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Technological Innovation, Entrepreneurship and Productivity in Germany, 1871-2015

Wim Naudé* Paula Nagler†

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Abstract

Entrepreneurship in Germany has been stagnating. As a result, the effectiveness of technological innovation to improve labor productivity weakened, which has been implicated in rising income inequality and poverty. In this paper we provide an overview of technological innovation and labor productivity growth from 1871. From this we show that over the past three decades the economy has found it increasingly difficult to transform technological innovation into labor productivity growth: in glaring contrast to earlier periods. Despite higher spending on R&D and more personnel than ever working in research labs, labor productivity growth continues to decline. Two interrelated reasons are offered for this phenomenon. The first is that the national innovation system itself has certain weaknesses. The second is entrepreneurial stagnation. We discuss the weaknesses of the innovation system and the nature and causes of entrepreneurial stagnation. We call for policies that will improve the innovation system, educational and managerial capabilities, venture capital investments, and the contestability of markets. Strengthening social protection and raising real wages are important supportive measures.

JEL Classifications: D31, L26, O33, O38, O52
Keywords: Entrepreneurship, Germany, Innovation, Social Protection, Industrial Policy

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1 Introduction

How entrepreneurial is Germany nowadays? Europe's single largest economy has fared remarkably well over the past decade. Its low unemployment rate, huge current account surplus and world-renowned manufacturing sector have been the envy of its EU partners. It has been proposed that the country's economic performance is based on its entrepreneurs. Audretsch and Lehmann (2016b, p.302) for instance claim that the country's economic performance is the result of 'a vibrant entrepreneurship scene [...] the most dynamic in continental Europe', and that entrepreneurship is 'blossoming in Germany'.

Audretsch and Lehmann (2016b) are unfortunateley wrong in this. Instead of 'blossoming', entrepreneurship has in fact been stagnating in Germany. As a result the ability of the economy to turn technological innovations into labor productivity growth has been weakening. This is a concern for two reasons: First, the recent economic success of the country may be instead based on more fragile foundations than is generally accepted, masking certain fundamental shortcomings. For instance, the innovation system may not be as successful as earlier, if one considers the following. In 2013 businesses spent around EUR 145 billion on innovation (Rammer and Schubert, 2016); spending on R&D more specifically increased by 66 percent since 2000; more than 400,000 people are working in research labs. However, in spite of this the labor productivity growth rate was five times lower in 2013 than in 1992 (Naudé and Nagler, 2017). It may be that the success of the economy may be more to do with dependence on an exporting model facilitated by having the Euro as currency, rather than on innovation-driven entrepreneurial growth. In this regard Burda (2016) recognises correctly that '[t]he German success story is context dependent [...]. A 30 to 50 percent appreciation of a new Deutsche Mark would pose a serious challenge to the survival of the SME model'.

The second reason to be concerned is that declining labor productivity growth has led to rising inequality and poverty. All indicators of poverty and inequality have worsened over the same time that labor productivity growth has been declining. With labor productivity unable to keep pace with that of competing countries, the national response in Germany has been to reduce real labor compensation through labor market and social policy reforms, which improved short-term employment prospects against the long-term costs of decreased labor productivity and sluggish domestic demand growth (Naudé and Nagler, 2017). In this light, improving the effectiveness of innovation and entrepreneurship should be key policy objectives.

We make our case as follows. First, in Section 2 we provide an overview of technological innovation and growth in German over the long period 1871 to 2015, since the establishment of Germany as a modern state at the end of the 19th century. The German economy was founded on a successful collaboration between the state, businesses and universities that allowed entrepreneurs to be very innovative, and, importantly, turn these innovations into large and successful businesses wherein labor could be productively absorbed. Increasingly after the Second World War, however, and at accelerating pace since reunification, the nature of innovations has started to change, and the ability of entrepreneurs to turn innovations into businesses or products that would result in maintaining labor productivity growth, has declined.

In Section 3 we identify and discuss two main interrelated reasons for this phenomenon. The first is that the national innovation system itself has certain weaknesses, as reflected in the declining number and quality of patents granted and declining total factor productivity growth. Underlying these weaknesses we identify historical reasons, defensive corporate strategies, weaknesses in the education system and the slow erosion of social welfare. The second reason for the declining ability of innovation to raise labor productivity growth, is entrepreneurial stagnation. This is due to declining 'Schumpeterian' innovation and a growing productivity gap between leading and lagging firms.

Section 4 contains a summary and policy recommendations. We conclude by calling for policies that will improve the innovation system, educational and managerial capabilities, venture capital investments, and the contestability of markets. Strengthening social protection and raising real wages are important supportive measures.

2 Trends in technological innovation, productivity and growth in Germany: 1871 to 2015

Technological innovation has historically been an important source of productivity and economic growth in Germany. A series of remarkable breakthrough product innovations in the late 19th and early 20th century laid the foundation for virtually the entire modern German economy. In the period before World War I rapid technological innovation resulted in the establishment of world-leading businesses and in accelerating economic growth. In contrast, after World War II, although the country experienced an initial period of reconstruction-growth known as the 'economic miracle', the nature of technological innovation was different and its impact on labor productivity steadily declined. We document these trends in this section.

2.1 Breakthrough innovations and the era of entrepreneur-engineers: 1871 to 1914

The period between the establishment of the modern German state in 1871 and the outbreak of the First World War in 1914 saw Germany's industrialization (Beise and Stahl, 1999)[1], and coincided with the 'first era of globalization' (Twarog, 1997). By all accounts Germany was still an 'industrial backwater' around 1850. Bairoch (1982, p.284) documents that Germany was still lagging behind the United Kingdom, the United States, China, India, France, and Russia in terms of manufacturing output

[1] Although Germany's industrial revolution started around 1850, various types of manufacturing activities and 'pre-industrialization' pockets can be found before this time. As Ogilvie (1996) points out, the regions around Nuremberg were containing fairly advanced manufacturing hubs for the time, and parts of the Rhineland and Saxony were industrializing on small-scale by 1780.

by 1860. One century later, however, Germany had not only caught-up and transformed, but had also become the world's leading innovator. Table 1 summarizes some of the remarkable radical innovations, invented and often commercialized by entrepreneur-engineers, with as we will elaborate below, the support of a developmental state and dynamic educational system.

Table 1: Radical innovations in Germany, 1871 to 1913

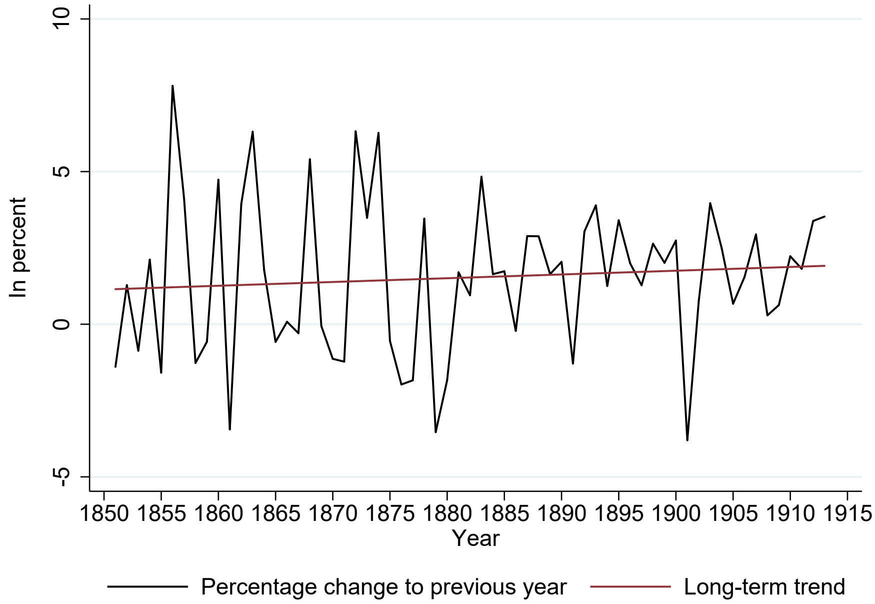
Entrepreneur-Engineer	**Radical Innovation**
Ernst Abbe (1840-1905)	Optic lenses
Albert Ballin (1857-1918)	Shipping lines (established the world's largest shipping company by 1900)
Andreas Bauer (1783-1860)	Steam powered printing press
Karl Benz (1844-1929)	4-stroke automobile engine
Melitta Bentz (1873-1950)	Coffee filter
Robert Bosch (1861-1942)	Spark plug
Gottlieb Daimler (1834-1900)	Internal combustion engine, motor cycle
Rudolf Diesel (1858-1913)	Diesel engine
Alfred Einhorn (1856-1917)	Novocaine
Paul Ehrlich (1854-1915)	Chemotherapy
Adolf Fick (1852-1937)	Contact lenses
Carl Gassner (1855-1942)	Dry cell battery
Hans Geiger (1882-1945)	Geiger counter
Heinrich Hertz (1857-1894)	Antenna
Fritz Hofmann (1871-1927)	Synthetic rubber
Felix Hoffmann (1868-1946)	Heroin and aspirin
Christian Hülsmeyer (1881-1957)	Radar (telemobiloscope)
Alfred Krupp (1812-1887)	No-weld railway tires, steel (by 1900 his company was the largest in Europe)
Heinrich Lanz (1838-1905)	Oil-fueled tractor
Julius Pohlig (1842-1916)	Cable car
Wilhelm Röntgen (1845-1923)	X-rays
Werner von Siemens (1816-1892)	Needle telegraph (today Siemens AG is the largest manufacturer in Europe)
Carl Zeiß (1816-1888)	Lens manufacturing

Data source: Authors' own compilation.

As Twarog (1997) documents, real per capita income grew by 15 percent per decade between 1850 and 1913, industrial production achieved a growth rate of 37 percent per decade, and the population living in cities of more than 100,000 people increased from 4.8 percent in 1871 to 21.3 percent in 1910. In just about half a century the Germany economy had been significantly transformed. Moreover total factor productivity (TFP) grew rapidly over this period. Burhop and Wolff (2005, p.640) find that total factor productivity contributed 63.9 percent to total net national product (NNP) growth between 1851 and 1913. And growth in GDP actually accelerated over this period as a result, as Figure 1 shows.

What made all these radical technological innovations summarized in Table 1 possible?

Figure 1: Per capita GDP growth in Germany, 1850 to 1913



Data source: Maddison Project.

Most economic historians agree that Germany's performance was enabled by the rise of its education and scientific sectors, and in particular by the collaboration between educational and research institutions, private entrepreneurs, and the government. Roughly between 1790 and 1840, German scholars, such as Wilhelm von Humboldt, re-created German universities as research institutions - heralding the modern research university - that were different from previous and other universities in its focus on new knowledge generation and innovation. This has been called the 'institutionalization of discovery' (ibid., p.226) and the 'industrialization of invention' (Meyer-Thurow, 1982, p.363).[2]

Science and engineering were preeminent in the best of these universities. Moreover, the 19th century also saw the rise of polytechnical and technical universities (*Technische Hochschulen*), where engineering and applied sciences were paramount. These institutions were widely accessible, and driven by the educated and rising middle classes of that period (Watson, 2010). The first steps were made to create a public research laboratory system in 1887, on the instigation of entrepreneur-engineer Werner von Siemens, namely the *Physikalisch-Technische Reichsanstalt* (Beise and Stahl, 1999). Further organizations of this kind included the *Kaiser Wilhelm Institutes*, established in 1911 on instigation of the chemical industries, to become the *Max Planck Institutes* after the Second World War. This 'industrial research system', influenced as much by entrepreneurs and businessmen as by the government and scientists, was one of the first of this kind in the world (Grupp et al., 2005).

The scientific breakthroughs at universities and polytechnical institutions were quickly

[2] As Watson (2010, p.835) points out, 'the concept of the modern PhD is a German idea', and as stressed by Mroczkowski (2014, p.412), 'the modern research university was actually a German institutional innovation'.

taken up and applied for commercial purposes by German entrepreneurs. One of the first examples were the contributions of scientists such as Rudolf Clausius, Julius Mayer and Hermann von Helmholtz to the understanding of the generation and conservation of energy. Their inventions stimulated entrepreneur-engineers such as Werner von Siemens to establish the firm of *Siemens und Halske* in 1847, which manufactured the world's first pointer telegraph, starting in effect the modern telecommunication industry. In 1851, Siemens invented the dynamo-electrical machine which would contribute to the eventual prominence of power engineering in Germany (Watson, 2010). Similarly, contributions in chemistry and organic chemistry led to the invention of synthetic color dyes, which - helped by the country's large coal reserves - led Germany to become the world's leading manufacturer of color dyes (Meyer-Thurow, 1982).

The color-dyes industry developed into a global leading pharmaceutical industry with firms such as the *Badische Anilin & Soda-Fabrik* (*BASF*), *Bayer*, and *Höchst*, introducing famous inventions such as the aspirin. The chemical and pharmaceutical industries led the way to the establishment of private industrial research laboratories with the main purpose to invent and apply new inventions commercially (Meyer-Thurow, 1982). In 1891, for instance, the firm of *Bayer* established its own industrial research laboratory under the direction of Carl Duisberg; this laboratory was described as being superior to 'every university laboratory then in existence', although it relied on the universities to supply it with PhD chemists (ibid., p.370).

The legacy of all these innovations have endured into present-day Germany: many of the largest German industrial firms in the post 1950 period trace their roots back to this time, such as *Siemens AG*, *Bosch AG*, *Bayer*, *Mannesmann*, *AEG*, *Thyssen*, and many others.

The examples given in the text and in Table 1 reflect the close cooperation between higher education and industry that was established during the period 1871 to 1913. This 'organizational' innovation was complemented by further organizational changes in the German industry, such as the establishment of cartels ('Interessengemeinschaft') that fixed prices and market shares, and which, according to Watson (2010), helped to fund the R&D activities undertaken by the growing industrial companies. The extent of privately funded R&D activities increased substantially and led to the establishment of various private research laboratories. One of these research labs, of *Bayer*, held around 8,000 patents by 1913 (Meyer-Thurow, 1982).

The third partner in the emerging innovation system after 1871 was the government. Not only did the national and state governments (i.e. the 'Länder') support universal education, but they also played what many considered the igniting role in Germany's industrialization through the promotion of the country's railway system (Fohlin, 1998). The railways created a large demand for steel, engines and machinery, but also for coal and coal-based energy (of which the country had plenty), and helped, in turn, to reduce transport costs, and hence improve the competitiveness of all industries and trade (Kopsidis and Bromley, 2016). By 1913 the largest employers in Germany were state-owned enterprises such as the *Prussian-Hessian Railway* (employing more than 500,000 workers) and the *Deutsche Reichspost* (employing more than 300,000 workers) (Labuske and Streb, 2008). Since a degree was a requirement for many government job, the higher education system experienced a huge boost, and confirmed its importance as a central pillar of the development of the economy and the civil society.

Mechanical engineering and specifically machinery manufacturing received an important impetus from the establishment of the railways, and at the same time, from the emerging innovation system. As a result, Germany was able to expand into international markets. Labuske and Streb (2008) find a significant impact of innovation (as measured by R&D expenditure) on the development and export growth of the machinery industry between 1870 and 1913. By the latter date, the exports of machinery were the single largest category of exports from Germany, and the country was the world's largest exporter of machinery. The beginning of Germany's manufacturing export model is thus to be traced back to this era.

The machinery industry was also highly innovative, with half of the most innovative firms of that time located in this sector (Labuske and Streb, 2008). Many of them are still prominent in Germany, for instance the *Heinrich Lanz AG*, producing agricultural machinery (taken over in the 1950s by *John Deere*), *Demag* (*Deutsche Maschinenbau-Aktiengesellschaft*) producing industrial cranes, *Rheinmetall AG*, producing automotive parts and weapons, and the *Bosch AG*, the largest producer of automobile parts. In 1890 the *Deutsch-Österreichische Mannesmannröhren Werke AG* was established to produce steel pipes. This company would develop into the industrial conglomerate *Mannesmann AG* that was taken over in 2000 by *Vodafone* for EUR 190 billion, the largest amount ever paid in an acquisition in Europe until that time.

More generally, the creation of the German Empire in 1871 centralized government and further increased economic freedom and entrepreneurship that had already started in the late 18th century, through the diminishing control of various industrial and trade guilds that were stifling competition and innovation (Ogilvie, 1996; Kopsidis and Bromley, 2016).[3]

Although some state governments granted patents from around 1812 onward, it was only in 1877 that the first Germany-wide (unified) patent legislation was enacted by the new centralized government. This was important in terms of creating incentives for research, and also of creating a tradable market of innovations to facilitate technological transfer[4] and improve the allocation and distribution of technology (Meyer-Thurow, 1982; Burhop and Wolff, 2013).

It should be noted that destructive events also affected the government's capacity to foster innovation and growth. France repatriation payments (around 5 billion Francs) after the Franco-Prussian War led to a huge inflow of money into the newly established German Empire in the years after 1871. The government, repaying loans to entrepreneurs

[3] Ogilvie (1996, pp.286-287) describes the depressing impact of the guilds on innovation by explaining how 'the Remscheid scythe smith's guild successfully resisted the introduction of water-driven scythe hammers in the 18th century'. The guilds were an outcome of the Thirty Years' War which 'forced German Princes to grant and enforce privileges to powerful institutions and groups [...] in exchange for fiscal, military and political support'. They 'prevented the emergence of industries in the period between 1600 and 1800' (ibid., p.297).

[4] As noted by Burhop and Wolff (2013) the trade in innovations, as measured by patent assignments, increased by 500 percent between 1889 and 1913.

and businesses that had supported it to finance the war, reinvested these funds on a massive scale to commercialize innovations and invest in the expansions of the railways. As Watson (2010, p.374) notes 'as many new iron works, blast furnaces, and machine-manufacturing factories were built during the three years after 1871, as had come into being during the previous seventy'.

After 1871 corporate legislation was introduced to allow joint stock companies for the first time. This had a decisive influence on the financing of innovation and industrialization, but only towards the end of the 19th century, when big joint stock credit banks such as *Deutsche Bank*, *Dresdner Bank*, and others were founded (Burhop and Wolff, 2005). As Fohlin (1998) shows, it was not the big credit banks or security-issues that funded industrial expansion during the initial stages of Germany's industrialization, but largely own funding, credit-cooperatives, and (outside of Prussia) funding by private bankers that funded entrepreneurial ventures, and the states that funded the expansion of the railways (Edwards and Ogilvie, 1996). The banking system as a whole developed in tandem with the industrial sector during the late half of the 19th century.

Finally, an important 'social innovation' in the years following the establishment of Germany was the establishment of the world's first welfare state (the German 'Sozialstaat'). This was deemed necessary for social stability, and moreover a political *stratagem* to ward off the rising socialist movement. The provision of these measures, which included health care and maternity insurance (introduced in 1883), insurance against work injury (1884) and old-age pension (1889) contributed to social inclusiveness. It also contributed to improving the effectiveness of innovation through facilitating the diffusion of technology and better labor market adjustments. Germany's participation on the First Industrialization was facilitated by an appropriate social welfare system. Its continued success in the Fourth Industrial Revolution will similarly require an appropriate social welfare system.

2.2 Incremental innovations and the era of Mittelstand-entrepreneurship: 1950 to 2015

Between 1914 and the creation of the Federal Republic of Germany with its Constitution in 1949, the economy and its institutions were devastated by the two World Wars. Despite these, many of the pillars of the German Empire, including numerous 19th-century corporate giants and scientific and educational institutions, survived. Under the pressure from the Allied Forces occupying Germany after the Second World War, the *Kaiser Wilhelm Institutes* were renamed *Max Planck Institutes*. Moreover, the Allied Forces limited their mandate to basic research (Comin et al., 2016). To fill the gap in the former 'triple-helix' landscape, the *Fraunhofer Society* (*FhG*) was established in 1949. The *FhG* nowadays consists of a number of research laboratories that conduct applied research and industrial innovation for improving the competitiveness of industry (Beise and Stahl, 1999). Despite its prominence, only a relative small proportion of total R&D in Germany is allocated to the *FhG* (about 2.5 percent of all R&D in 2010).

Grupp et al. (2005) discuss the historical innovation patterns in Germany from 1850 until 2000. They use total scientific expenditure as a percentage of total government expenditure as an indicator for innovation. Scientific expenditure includes R&D, training and teaching costs, and the costs of maintenance and diffusion of knowledge. The authors find that innovation expenditure increased during this period from around 1 percent in 1850 to a maximum of 6.5 percent in the 1970s, before declining to approximately 5 percent at the time of German reunification. R&D expenditure only amounted to 2.4 percent in 2004. When comparing this trend with data on TFP growth for the post-war period (there is no TFP for the pre-war period), it can be seen that TFP growth peaked in the 1970s after which it declined.

Accompanying this decline, Germany has also experienced a decline in manufacturing employment and in the share of manufacturing in GDP. The extent of this de-industrialization process, however, has not been as significant in Germany as, for instance, in the United States, where more than 5 million jobs in manufacturing were lost between 2000 and 2014 (Dauth et al., 2017).

We already showed (in Figure 1) that economic growth accelerated in terms of per capita GDP over the period 1850 to 1913. In contrast, the period 1950 to 2010 saw a deceleration of per capita economic growth as depicted in Figure 2. Initially though, between 1950 and the mid-1970s, average annual GDP per capita growth amounted to 5.0 percent on average. During this period the German economy was described by the term 'Wirtschaftswunder' (economic miracle). Growth was driven by three institutional factors : the reconstruction of the country under the *Marshall Plan*, the introduction of social-market policies, including the model of 'Mitbestimmung' (co-management) in which workers obtained representation in the board of company directors (Comin et al., 2016) and the success of small and medium enterprises (SMEs) from the so-called 'Mittelstand' to grow their exports to global markets.

The term *Mittelstand* refers to the small- and medium-sized enterprises that form the bulk of manufacturing enterprises in the country. They have a number of characteristics in common, which are referred to as 'enlightened family capitalism', such as family (private) ownership, long-term orientation, social responsibility, and an excellent focus on customer care (Fear et al., 2015, p.13). Today more than 70 percent of Germany's exports come from *Mittelstand* firms. Over time, many of these firms became world leaders in their field, being described as Germany's 'hidden champions' (Simon, 2009). Fear et al. (2015) argue that the success of *Mittelstand* firms was not so much driven by their innovative abilities, as by doing 'good business': Their focus on customer needs and quality, reliable products, and services. By 2015 the top 20 'hidden champions' employed around 72,000 workers, as Table 2 shows.

Despite these institutional features and the rise of the Mittelstand with its 'hidden champions', growth eventually declined to an average of 2.0 percent between 1975 and 1990, and further to 1.0 percent between 1990 and 2010. During this latter period Germany was even labeled the 'Sick Man of Europe'.

Audretsch and Lehmann (2016a) point out that even before the unification German 'competitiveness began to sag', and that while everybody had expected a 'peace dividend'

Table 2: The top 20 hidden champions in Germany, 2015

Company	**Sector (product)**	**Turnover in mio EUR (latest)**	**Employment (latest)**
Herrenknecht	Machinery (tunneling)	1,300	4,955
Otto Bock	Health care (mobility)	1,000	7,614
Lürssen	Shipbuilding	829	1,635
Delo	Chemicals	80	500
Windmöller & Holscher	Machinery (flexible packaging)	500	2,000
Grimme	Agricultural machinery	438	2,200
Haver & Boecker	Machinery	470	2,870
Duravit	Ceramics	380	5,700
Kaeser Kompressoren	Machine tools	650	5,000
Peri	Construction tools	873	5,300
Schunk	Machine tools	360	2,700
Dorma	Construction materials	856	6,500
Sick	Industrial sensors	1,000	6,597
Mennekes	Industrial plugs	100	800
Abeking & Rasmussen	Shipbuilding	na	393
KWS Saat	Biotechnology	1,003	4,843
Renolit	Chemicals	410	4,500
Sennheiser	Audio equipment	385	2,100
Max Weishaupt	Energy	540	3,000
Big Dutchman	Agricultural machinery	905	2,853
Total		**7,780**	**72,060**

Data source: Authors' own compilation.

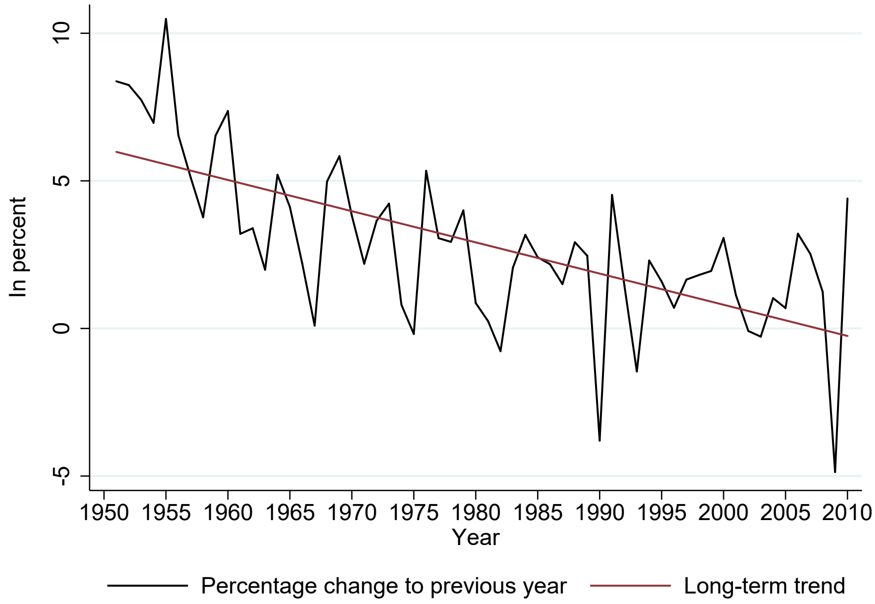
after the unification and end of the Cold War, this never materialized, because the reunification process was accompanied by a negative shock to labor productivity. This was a result of the re-integration of workers from the former East Germany, whose productivity were 40 to 70 percent of that of West German workers. This negative productivity shock occurred just as the country was 'exposed to new global competition' at the end of the Cold War (ibid., p.4).

Figure 3 shows that the percentage change in real labor productivity per hour worked has been on a long-term decline since the 1990s. Labor productivity growth rates were five times lower in 2013 than in 1992.

Figure 4 contrasts the index of labor productivity, showing that it has overall declined since 2004 (relative to the EU 28 countries), dipping after the Great Recession in 2008/2009, with R&D intensity, defined as the gross domestic expenditure on R&D, which increased considerably over the same period, especially since the mid-2000s, peaking at almost 3 percent in 2014.[5] The figure makes clear that R&D expenditure (innovation),

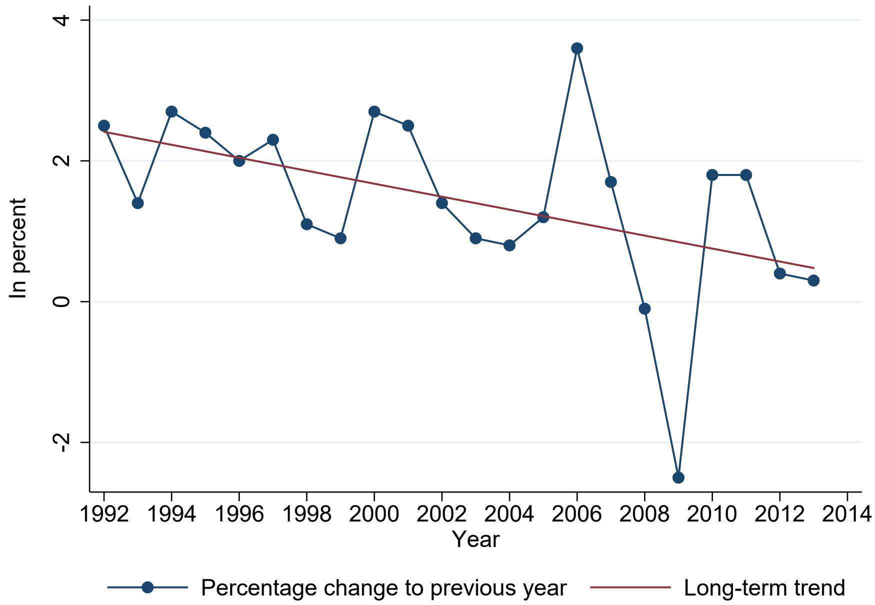
[5] These declines in productivity are highly unlikely, as some have argued, to be due to mismeasurement of the value-added effects of ICT technologies. Syverson (2017) contrasts these arguments, concluding that '[f]or the mismeasurement hypothesis to explain the productivity slowdown [...] current GDP

Figure 2: Per capita GDP growth in Germany, 1950 to 2010



Data source: Maddison Project.

Figure 3: Percentage change in real labor productivity per hour worked in Germany, 1992 to 2013



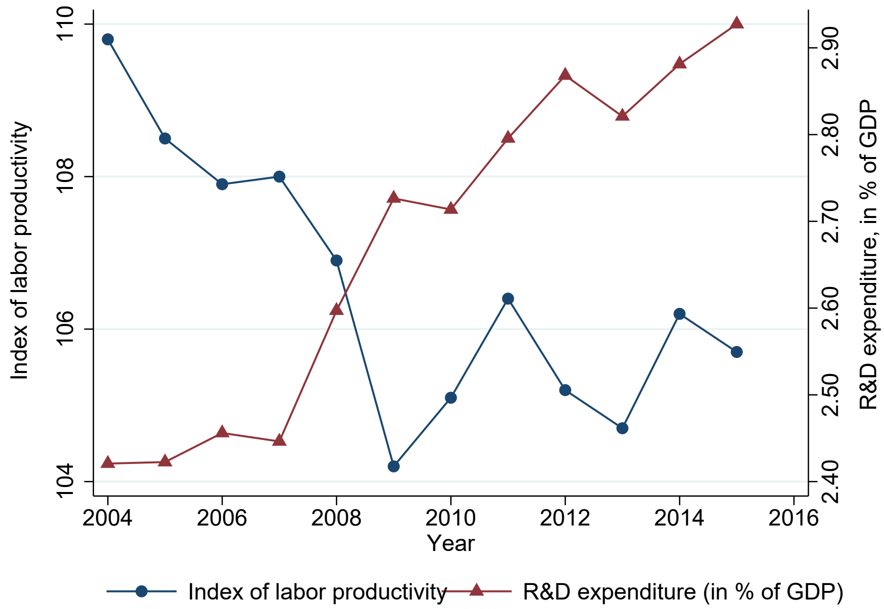
Data source: European Commission AMECO database online.

since 2004 at least, has not contributed to raising labor productivity relative to other European countries.[6]

measures must be missing hundreds of billions of dollars in incremental output'.

[6] Bloom et al. (2017, p.46) similarly find that research productivity declined in the United States over the period 1930 to 2000, stating that '[j]ust to sustain constant growth in GDP per person, the US

Figure 4: Labor productivity per person employed and R&D expenditure in Germany, 2004 to 2015



Data source: Eurostat (Index of labor productivity) and OECD (R&D expenditure). *Notes*: Nominal labor productivity per person employed and hour worked (EU28 average=100 in each year).

What have been the reasons for the decline in labor productivity growth in Germany since the 1970s? In the next section we provide evidence that it has been due to weaknesses in the innovation system and the stagnation of entrepreneurship [7].

3 Explaining the decline in German productivity growth

There are two interrelated reasons for the decline in German productivity growth as documented. The first is weaknesses in the innovation system. The second is entrepreneurial stagnation. We discuss these two sets of reasons in the following subsections.

must double the amount of research effort searching for new ideas every 13 years'.

[7] There is some discussion in the literature on the decline in labor productivity growth in the United States where it has been claimed that the productivity slowdown could be due to mismeasurement of ICT innovations. A number of recent papers however reject the 'mismeasurement hypothesis'. For instance Byrne et al. (2016) finds that if they adjust for possible mismeasurement of IT hardware that it makes 'the slowdown in labor productivity worse' and Byrne et al. (2017, p.4-5) conclude that 'if the pace of innovation in high-tech sectors has been more rapid than indicated in official statistics then it is perhaps even more puzzling that overall labor productivity growth has been sluggish in recent years'.

3.1 Weaknesses in the innovation system

This subsection is organized as follows. First we outline the weaknesses in the German innovation system using various measures of innovation. Then we discuss four reasons for the decline in the innovation system. We conclude this subsection by asking what should and can be realistically done to fix this.

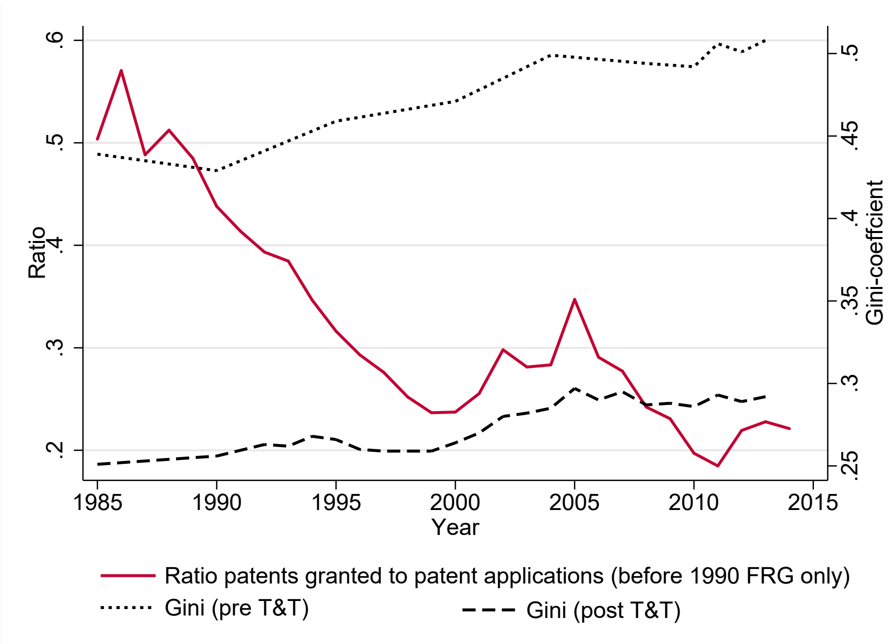
3.1.1 Measures of innovation over time

Using different measures of 'innovation' we can paint a consistent picture of Germany as a country that is generating less and less effective innovations, despite the government and corporate sector channeling significant amounts of investment into innovation.

We first use patent data, an often used 'output' indicator of innovation. An important distinction is between patent applications and patents granted. The difference lies in the ratio of successful (granted) patents to patent applications, which is shown in Figure 5. The figure shows that the recent trend in Germany has been a reduction in the ratio of patents granted relative to patent applications.

In absolute terms the number of patent applications increased from around 43,100 in the mid-1980s (FRG only) to almost 66,900 in 2014, but the number of successful (granted) patents decreased from around 21,700 in the mid-1980s to only 14,800 in 2014. In other words, Germany has experienced a decline in the number of 'successful' innovations.

Figure 5: Ratio patent applications to patents granted and the Gini-coefficient in Germany, 1985 to 2014



Data source: WIPO (Patents) and OECD (Gini-coefficient). *Notes*: From the mid-1980s to the German reunification in 1990, only patent data from the FRG.

To the extent that the decline in successful (granted) patent applications reflects a decline in innovativeness, the broad reasons are discussed in the next section. It can be however noted that patents are far from being a perfect measure of innovativeness, and that some caution is warranted in making strong conclusions. First, because patent offices may be simply getting stricter, and second, because the growth in the number of patent applications might not be driven by quality. Instead they could reflect a legacy of the *Arbeitnehmererfindergesetz* (German Employee Invention Act), through which firms tend to apply for patents on employees' ideas, irrespective of whether they merit the effort or not.

There is strong evidence that the quality of German patents may be declining. A common measure the quality of a patent is the average number of citations that it has received over a period of time. Using this measure and data from the USPTO Kwon et al. (2017) finds that the quality of Germany's patents as against the United States has been in continuous decline. For instance, in the 1980s patent citations were on average 14 percent lower, in the 1990s 30 percent lower, and in the 2000s even 41 percent lower. This decline was steeper than that of the United Kingdom and Japan, while emerging Asian countries, in contrast, have improved their position in the global patent quality ladder.

A second, 'indirect' measure of innovation is total factor productivity (TFP). TFP growth has been declining in Germany since the 1970s, to a growth rate of only 0.5 percent *per annum* over the past ten years (OECD, 2016). As the OECD (2016, p.6) notes, TFP growth is on a long-term decline in Germany since the 1970s. Over the period 1996 to 2005 TFP growth in Germany averaged 0.4 percent, which puts it on the 34th position out of 37 OECD countries. Only Portugal, Italy and Spain did worse.

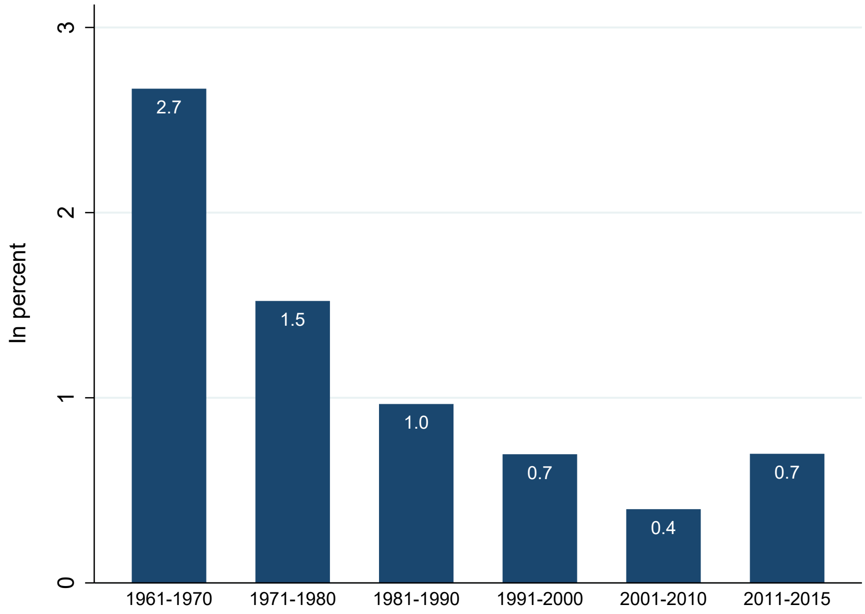
Figure 6 shows that German TFP grew annually by over 2.5 percent on average between 1961 and 1970. This growth declined over the subsequent decades, with the lowest annual growth rate experienced from 2001 to 2010, amounting to only 0.4 percent. Recently annual TFP growth has seen a moderate increase, rising to an average of 0.7 percent between 2011 and 2014, the same rate as in the decade from 1991 to 2000.

The 1960s were thus, at least measured by TFP, Germany's period of 'peak innovation', although there was no comparable list of breakthrough innovations as in the period from 1850 to 1913. The decline from the late 1970s onward, and especially since the 1990s, may be explained by a lack of radical innovations in the field of ICT (defining the 'third industrial revolution'), a slower diffusion of technology, and a slower capacity to learn and adapt new technologies, as the OECD (2016) posits - which may also reflect the relatively slower growth in high(er) skills in Germany over this period. Baumgarten (2013, p.5) finds that the 'German establishments invested more in technology during the 1980s than during recent years [...] while 34 percent of firms invested in ICT in 1996, only 29 percent did so in 2010.'

Although Germany today is a leader in traditional and medium technology industries such as automobiles, printing press and machine tools, it is not an innovation leader in semiconductors, computing, 3D-printing, nanotechnology, robotics or molecular biology - the drivers of what has been termed the 'fourth industrial revolution' or 'Industrie 4.0'[8]

[8] The term 'Industrie 4.0' is ascribed to Henning Kagermann, head of the German Academy of Science

Figure 6: Average annual TFP growth in Germany, 1960 to 2015



Data source: European Commission AMECO database online.

(Mroczkowski, 2014).

Data from the World Intellectual Property Organization (WIPO) show that only four German firms are among the top 30 innovative companies in the areas of 3D-printing, nanotechnology and robotics, as measured in terms of patent applications. Three of these are in 3D-printing, namely *Siemens*, *MTU Aero Engines* and *EOS*; and one in robotics, *Bosch* (WIPO, 2015). Increasingly, German firms lag behind those from the United States, Japan, South Korea, and also China. The WIPO (2015) notes that 25 percent of all patent applications in 3D-printing and robotics, and 15 percent in nanotechnology have been made by Chinese firms since 2005. Moreover, the top 20 patent applicants in nanotechnology do not include a single German firm since 1970.

Why did Germany's innovation system decline in its effectiveness after World War II? There are four likely reasons.

3.1.2 The historical context

The first is the historical context, and specifically the impact of the Second World War. According to Fohlin (2016, pp.18-19) World War II can be seen as a structural break in Germany's innovativeness. This is because of the destruction resulting from the war, the effects of the Cold War, the division of the country until 1990, and the subsequent costs of reunification. As a result of this particular combination, the author concludes that 'Germany could not pour large portions of its national resources into risky investments in research and development of new technologies'.

and Engineering (Acatech) (The Economist, 2015).

Germany also experienced a significant *brain drain*, when highly skilled labor fled the country during and after the Nazi period (Fohlin, 2016). The detrimental and long-run impacts of the human capital loss on Germany's skills are discussed in Moser et al. (2014) and Waldinger (2016). Moser et al. (2014, p.3222) document that '[b]y 1944, more than 133,000 German Jewish émigrés found refuge in the United States' and show that in the field of chemistry, for instance, their contributions made a significant impact on US patenting.

Waldinger (2016) estimates that the dismissal of Jewish scientists, including eleven Nobel Laureates such as Albert Einstein, Max Born, Fritz Haber and Otto Meyerhof, from public institutions by the Nazis after 1933, had a long-term negative impact on scientific output. Furthermore, after the Second World War, the Allied Forces required research institutes to focus only on basic research, to the detriment of application and commercialization. As various historians point out: what disadvantaged Germany, advantaged the United States.

3.1.3 Defensive corporate strategies

The second reason for the decline in the effectiveness of innovation is the changing nature of innovation undertaken by firms, which is a result partly of historical factors, but also of entrepreneurial stagnation caused by defensive corporate strategies. We discuss this in more detail in the next section. For now however, from the innovation point it is the case as Breznitz (2014) discusses, that the German innovation system 'got stuck' at producing primarily incremental innovations in existing (and old) industries, rather than radically innovating and creating new industries and markets. As an example, Meyer-Thurow (1982, pp.380-381) can be quoted, who conducted a case study of the pharmaceutical giant *Bayer AG* and concludes that the company's innovation system was,

> '[e]xtremely effective at maintaining and extending the company's superiority whenever it had established itself in the market [...]. But when Bayer tried to break into markets established by other companies or break new technical and scientific ground, industrial research proved less effective [...] industrial research was not a master key to entrepreneurial growth.'

Not only was incremental innovation the choice of strategy of the large corporate giants, but also of the *Mittelstand*. Most *Mittelstand* firms have historically clustered around the traditional late 19th and early 20th century giants of the German economy such as the automotive, machine engineering, electricity, and chemical industries. Many of these firms were also founded during this era, or even before, although for different reasons. The model of incremental innovation is part of the strategy of the *Mittelstand* to remain internationally competitive on the basis of quality, not costs. German firms therefore continuously innovated to improve their existing products and services, but not to introduce novel products *per se*. This focus on quality has been described as a 'razor-thin focus on just a single product' (Girotra and Netessine, 2013). As Fear et al. (2015, p.12) explain,

> 'By and large, German companies are not pioneering leaders in basic innovations [...] rather they demonstrate technological excellence by applying basic innovations to solve customer-specific needs, and in the meticulous and customer-driven perfection of traditional products.'

By combining incremental innovation to produce specific products of exceptional quality and a focus on customer needs, in the context of a growing globalization of the world economy in the 20th century, the international export focus provided these *Mittelstand* firms with the possibility to make use of economies of scale. These firms are hugely benefiting from the adoption of the Euro as currency, which together with their service-focus (see Section 2.2) have turned Germany into a 'hyper-competitive' economy (Dubner, 2017).

3.1.4 Weaknesses in education

The third reason for the decline in the effectiveness of Germany's innovation system is due to weaknesses in its education system. The weaknesses of a generally much-praised education system have been reflected in the relatively poor and, at times, even declining rankings of Germany in global skills rankings.

In terms of the Global Talent Index, for instance, Germany is ranked 16th in the 'Creative Class Ranking', 28th in the 'Talent Ranking', and only 38th in its 'Educational Attainment' (Florida et al., 2015). In the Global Index of Cognitive Skills and Educational Attainment Germany ranked 12th out of 39 countries in terms of 'Cognitive Skills', measured by Grade 8 PISA (Programme for International Student Assessment) Scores and Grade 4 PIRLS (Progress in International Reading Literacy Study) and TIMMS (Trends in International Mathematics and Science Study) achievements in sciences and mathematics, in 2014. The country's score in the 'Index of Cognitive Skills' declined from 0.56 to 0.48 between 2012 and 2014.

These relatively poor outcomes may reflects that the education system may be too specialized and intertwined with the current industrial structure; and second, that the education system itself may be 'un-entrepreneurial' and too bureaucratic, and hence not adjusting flexibly enough to the challenges that the economy is facing.

The specialization of the German education system is rooted in the important role of manufacturing within its economy. Manufacturing value-added contributed 23 percent to GDP, and manufactures exports 84 percent to merchandise exports in 2016; 28 percent of its labor force was employed in industry, consisting of manufacturing, mining and construction 2015.[9] Iversen and Cusack (2000) point out that the reallocation of workers from manufacturing to services seems to have been easier in the United States, and argue that in Germany it is more difficult to transfer skills to another sector, because of the more specialist type of skills. Many skills in Germany are firm specific, especially in

[9] Data source: World Development Indicators.

the typical *Mittelstand* manufacturing firms.[10] The challenge in Germany is thus the transferability of skills. The authors warn (ibid., p.346) that '[a] country like Germany with a training system that emphasizes specific skills will be politically more sensitive to occupational shifts than a country like the US where the educational system emphasizes general skills'.

Germany's tertiary education enrollments are relatively more concentrated or specialized than those of fellow OECD countries such as France, Italy, the United Kingdom, and the United States. In 2014, around 21 percent of all tertiary education enrollments were in engineering, manufacturing and construction programs, almost three times as much as in the United States, and twice as much as in France or the United Kingdom. In contrast, Germany has the lowest percentage of tertiary students enrolled in education programs in health and welfare, and in social sciences, in comparison to those countries. In the former, it has proportionately almost three times less students than the United States. In services study programs Germany also has relatively few students, at 2.15 percent compared to 7.01 percent in the United States. It is not *per se* a problem having many engineering students, it is rather the students missing in other fields that limit the ability of the labor market to adjust.

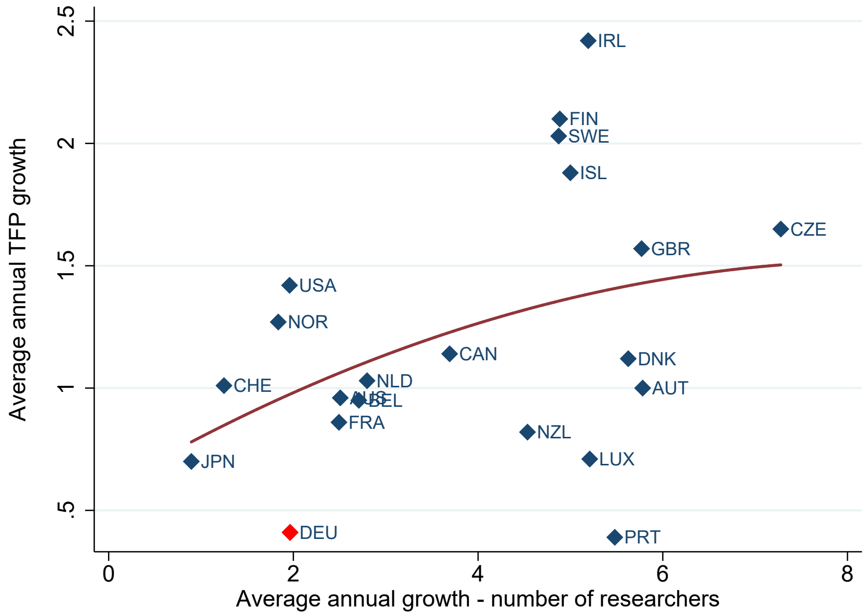
In addition to be relatively specialized, it is also suggested that the German education system is not able to keep up the 'production' and 'delivery' of the highly skilled workers that are needed in the R&D sector. Figure 7 plots the relationship between growth in the number of R&D researchers and TFP growth in selected OECD countries between 1996 and 2005. The figure shows that Germany had one of the lowest levels of growth in the number of R&D researchers - and, at the same time, one of the lowest TFP growth levels. Indeed, it is notable that the R&D intensity in manufacturing is lower than in Japan, the United States, France and South Korea, despite the importance of manufacturing for jobs and exports in Germany.[11]

Why has the education system not been more dynamic in the light of these weaknesses? The conclusion suggests that higher education has been relatively stagnant due to a lack of incentives to be innovative itself. Fohlin (2016, pp.19-20) points out that '[...] academics became government employees with neither the pressure of private incentives, nor the competition from private universities to spur research productivity'. Education policy is fragmented across the 16 'Länder', the dual vocational system is difficult to enter, and is limited to 378 formal occupations; overall the education system is too much tailored to industrial needs (Malmer and Tholen, 2015). According to Mroczkowski (2014, pp.415-416), '[t]he country that invented the 'triple-helix', today is criticized for insufficient entrepreneurship and innovation, and for coddling university academics who are described as conservative, inward looking, and resistant to change'.

[10] 'Most skills acquired, in either manufacturing or in agriculture, travel very poorly to service occupations' (Iversen and Cusack, 2000, p.327).

[11] As documented by Veugelers (2013), German manufacturers spend on average 8 percent of value added on R&D, compared to 12 percent in Japan, 11 percent in the United States, and 10 percent in France.

Figure 7: Growth in R&D researchers and TFP growth in selected OECD countries, 1996 to 2005



Data source: Authors' own compilation based on data from Welfens (2015, p.480, average TFP growth data derived from the European Commission AMECO database online) and the World Bank Development Indicators online (Number of researchers). *Notes*: Growth in R&D researcher are from 1996 to 2005, with the following deviations: AUS, CHE (1996-2004); FIN, NOR, NZL, SWE (1997-2005); AUT (1998-2005); LUX (2000-2005).

3.1.5 Erosion of the welfare state

A possible fourth reason for the decline in the effectiveness of innovation may be the slow but steady erosion of the social welfare system since the late 1980s. This has lead to a decline in unionization in Germany over the past three decades. Unionization reached a peak in 1991, and subsequently declined (Naudé and Nagler, 2017). This may have contributed to the decline in the effectiveness of innovation by slowing the diffusion of technologies. Addison et al. (2013) present evidence that unionization has been beneficial for innovation in the past, because participation of workers in management helped with the facilitation of new technology adoption and diffusion.

Another aspect of the erosion of the welfare state that could have contributed to the decline in the effectiveness of innovation is the greater labor market flexibility introduced by the Hartz reforms which has helped the country maintain high employment rates (which has been much lauded) but at the price of declining firm productivity. The reason for this is that the specific practice of 'short-time' work [12] has hindered the reallocation of workers from less to more productive firms (Cooper et al., 2017).

[12] See Brenke et al. (2011) for a discussion and evaluation of the short-time work program, which they describe as very context specific to Germany.

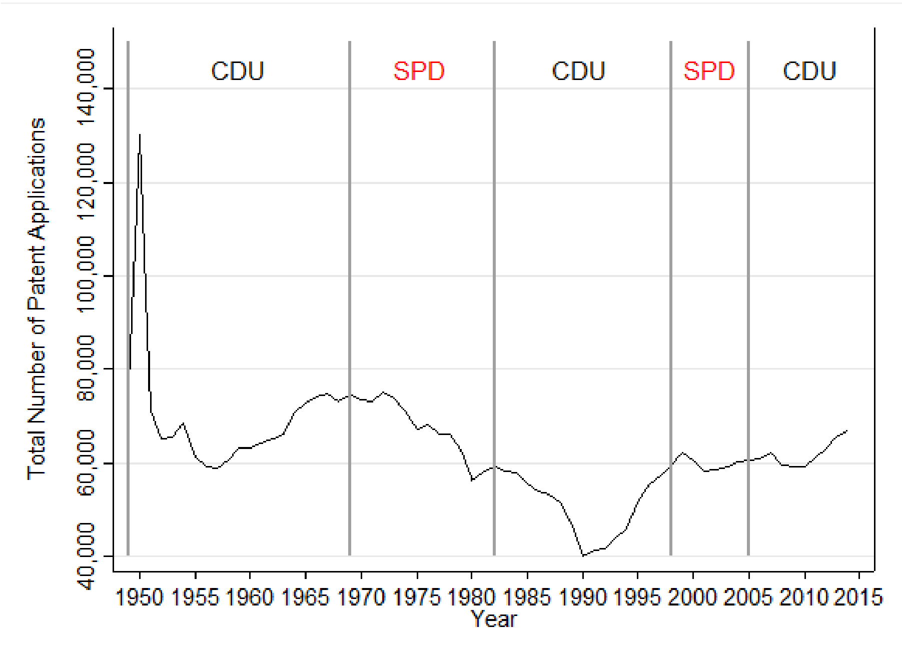
3.1.6 The policy challenge

What is to be done? If it is indeed the case that the effectiveness of innovation has declined over the past three decades then a obvious policy recommendation is to fix the innovation system. This may however be more easily said than done. Germany's innovation system, as measured for instance in patents, has shown itself to be quite robust over time, with various successive post-war governments being essentially unable to effect noticeable shifts in innovation outcomes. This has been identified and discussed by Grupp et al. (2005, p.27-28) who concludes that:

> 'Most astonishingly the German innovation system was very stable although it witnessed several political system changes in the past century [...] This persistence of the innovation system points to a resistant innovation culture in and around Germany which may not be influenced so much by external shocks and incentives'.

Figure 8 shows this, by plotting the number of patent applications since 1950, indicating the various political parties that were in office during this time.

Figure 8: Number of patent applications and political parties in office, 1950-2015



Data source: Authors' compilation based on data from USPTO.

As can be seen from Figure 8 it does not seem to matter which political party, whether CDU or SDP, has been in office: The outcomes from the innovation system as measured in terms of patents granted has been largely unresponsive. It signals the strong possibility that changing the innovation through the political process may be a difficult task. This is not to say it should not be considered though. While a more thorough discussion falls outside the scope of this paper, Rammer and Schubert (2016) has called for more robust public support of firm-level innovation efforts, including unconditional tax credits for R&D and innovation, public subsidies and collaboration, pointing out that 'Germany is among the countries with the lowest shares of state-funded enterprise R&D', showing that the share of state-funded enterprise R&D is more than twice as high in France, the United Kingdom and the United States as in Germany (Rammer and Schubert, 2016, p.29).

In the next section we discuss the second reason for the declining ability of innovations to maintain labor productivity growth: Entrepreneurial stagnation.

3.2 Entrepreneurial stagnation

Another reason for the decline in impact of innovation on labor productivity growth is what can broadly be described as entrepreneurial stagnation.[13] This does not refer to a general lack of entrepreneurship, nor of business firms in the economy, even though in terms of the Global Entrepreneurship Index 2018, Germany is not ranked among the top ten countries in the world or even in Europe [14] (Acs et al., 2017). It rather means for present purposes that entrepreneurship has not been as effective in producing and commercializing innovations in recent times, as it was during earlier periods, and had become less 'Schumpeterian' (Henrekson and Sanandaji, 2017).

The two main reasons for this phenomenon that we will discuss in this section are(i) the 'defensive' corporate strategies and approaches of the large corporations and the *Mittelstand*; and (ii) a growing gap between high- and low-productive firms. See also Jones and Jin (2017).

3.2.1 Defensive corporate strategies and the decline of Schumpeterian entrepreneurship

Germany's essentially 'settled 19th century industries' have been described as 'dominant and entrenched' with the potential to 'shift resources towards themselves' (Fohlin, 2016, p.19). Relatedly Andrews et al. (2016) identify a 'decline in the contestability of markets' as one of the reasons for the slower diffusion of technology [15]. Adelet McGowan et al. (2017) describes how a lack of contestability help keep low-productivity 'zombie firms' alive. The results of this has been threefold: A focus on incremental, rather than

[13] Naudé (2016) argues that Europe is in an 'entrepreneurship crisis', which is also echoed by Henrekson and Sanandaji (2017) and Elert et al. (2017, p.1) who describes the European Union as suffering from an 'innovation deficit'.

[14] Only about 50 percent of the German population see entrepreneurship as a good career choice, which lower than the OECD average and much lower than the 80 and 70 percent averages in respectively the Netherlands and United States (Jones and Jin, 2017).

[15] Andrews et al. (2016) recommend competition policy to address this shortcoming. Watzinger et al. (2017, p.4) argue that competition policy is beneficial for innovation, citing the example of *Bell Labs* in the United States, and concluding that 'antitrust enforcement can have an impact on the long-run rate of technological change [...] the anti-trust lawsuit led to a quicker diffusion of the transistor technology, one of the few general purpose technologies of the post-World War II period'.

breakthrough innovations, a related decline in 'Schumpeterian' entrepreneurship and a decline in fixed capital investment (an important channel for the diffusion of technology).

The essential corporate strategy of these entrenched German firms is a 'defensive' one focused on incremental innovations[16], resulting in a decline of the quality of technological breakthrough innovations and relatedly 'Schumpterian' entrepreneurship.

Henrekson and Sanandaji (2017) measure 'Schumpeterian' entrepreneurship not by the number of self-employed or the start-up rate, but by indicators such as(i) the per capita number of self-made billionaire entrepreneurs, (ii) the number of large firms that were founded by individual entrepreneurs after 1990, (iii) venture capital investments as percentage of GDP and (iv) the number of 'unicorns', i.e. the number of recent start-ups with a market capitalization of at least USD 1 billion. Regarding these measures, Henrekson and Sanandaji (2017) report that Germany has only 0.52 billionaires per million inhabitants compared to 1.37 in the United States and 0.55 in East Asia; it has only three large firms founded since 1990, compared to 60 in the United States and 22 in China; and it has only five 'unicorns', compared to 115 in the United States and 47 in China.

As far as venture capital (VC) as indicator of Schumpeterian entrepreneurship is concerned, we can note that VC investment is often used as an indicator of innovation. This is because VC is generally used to finance high-tech start-ups. Adelet McGowan et al. (2017, p.6) point out that the assets of knowledge-intensive firms 'are more reliant on equity funding' and Henrekson and Sanandaji (2017, p.10) state that VC investments 'are by definition focused on innovative and growth-oriented firms'. Fohlin (2016) describes how the VC market expanded in the United States in the late 1970s, in tandem with the ICT revolution. The location of VC investments also gives an indication of the location of innovative firms producing more radical innovations.

Florida and King (2016) estimate the total value of VC investment worldwide to USD 42 billion in 2012. Of this amount, only 13.5 percent was invested in Europe [17]. According to Bertoni et al. (2015, p.557) 'the European VC market remains fragmented'. Within Europe, Germany's share of VC is relatively small, behind the United Kingdom, France, Denmark, and Russia. Florida and King (2016) report that among the top 10 European cities for VC investment, there were only three from Germany (Berlin, Stuttgart, Munich), and that among the top 20 global cities for VC investment there was no German city at all.

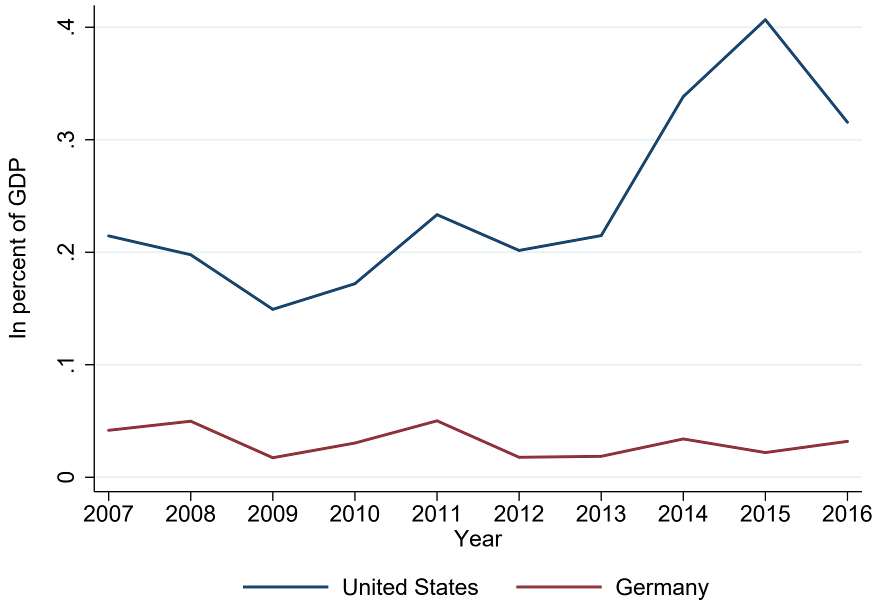
Germany thus does not stand out in term of VC - on the contrary, it is in fact lagging

[16] Meyer-Thurow (1982) states that a major goal of R&D expenditure by individual companies was to prevent new firms of entering the market, and hence keeping competition out, rather than to create new markets. Erixon and Weigel (2016, p.59) describe the strategies of large German corporations as being essentially 'defensive', and that they 'favor the allocation of resources according to a rentier formula; and it crowds out innovations'

[17] There is also a potentially important qualitative difference between VC in Europe and the major global VC markets in the United States, namely that governmental VC investors are more likely than individual VC investors to invest in early-stage start-ups, which the opposite from the United States. It could be that government VC investors are less effective in spotting, screening and coaching start-ups than individual VC investors (Bertoni et al., 2015).

behind, compared to the United States, China, and other emerging market regions (Jones and Jin, 2017). Consider, for instance, Figure 9, where VC investment is compared between the United States and Germany, in percent of GDP, between 2007 and 2016. The figure indicates that there has been a surge in VC investment in the United States since 2013, reaching more than 0.4 percent of the US GDP by the year 2015, which amounted to almost 20 times the proportion of VC investment in Germany.

Figure 9: Venture capital investment in the United States and Germany, 2007 to 2016



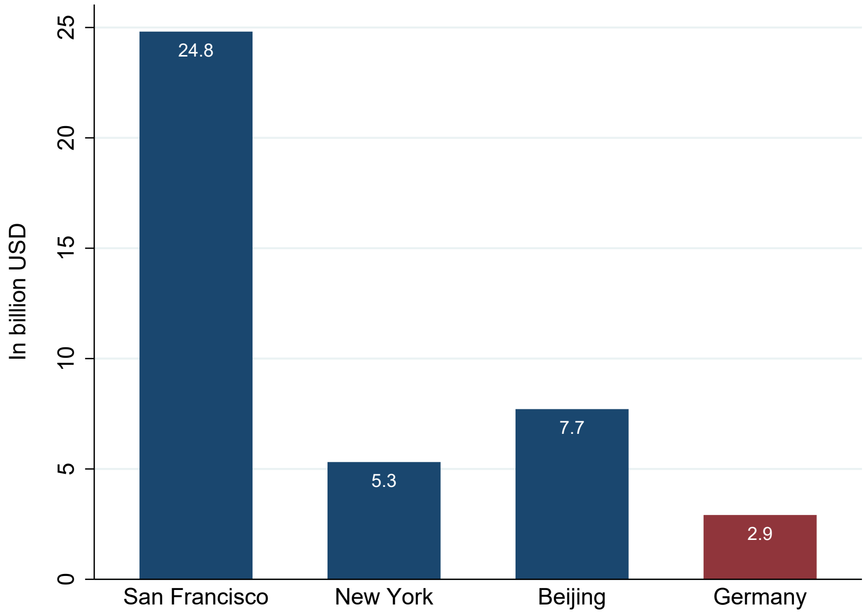
Data source: Authors' own compilation based on data from Statista.

In 2014, the VC investment in only two US city-regions (San Francisco and New York) was already 10 times the total VC investment in the whole of Germany. Other city-regions, such as Beijing, have also experienced more than double the VC investments compared to the entire country of Germany, as Figure 10 indicates. Moreover, according to EVCA data, the volume of investments by non-member companies in VC in Germany has declined from EUR 864 million in 2007 to EUR 607 million in 2014.

Comin et al. (2016) consider the relative lack of VC in Germany a symptom of an 'innovation crisis', which the *Ifo Institute for Economic Research* in Munich had already identified two decades ago. Audretsch and Lehmann (2016a, p.5) refer to *Der Spiegel* and *The Wall Street Journal*, describing Germany's computer chip, biotechnology and energy industries as 'disasters' by the 1990s. Comin et al. (2016, p.417) further describe how the 'Neuer Markt' (new market) for high-risk start-up finance collapsed, and how a host of government policies since 1989, intended to stimulate new emerging technologies such as biotechnology, was deemed to have largely 'disappointed' by 1998. The ROBO Global Robotics and Automation Index contains data on financial performance of 1,000 companies in the industry, of which only 4 percent are from Germany. The bulk of firms is from the United States (42 percent) and from Japan (30 percent).

In addition to reducing the degree of breakthrough innovations and Schumpeterian entrepreneurship, the defensive corporate strategies in Germany has led to a slower

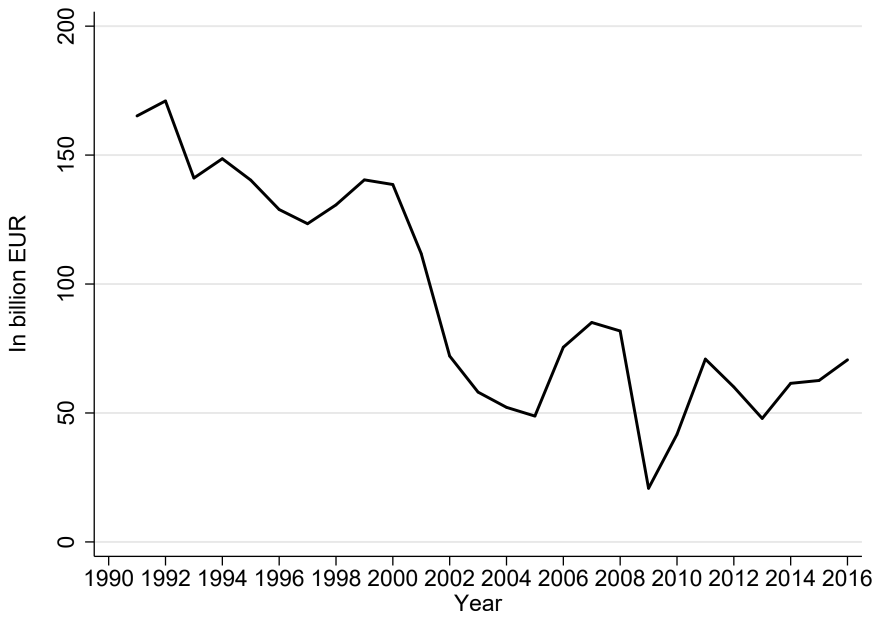
Figure 10: Venture capital investments in selected world cities and regions, 2014



Data source: Authors' own compilation based on data from Florida and King (2016).

diffusion of technology as a result of declining fixed capital investment. Erixon and Weigel (2016, p.27) has noted fixed capital investment in the economy has declined 'pretty dramatically', and given that technology diffuses through the economy embodied in capital investment, this presents one reason for the slower diffusion of technology. In Figure 11 the precipitous decline in net fixed capital investment in Germany since 1991 is depicted.

Figure 11: Net fixed capital investment (at 2010 prices) in Germany, 1991 to 2016



Data source: European Commission AMECO database online. *Notes*: Net fixed capital investment in billions of EUR.

3.2.2 The productivity gap between firms and regions

A second cause of entrepreneurial stagnation in Germany is that it appears that a growing gap has developed between leading and lagging firms in terms of innovation and productivity. The European Commission (2017) shows that existing evidence suggests that the impact of research and innovation (R&I) investment on productivity growth[18] has been declining in general in Europe, and not just in Germany. It ascribes this as due to 'obstacles to the diffusion of innovation from productivity-leading companies' (ibid., p.4). While the evidence so far comes from aggregate OECD data there is little reason to suspect that Germany is different.

The productivity gap between 'leading and lagging firms' occurs when the lagging firms cannot absorb the technology from leading firms, and moreover when lagging firms start to find it increasingly hard to innovate or benefit from innovations (Andrews et al., 2016; Adelet McGowan et al., 2017). That this may be the case in Germany is indicated by the declining start-up rate of new firms since 1990[19] and in the small share of firms (only 1 percent)[20] that indicate that they are aiming to grow (Henrekson and Sanandaji, 2017). Moreover, the increase in the proportion of lagging firms is also indicated by the declining number of German firms that invest in innovation.

According to data from the Mannheim Enterprise Panel, the Gini-coefficient for the proportion of firms with more than five employees that invest in innovation, increased from 0.88 in 1994 to 0.95 by 2013. This extreme level of inequality in terms of innovation implies that most firms in Germany invest nothing in innovation. Rammer and Schubert (2016) finds that the growth rate in R&D of businesses in Germany between 2001 and 2013 averaged 4 percent, but that thus was mainly the result of a few larger enterprises who grew on average their R&D budgets by 4.9 percent compared to 1.8 percent in the case of small and medium sized firms. They conclude that '[w]hile Germany is often hailed for its highly innovative SME sector, this suggests that the German innovation system is gradually loosing one of its most important pillars' (Rammer and Schubert, 2016, p.28).

Figure 12 depicts the growing gap in productivity between leading and lagging firms in the OECD since the 1990s. This figure shows that '[b]etween 2001 and 2013, labor productivity at the global frontier increased at an average annual rate of 2.8 percent in the manufacturing sector, compared to productivity gains of just 0.6 percent for laggards'.

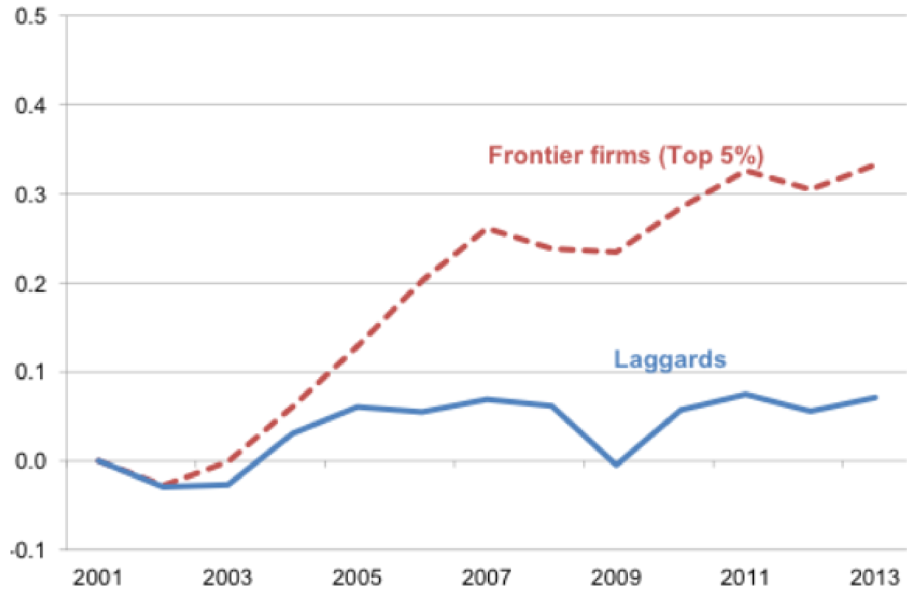
This lack of technology diffusion among firms, and the resulting polarization in labor productivity between leading and lagging firms, might be due to, among other factors, the relatively poor management practices in German firms, especially among

[18] The European Commission (2017, p.3) reports that a 10 percent increase in R&I investment has been associated with an improvement in productivity of between 1.1 and 1.4 percent in the past, but that this relationship seems to be breaking down.

[19] Data from the Mannheim Enterprise Panel show that the index of start-up activity (measuring the proportion of new firm entry) in Germany fell from 120 to 60 between 1990 and 2013, a 50 percent decline.

[20] In comparison 3.6 percent of US firms indicate that they plan to grow, 3.9 percent in China, and 5.7 percent in Switzerland (Henrekson and Sanandaji, 2017).

Figure 12: Widening labor productivity gap - labor productivity increase of frontier vs laggard manufacturing firms (value-added per worker, in percent) in the OECD, 2001 to 2013



Data source: Andrews et al. (2016) based on the recent update of the OECD-Orbis productivity database (Gal, 2013). *Notes*: The global frontier is measured by the average of log labor productivity for the top 5% of companies with the highest productivity levels within each 2-digit industry. Laggards capture the average log productivity of all the other firms. Unweighted averages across 2-digit industries are shown for manufacturing firms, normalized to 0 in the starting year. The time period is 2001 to 2013. The vertical axis represents log-differences from the starting year: The frontier in manufacturing has a value of about 0.3 in the final year, which corresponds to approximately 30% higher in productivity in 2013 compared to 2001. See details in Section 3.3 of Andrews et al. (2016).

SME (or *Mittelstand*) firms (Broszeit et al., 2016) and in firms in eastern Germany (Burda and Severgnini, 2017).

Broszeit et al. (2016) find, using the German Management and Organizational Practices (GMOP) data set, that(i) German firm level productivity lags behind that of US firms; (ii) a relatively wide productivity dispersal between firms exists; and (iii) a possible explanation for this finding lies in the poor management quality (on average) in German firms. Specifically, a poorer management quality means that firms have less absorptive capacity to learn from firms at the technological frontier. The authors conclude that this shortcoming is particularly a problem for the *Mittelstand*, since '[g]iven the comparatively low level of management scores for these types of establishments, there is substantial potential for catching up' (ibid., p.28).

As far as Eastern Germany is concerned, where labor and total factor productivity (TFP) are only 75 percent of that of Western German firms, Burda and Severgnini (2017) conclude that 'the stubborn east-west TFP gap is best explained by low concentration of managers, low start-up intensity and the distribution of firm size'. The relative lack of management skills that are implicated are according to Fohlin (2016, p.21) explained by the historical lack of business school education in that 'the post-war German education system provided essentially no counterpart to the United States' business school education'.

In conclusion, entrepreneurial stagnation in Germany is characterized by the defensive strategies of large incumbent firms and a growing productivity gap between firms. A reason for both has to do with relatively poor management practices and lack of effective competition (contested markets). The combination of these result in a decline in fixed capital investments and in the ability of lagging firms to learn from and catch up to leading firms [21]. Inadequate competition allows lagging firms to survive, instead of pushing them out of the market, forcing larger firms to make capital investments to compete. As a result, the diffusion of technology has become sluggish, the economy has become less 'Schumpeterian', and with it labor productivity growth has declined.

4 Concluding remarks

In their book *The Seven Secrets of Germany*, Audretsch and Lehmann (2016a, p.7) argue that Germany's relatively good economic performance, especially since 2010 when the rest of Europe was struggling with the effects of the global financial crisis, was due to 'a remarkable entrepreneurial society' which moreover is 'an important role model for countries in Europe and elsewhere'. We believe that, as the evidence in this paper has shown, this view is unfortunately wrong.

Germany has performed well in terms of employment growth, exports and macro-economic stability. It has not performed so well, however, in terms of relative and absolute poverty and inequality. All measures of income inequality (before and after tax) increased markedly after 1990, as well as the 'at-risk-of-poverty rate'.Somaskanda (2015) reports, citing the *Paritätischer Gesamtverband*, that Germany is at its highest poverty levels since reunification with 12.5 million poor people, of which 3 million are estimated to be 'working poor'. Felbermayr et al. (2014) note that the rise in wage inequality was faster in Germany than in the United States, the United Kingdom, and Canada between the mid-1990s and 2010. Concern has also been expressed that the success of the economy has more to do with the dependence on an exporting model, facilitated by having the Euro as currency, rather than on innovation-driven entrepreneurial growth (Burda, 2016). And last, not but least, labor productivity growth has continuously declined in Germany since the 1990s, despite high employment, successful exports, and significant and growing expenditures on innovation.

In this paper we show that the decline in labor productivity growth, which has been implicated in the rise in income inequality, can be explained by weaknesses in the innovation system, and by entrepreneurial stagnation. Revamping the German technological innovation system is therefore advised, but may be a difficult task to implement: The recent historical evidence suggests that the innovation system has become rather entrenched. It will be difficult for the government and industry to significantly alter the nature of the country's innovation system over the short- to medium-term. Nevertheless more consideration should be given to state-support for

[21] The between-firm pay inequality as a result of the gap between leading and lagging firms in productivity growth is one of the reasons for growing income inequality in Germany. As Erixon and Weigel (2016, p.235) put it, 'a factor of rising inequality is that people work for the wrong firms'.

innovation activities, such as through unconditional tax credits for R&D and by addressing the fact that most SME are not innovating much (Rammer and Schubert, 2016). It is perhaps worthwhile to re-iterate the finding of Rammer and Schubert (2016, p.28) with respect to the declining innovativeness of SMEs that '[t]he German innovation system is gradually loosing one of its most important pillars'. Moreover, to generate more breakthrough-type innovations in areas of the new industrial revolution where the country has fallen behind, will necessitate initiatives to be embedded in an appropriate industrial policy, which could however face political difficulties on the national level and constraints on the EU level.

It may be therefore more effective to focus on addressing the country's entrepreneurial stagnation, which is characterized by the defensive strategies of large incumbent firms, a growing productivity gap between leading and lagging firms, and declining innovative activities by SMEs. Reasons for these features are relatively poor management practices and lack of effective competition (contested markets). The combination of these have been shown to result in a decline in fixed capital investments and in the inability of lagging firms to learn from and catch up to leading firms. Inadequate competition allows lagging firms to survive, instead of pushing them out of the market, forcing larger firms to make capital investments to compete. As a result, the diffusion of technology has become sluggish, the economy has become less 'Schumpeterian', and with it labor productivity growth has declined.

There is no shortage of concerns about entrepreneurial stagnation in Europe and hence no shortage of perscriptions for a more entrepreneurial vibrant Europe. Many of these may be relevant also for Germany. Recent examples include Leceta et al. (2017) and Elert et al. (2017). Leceta et al. (2017) argues for actions that focuses on 'people, places and policies' and puts forward a list of no less that 55 policy recommendations from which one may conclude that truly comprehensive effort is required to turn European countries into more conducive places for entrepreneurs. Similarly, Elert et al. (2017) propose reforms across nine broad areas in the EU to make countries more entrepreneurial, so that innovation can have a better 'Schumpeterian' impact. These nine areas exhaustively cover what can be described as the institutions governing the entrepreneurial ecosystem, including laws, tax systems, social insurance, regulations, human capital, and intellectual property.

A comprehensive discussion and evaluation of proposals such as by Leceta et al. (2017) and Elert et al. (2017) falls outside the scope of the present study, but is worth a consideration and further investigation in the future. From our survey of the key features of the Germany institutional environment since the 1870s however, our conclusion is that four areas should be highlighted for special attention: education and managerial capability, venture capital, the contestibility of markets, and the social welfare system. The latter may be particularly important and at the same time be in danger of being unappreciated as a tool to improve entrepreneurship and innovation. It should be kept in mind, as this paper has shown, that Germany's industrialisation in the 20th century was greatly facilitated by its becoming the world's first social welfare state. Its continued economic success in the Fourth Industrial Revolution will likewise require an appropriate social welfare system.

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