same period, the number of British scientists was 122, 174 scientific and technological achievements, and France had 88 and 107. Germany was almost the sum of Britain and France. Before 1914, there were 14 German scientists who won the Nobel Prize in natural science, one third of all the winners. From 1901 to 1940, German scientists won 36 Nobel prizes, far more than Britain, France and the United States. During the period of industrialization, the invention and creation of German scientists played an important role. For example, the design and application of steel-making process, coal tar refining process and new generator which are suitable for the characteristics of German iron ore have promoted the rapid development of German iron and steel, chemical and electrical industries, far ahead of European countries, showing a strong ability of technological innovation.

#### **4.4. Unique and Systematic Vocational Education**

Germany is the first country to pay attention to vocational education. In the 19th century, vocational education gradually became an important part of German education system. In 1817, Prussia set up handicraft schools in various cities, gradually forming a network of local industrial schools. In 1850, a national unified secondary technical school was established, with 26 state-level new vocational schools, offering model making, pure mathematics, applied mathematics, physics, chemistry, mechanics, machinery and other subjects. The Federal Constitution stipulates that if there is an industrial training school in the place where the factory is located, the factory owner must provide convenience for the workers to enter the school. By 1900, Germany had 1070 industrial schools with 152900 students and more than 2000 skill training schools in rural areas. By 1913, Germany had trained 3000 engineers every year, while Britain had only 350 graduates in related fields every year, which was regarded as an important reason why Britain was overtaken by Germany in high-tech industries such as electrical and chemical industries. The systematization, organization, standardization and popularization of German vocational education are

unparalleled in Europe in the 19th century, and gradually developed into a unique "dual system" vocational education mode in the 20th century.

#### **4.5. German National Spirit**

Influenced by geographical characteristics and cultural tradition, German national spirit is tough and rigorous. The primary purpose of compulsory education in Prussia is to cultivate obedient and God fearing people and reserve qualified troops, not to develop economy. However, due to the close combination of education and military service system, the people have received education and military training for a long time, forming a unique spiritual tradition; second, the quality of education and culture is generally high, good at thinking and debate; the third is to advocate self-improvement, keep improving and never be satisfied. These characteristics have played a great role in the process of industrialization in Germany, bringing up a group of industrial workers who can quickly master industrialization skills, have strong organization and high efficiency, and a scientific research team with high quality, stable echelon and strong professionalism. This is still an important factor in Germany's economic success.

### **5. Human Capital Investment: Policy, Fund and Innovation**

#### **5.1. Enlightenment of Human Capital Thought**

Prussia was the first country to put forward the strategy of "rejuvenating the country through science and education". The German monarch and Juncker landlord class believed that systematic education was the best way to achieve national unity and maintain national strength. In the middle of the 18th century, Frederick the great foresaw the role of science and technology in the future development of the country. He built education and science with the attitude of building the army. He introduced a large number of science and technology and scientists from France, and gave full support to the development of education and Science and technology in his country. He regarded it as the foundation of the country, and established the purpose of German education "serving the country". Hegel emphasized the legitimacy and rationality of the establishment of a strong German government. Fichte said, "the mission of German education is to realize a single German culture, a single German nation, and a single German state.". At the beginning of the 19th century, Germany was defeated in the Jena war. The internal and external environment did not allow Germany to develop gradually according to the British market economy model. It had to rely on the national strength to take the unique road of leapfrog catch-up. Liszt, an economist who has a profound influence on the choice of the way of Germany's rise, puts forward the concept of comprehensive productivity and spiritual capital. He thinks that the country

must develop sustainable productivity, and the core lies in cultivating useful talents. He believes that investment in wealth creating productivity is more effective than investment in wealth production itself. "Wealth creating productivity is more important than wealth itself. I don't know how many times." he emphasizes the revitalization of education to improve the "culture, industry and power" of the people. "Most of the consumption of a country should be used for education of the next generation, This is the earliest form of human capital investment. Liszt's educational ideas are not only widely practiced in Germany, but also his "spiritual capital" has become the rudiment and pioneer of modern human capital theory.

## **5.2. Education Reform Continued to Advance**

1809 Germany carried out the education reform in, established a complete education mode managed by the government, and became the first country to recover the right of education from the church "William Humboldt, the father of German education, proposed that primary education should develop students'; rationality and moral sentiment, secondary education should pay attention to the teaching of natural science, and university education should adhere to the three principles of "independence, unity of freedom and cooperation, and unity of teaching and research", which not only greatly promoted the rapid improvement of German human capital, but also had a revolutionary impact on modern educational thought. The key points of this educational reform are: to popularize primary education and improve the cultural quality of the whole nation; we should reform and improve the education plan of complete middle schools, strengthen patriotism education, set up a school year system and curriculum, and establish a system of examination, promotion and repetition; taking Berlin University as the main body, we should implement the system of professors'; Association, establish the central position of philosophy school, introduce natural science courses, and clarify the freedom of teaching and learning. In 1859, Prussia officially set up modern schools, added modern science courses, and expanded the scale of education, expanding secondary education from a few privileged levels to ordinary people. After Bismarck, the "iron Prime Minister", came to power in 1862, he issued a series of imperial education decrees to strengthen the reform of education and rectify the way of education. The key points are: to popularize compulsory education in primary schools, eliminate illiteracy and improve the quality of the whole people; we should set up diversified middle schools, encourage vocational schools and adult spare time schools, and cultivate all kinds of urgently needed technical talents; a large number of technical universities and comprehensive universities were established to train teachers and high-tech talents. Generally speaking, several educational reforms in Germany in the 19th century realized the combination of education with state power and social needs, which laid a solid foundation for German industrialization.

## **5.3. The Investment Is Increasing**

After the defeat of Jena, Prussia ceded territory to make reparations, and the national economy faced a huge crisis. However, King William III of Prussia claimed that "the country's material losses should be compensated with spiritual strength", "it is precisely because of poverty that education is the best way to get rid of poverty", which has been widely supported by all sectors of society. In 1809, the government put forward special funds to carry out education reform, paying 150000 taels a year to set up the University of Berlin, and then increased. In 1838, Prussia spent as much as three million thalles on education. After the reunification of Germany, the investment in education increased further, reaching 96 million tales in 1880, accounting for 1.6% of the national GDP, and increased to 1.9% in 1900. The growth rate of education funds and the proportion of national GDP were in the forefront of the world at that time.

Investment in industrial talents and civil servants is also increasing. In 1816, Prussia implemented the "industrial upgrading plan", the main measures include: providing subsidies for travel abroad, especially in Britain, training young people in technical colleges, subsidizing engineering and technical personnel, and starting companies. The program provides subsidies for the creation of research institutes, exhibitions, students and companies, and even in some areas, awards for patents and monopolies. In 1873, Germany promulgated the imperial official law, which reformed the civil service system. The selection criteria, knowledge and discipline of officials were more strict, and their salaries and pensions were guaranteed in detail. Even when the work department was cancelled temporarily for some reason, the officials retired temporarily to receive the pension.

## **5.4. The Mode of Social Security Has Been Gradually Established**

After the reunification of Germany, the industrial workers grew rapidly with the process of industrialization, but at that time, the wages of German workers were much lower than those of Britain and France. In order to maintain social stability, Germany reformed the social security mode. The "big insurance law" was promulgated to provide comprehensive social protection for workers, and special legislation was made to solve the welfare problems of workers, such as diseases (1883), accidents (1884) and pension (1889). The main features are as follows: first, compulsory social insurance, with the state as the main body, distributes and redistributes national income through compulsory legislative means; second, it is managed by social legal person organization rather than private organization; third, the insurance fund is mainly provided by the insured and relevant units; fourth, the amount of insurance depends on the region and income. In 1911, Germany integrated these acts into a single German imperial code, forming the world's first complete set of social insurance methods, which became the object of learning and imitating in European countries.

## 6. Conclusion

In the mid to late 19th century, the advantages of human capital created by German culture, education and science and technology highly matched the needs of national development, which not only effectively promoted the industry and economy, but also greatly enhanced the military strength and comprehensive national strength. When commenting on Prussia's victory in the dynastic war, Paul Kennedy pointed out that it was "the victory of the military system", "but the backing of all this was such a nation: it had a much higher level of primary education and technical education, its universities and scientific facilities were unparalleled, and its chemical laboratories and research institutions were second to none". It can be said that the advantages of German human capital not only played an important leading, creating and promoting role in the three dynastic wars, but also in the whole process of the rise of Germany in the 19th century.

From the experience of Germany, human capital has a fundamental impact on the rise of a country. The general logic is that the rise of a country needs strong comprehensive national strength and good social order. The comprehensive national strength mainly comes from economic creation. The potential of economic creation lies in the quantity and quality of population and resources. The vitality of economic creation comes from the effective market mechanism and government behavior to encourage innovative talents and innovative activities. The emergence of innovative talents and innovative activities requires a large number of high-quality citizens and excellent national spirit. The cultivation of national quality and national spirit comes from long-term investment in education, culture, training, health and medical treatment. At the same time, a good social order stems from the optimization and reasonable flow of social strata. The premise of flow is fair opportunity, effective stimulation and perfect social security, which is the institutional mechanism to promote people to make the best use of their talents and live and work in peace and contentment. When a country's human capital has accumulated to a certain extent and formed a greater advantage, and under the implementation of appropriate national strategies or even seemingly accidental historical opportunities, the vitality of human capital has been fully released, leading to the release of social creative potential and national economic potential, which often opens the road to the rise of the country.

## Acknowledgements

Research project of social science planning in Shandong Province. Thanks for the support of Shandong Academy of Social Sciences. Collaborative innovation research on major theoretical and practical issues of social science planning in Shandong Province in 2020 "Research on the high quality development of economy promoted by Finance". (20CCXJ24)

## References

- [1] Becker S O, Grosfeld I, Grosjean P A, et al. Forced Migration and Human Capital: Evidence from Post-WWII Population Transfers [J]. Social Science Electronic Publishing.
- [2] Bond, M., et al. "Digital transformation in German higher education: student and teacher perceptions and usage of digital media." *International Journal of Educational Technology in Higher Education* 15.1 (2018): 48.
- [3] Dittmar, J. E., and R. R. Meisenzahl. "Public goods institutions, human capital, and growth: evidence from German history." LSE Research Online Documents on Economics (2020).
- [4] Mincer, J. 1958. Investment in human capital and personal income distribution. *Journal of Political Economy* 66 (August): 281–302.
- [5] Mincer, J. 1974. *Schooling, experience and earnings*. New York: Columbia University Press.
- [6] Mincer, J. and S. Polachek. 1974. Family investment in human capital: Earnings of women. *Journal of Political Economy* 82 (2) Pt II: S76–S108.
- [7] Maurseth, Per Botolf, and B. Frank. "The German Information and Communication Technology (ICT) Industry: Spatial Growth and Innovation Patterns." *Regional Studies* 43.4 (2009): 605–624.
- [8] Moglie, M. L., L. Mencarini, and C. Rapallini. "Does income moderate the satisfaction of becoming a parent? In Germany it does and depends on education." *Journal of Population Economics* (2018).
- [9] Poelhekke, Steven, "Human Capital and Employment Growth in German Metropolitan Areas: New Evidence" *REGIONAL STUDIES*, 47: 2 (2013), 245–263.
- [10] Prantl S, Spitz-Oener A. The Impact of Immigration on Competing Natives' Wages: Evidence from German Reunification [J]. *The Review of Economics and Statistics*, 2020, 102.
- [11] Roy I, D Consoli. Employment Polarization in Germany: Role of Technology, Trade and Human Capital [J]. *Jena Economic Research Papers*, 2015.
- [12] Schultz, T. 1961. Investment in human capital. *American Economic Review* 51 (March): 1–17.
- [13] Stein, Volker. "Human Capital Management: The German Way." *Zeitschrift Für Personalforschung / German Journal of Research in Human Resource Management*, vol. 21, no. 3, 2007, pp. 295–321.
- [14] Scholl, T., T. Brenner, and M. Wendel. "Evolving localization patterns of company foundations Evidence from the German MST-industry." *Journal of Evolutionary Economics* 26.5 (2016): 1–21.
- [15] Souza, W. D., and B. Gabriel. "Immigration and the path dependence of education: the case of German-speakers in So Paulo, Brazil (1840–1920)." *Economic History Review* (2018).
- [16] Vehrke F J. Fostering place-based innovation and internationalization – the new turn in German technology policy [J]. *European Planning Studies*, 2018.