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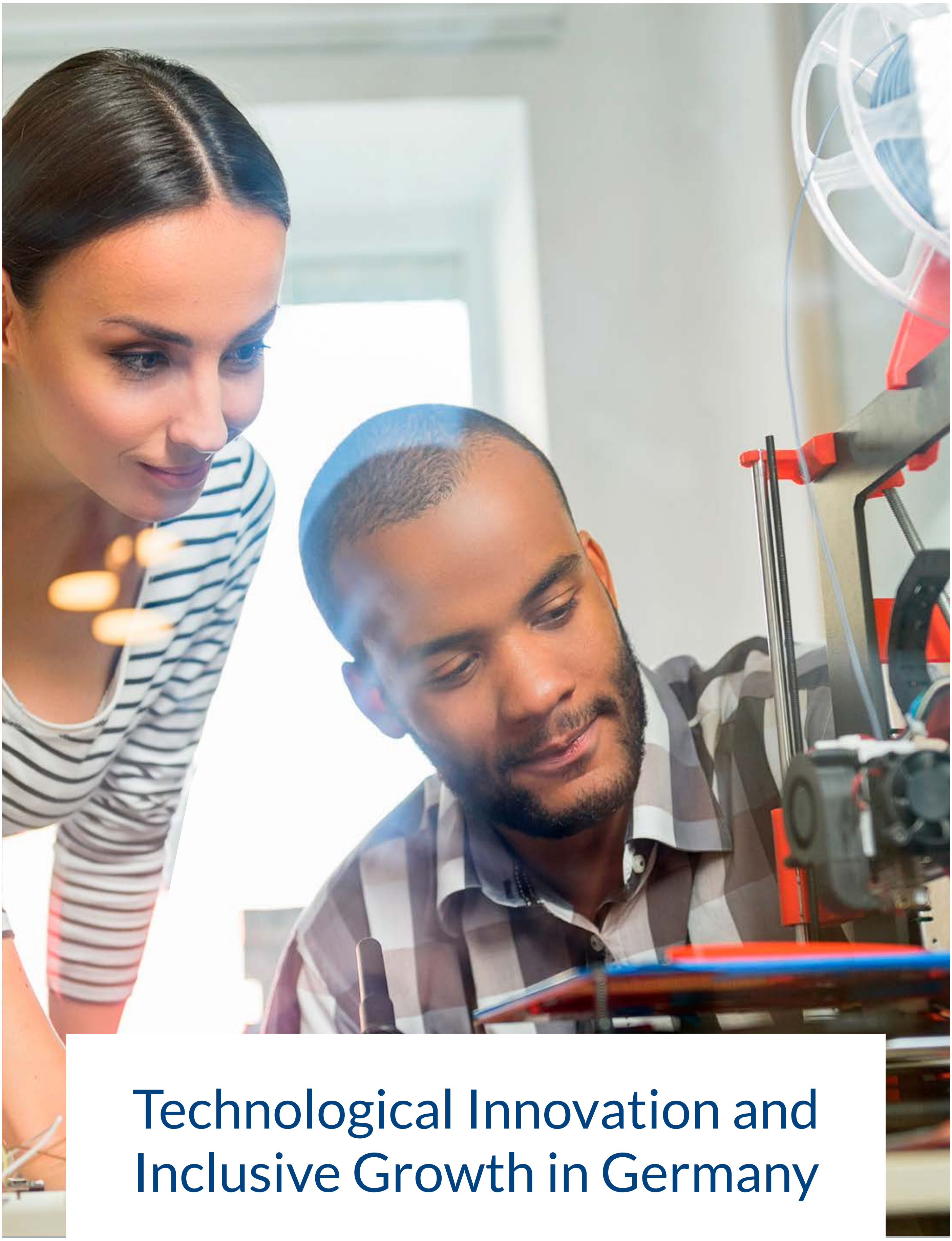

Technological Innovation and Inclusive Growth in Germany

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Executive Summary

Growing inequality

Over the past 30 years all indicators capturing income and wealth inequality deteriorated in Germany. Income inequality was relatively low before 1990, and even declined over much of the 20th century, but it changed direction after German unification. Over the past decades, the rise in wage inequality was faster in Germany than in the United States, the United Kingdom and Canada.

Not too much, but too little innovation

One explanation for rising inequality has been 'too rapid' and 'pervasive' technological innovation, replacing human labor and generating higher wages for certain high-skilled workers alone. With increased digital innovation and automatization over recent decades, policymakers feared severe job losses and forecasts suggested that even more jobs could be lost due to future technological progress (Frey and Osborne, 2015). There is, however, little evidence so far that this is occurring. Instead, this study shows that inequality in Germany started to increase in the 1990s due to the opposite effect – the country's declining achievements in technological innovation.

The real problem: Innovation and declining labor productivity growth

Germany spends more than EUR 80 billion on research and development (R&D) each year. Almost 400,000 scientists work in R&D. This study finds that all these efforts are not leading to stronger labor productivity growth. Instead, it has been consistently declining, even in the face of increased spending on innovation; it was five times slower in 2013 than in 1992. This decline is inconsistent with a scenario of technological innovation replacing human labor: if large-scale replacement of human labor occurred, one should normally see a massive boost to labor productivity for those workers who still remain in the workforce. A recent study in Germany also concludes that robots have not destroyed jobs in Germany, but working in environments with robots brings a higher chance of remaining employed (Dauth et al., 2017b).

Real labor compensation is crucial for inclusive growth

As labor productivity stagnated, and the country's international competitiveness weakened, government and businesses started to reduce real labor compensation from the mid-1990s. As a result, various welfare benefits were also reduced or abolished. Self-employment and forms of irregular and part-time employment with low(er) wages increased, while union density rates dropped. The level of working- and 'at-risk-of-poverty' doubled between 2005 and 2015.

Several industries have also lowered their relative labor costs by outsourcing and offshoring production, which put pressure on wages in Germany. As technological innovations are often embedded in the capital stock, the decline in net fixed capital investment not only led to reduced levels of investments in innovation by firms, but also contributed to a sluggish diffusion of technological innovations throughout the economy. The net result was that profits grew faster than labor wages, leading to a decline in the relative share of labor in national income, with top incomes rising out of all proportion (Piketty, 2013).

Firms and management also matter for innovation and inclusive growth

This rise in inequality was exacerbated by two features related to the private sector: first, good management skills relevant for innovation were in relative short supply, leading to a rise in CEO wages. Second, this lack of management skills resulted in an increasing divergence of company-level productivity growth, generating, in turn, high productivity frontier firms vs. low productivity laggard firms. The same skills absence further contributed to a more sluggish diffusion of technological innovation throughout the economy, making innovation less effective.

Falling behind in cutting-edge technologies

While Germany is highly competent in traditional and medium-technology industries, such as automobiles and machine tools, it has failed to acquire the innovation lead in semiconductors, computing, 3D-printing, nanotechnology, robotics or molecular biology – the drivers of what has been named the 'fourth industrial revolution' or Industry 4.0 by the World Economic Forum. 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 numbers). The top 20 patent applicants in nanotechnology have not included a single German firm since 1970. Here, German firms are lagging behind those from the United States, Japan, South Korea, and increasingly also China. In addition, innovative industries such as photo-voltaics (PV) have increasingly moved abroad: in 2013 alone, almost half of the roughly 100,000 workers in Solar PV manufacturing in Germany lost their jobs.

Policy implications

This study shows that Germany needs innovation that increases labor productivity. For this to occur, it is clear that a fundamental change is required in the national innovation system. The country has a tradition of establishing a unique and effective collaboration between industries, government and higher education institutions, also called the 'triple-helix' system, which has been much lauded for its strongly specialized system of vocational and scientific training. However, the high degree of specialization may have led to rather incremental innovation in recent decades – with little effect on inclusive growth. This study thus calls for increased diversity in the German education system, allowing for lifelong learning and a higher degree of workforce adaptability to new working environments. Moreover, this study also finds that Germany requires a new industrial innovation policy that focuses on high quality innovation and not solely on protecting incumbent sectors and firms. In addition, Germany needs a venture capital strategy, allowing new high-tech firms to thrive that can eventually produce decisive innovations and, consequently, more inclusive growth.

All these policies aimed to achieve sustained and inclusive growth in Germany will pay off in the long run. In the meantime, the social welfare state is key to keeping growth inclusive. This study suggests that Germany could opt for innovative measures and schemes the strengthen the idea of the progressive taxation and reduce inequality. Options to achieve this goal are to improve benefits for low income households and to improve market contestability as well as to set incentives for companies to invest and raise wages for all workers.

Zusammenfassung

Zunehmende Ungleichheit

In den letzten 30 Jahren wiesen Indikatoren für wirtschaftliche Entwicklung eine zunehmende Ungleichheit bei Löhnen und Vermögen in Deutschland auf. War jene Ungleichheit vor den 1990er Jahren noch gering und nahm zuvor im Laufe des 20. Jahrhundert sukzessive ab, so wuchs sie seit der Wiedervereinigung stärker als etwa in den USA, Großbritannien und Kanada.

Nicht zu viel, sondern zu wenig Innovation

Eine oftmals angeführte Erklärung für diese Entwicklung ist die angeblich zu schnelle und zunehmend wichtiger werdende technologische Innovation: diese ersetze menschliche Arbeitskraft durch Roboter und lediglich hochausgebildete Spezialisten würden Lohnsteigerungen erfahren. Aufgrund der zunehmenden Digitalisierung und Automatisierung fürchten viele daher einen massiven Arbeitsplatzabbau, der mit abermals wachsender Ungleichheit einhergeht. Einige Studien gehen gar davon aus, dass jeder zweite Arbeitsplatz gefährdet sein könnte (Frey und Osborne, 2015). Bisher gibt es jedoch kaum Anzeichen für diese Entwicklung. Diese Studie zeigt, dass die seit den 1990er Jahren wachsende Ungleichheit vielmehr ein Ergebnis einer gegenteiligen Entwicklung ist – des zu geringen Erfolgs von technologischen Innovationen in Deutschland.

Die Steigerung der Arbeitsproduktivität ist die zentrale Herausforderung

Deutschland investiert mit jährlich mehr als 80 Milliarden Euro eine beträchtliche Summe für Forschung und Entwicklung – ein Bereich, in dem schon heute mehr als 400.000 Menschen in Deutschland beschäftigt sind. Das zentrale Problem liegt laut dieser Studie darin, dass diese Anstrengungen nicht zu einem stärkeren Wachstum der Arbeitsproduktivität führen. Jenes Wachstum hat in den letzten Jahren sukzessive abgenommen, trotz der hohen Ausgaben für Forschung und Entwicklung. Die Arbeitsproduktivität wuchs im Jahr 2013 etwa fünf Mal langsamer als im Jahr 1992. Dieser Umstand spricht gegen die Vorstellung, dass der technologische Wandel menschliche Arbeitskraft ersetzt: in diesem Fall würde die Arbeitsproduktivität derjenigen, die weiterhin im Arbeitsmarkt verbleiben, stark ansteigen. Untersuchungen zeigen etwa, dass der zunehmende Einsatz von Robotern in der deutschen Arbeitswelt nicht zu weniger Arbeitsplätzen geführt hat. Das Gegenteil ist offenbar der Fall: Arbeitsplätze, in deren Umfeld Roboter zum Einsatz kommen, seien zukunftssicherer (Dauth et al., 2017b).

Reallohnverluste gefährden inklusives Wachstum

Das sinkende Wachstum der Arbeitsproduktivität setzt die Wettbewerbsfähigkeit der deutschen Wirtschaft unter Druck. Infolgedessen sanken die Reallöhne seit Mitte der 1990er Jahre. Zusätzlich wurden die Leistungen des Sozialstaats teilweise reduziert, der Niedriglohnsektor nahm an Bedeutung zu und Gewerkschaften gerieten unter Druck. Der Anteil der von Armut betroffenen Menschen, die in Arbeit sind, verdoppelte sich zwischen den Jahren 2005 und 2015. Gleichzeitig verlagerten zahlreiche deutsche Unternehmen Teile ihrer Produktion in das Ausland, was den Lohndruck verschärfte. Hinzu kommt, dass deutsche Firmen bei Zukunftsinvestitionen zurückhaltend waren, sodass tiefgreifende Innovationen weniger stark gefördert wurden. Die Folge: zahlreiche technische Innovationen durchdrangen nicht alle Teile der deutschen Wirtschaft. All diese Faktoren sorgten außerdem dafür, dass Profite schneller wuchsen als Lohneinkommen und die Ungleichheit zunahm (Piketty, 2013).

Auch Unternehmen und Management sind von Bedeutung

Die wachsende Ungleichheit wurde laut dieser Studie aufgrund von zwei weiteren Entwicklungen in der deutschen Wirtschaft verschärft: Zum einen sind die Anforderungen an das Topmanagement und die Nachfrage nach Managementfähigkeiten für Innovations- und Zukunftsfähigkeit gestiegen und die Spitzengehälter daher stark gewachsen. Zum anderen sind diese Managementfähigkeiten ein entscheidender Erfolgsfaktor für Innovationskraft. Da nicht alle Firmen über das entsprechende Management-Know-How verfügen, kommt es zu einer Spaltung in Firmen mit hohem und solchen mit niedrigem Produktivitätswachstum. Zugleich kommt der technologische Fortschritt nicht in der Breite bei allen Unternehmen und in allen Branchen an, sodass die Innovationsfähigkeit gesamtwirtschaftlich abnimmt.

Deutschland fällt bei Spitzentechnologien zurück

Deutschlands Stärken liegen vor allem in der Industrie, etwa im Maschinenbau oder im Automobilsektor. Deutschland ist hingegen nicht an der Spitze der heute so innovationsstarken Branchen wie beispielsweise der Halbleitertechnologie, Computern, 3D-Druck, Nanotechnologie, Robotik oder der molekularen Biologie – all diese Bereiche treiben die vom Weltwirtschaftsforum benannte „Vierte Industrielle Revolution". Gemessen an den Patentzahlen sind lediglich vier deutsche Firmen unter den Top 30 der innovativsten Unternehmen im Bereich des 3D-Drucks, der Nanotechnologie und der Roboterindustrie. Unter den Top 20 der Patentbewerber seit 1970 ist keine deutsche Firma. Deutsche Unternehmen fielen in den genannten Industrien hinter Ländern wie die USA, Japan, Südkorea und China zurück. Gleichzeitig verlagerten innovationsstarke Zukunftsfelder wie die Photovoltaik-Industrie (PV) ihre Aktivitäten ins Ausland: Allein im Jahr 2013 verlor fast die Hälfte der rund 100.000 Beschäftigten in der deutschen PV-Industrie ihre Arbeit.

Handlungsempfehlungen

Die vorliegende Studie zeigt, dass die deutsche Wirtschaft mehr tiefgreifende Innovationen benötigt, die auf die Steigerung der Arbeitsproduktivität abstellen. Dafür bedarf es eines fundamentalen Wandels der Innovationsbemühungen. Deutschland konnte traditionell auf eine effektive Kooperation aus eng verzahnten Branchen, dem Staat und den Hochschulen als sogenannte „Triple Helix" bauen, die mit einem stark spezialisierten Ausbildungssystem einen wichtigen Beitrag zum Wirtschaftswachstum leistete. Diese Spezialisierung hat laut dieser Studie in den letzten Jahrzehnten eher zu Prozessinnovationen geführt – diese wiederum tragen aufgrund ihres weniger starken Effekts auf die Arbeitsproduktivität nur bedingt zu inklusivem Wachstum bei. Ein stärker generalistischer Ansatz im Ausbildungssystem kann lebenslanges Lernen erleichtern und so Arbeitnehmer für die sich durch tiefgreifende Innovationen ständig wandelnde Arbeitswelt rüsten. Viele Initiativen heutiger Industrie- und Innovationspolitik zielen vor allem darauf ab, etablierte Branchen zu fördern und die starken Branchen in Deutschland zu schützen. Dieser Ansatz führt laut dieser Studie zu einer Innovation „der kleinen Schritte" und stärkt weniger jene Bereiche, in denen Deutschland Potenzial zum Aufholen hat. Deutschland braucht daher einen neuen Ansatz in der Industrie- und Innovationspolitik, der spezifisch auf tiefgreifende Innovationen abstellt.

Diese Maßnahmen werden mittel- und langfristig greifen und können nachhaltiges und inklusives Wachstum ermöglichen. In der kurzen Frist kann der Sozialstaat einen Beitrag zu inklusivem Wachstum leisten. Konkrete Möglichkeiten liegen etwa darin, Leistungen für Haushalte mit geringen Einkommen zu erhöhen und gleichzeitig den Wettbewerb so zu verbessern, dass Unternehmen verstärkt investieren und Löhne erhöhen.

Contents

1 Introduction

Economic growth in Germany is no longer as inclusive as it used to be. Between 1990 and 2010 all measures of income and wealth inequality rose considerably,[1] which even led the media to portray Germany as a 'divided nation'.[2] Income inequality was relatively low before 1990, and even declined over much of the 20th century, but changed direction after German unification.

The rise in income inequality from 1990 onwards is depicted in Figure 1 through various inequality indicators and the 'at-risk-of-poverty rate'. It can be seen that all measures of income inequality (before and after tax) increased markedly after 1990 along with the 'at-risk-of-poverty rate'.[3] Felbermayr et al. (2014) furthermore document 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. This rise in income and wage inequality has been accompanied, and to a certain extent occasioned, by a simultaneous increase in wealth inequality. Using data from the Socio-Economic Panel (SOEP), Frick and Grabka (2009) show, that the Gini coefficient for wealth increased from 0.77 to 0.80 during this period, and wealth grew particularly strongly at the top 1 percent of the wealth distribution.

A growing number of studies have investigated the reasons for this rise in income and wealth inequality (see for instance Dustmann et al., 2009, 2014; Biewen and Juhasz, 2012; Felbermayr et al., 2014). The present study contributes to this literature by arguing that a decline in the effectiveness of technological innovation, together with the erosion of the social welfare state, have been important causes. It was precisely because technological innovation had become less and less effective at raising labor productivity in Germany that policy makers and the corporate sector turned to measures to curb labor compensation so as to improve international competitiveness.

This study shows that technological innovation has historically been a driving force for inclusive economic growth in Germany, and identifies three reasons why this is no longer the case. These are (i) historic legacies, (ii) weaknesses in the education system, and (iii) entrepreneurial stagnation. Improving the impact of technological innovations on labor productivity growth will require a more diversified education system, a deepening of active labor market policies, better immigration policies, and more competitive markets. Ensuring these recommendations are enacted in a coordinated fashion points to the need for an appropriate industrial innovation policy.

The call in this study for more and better technological innovation and the message that it is a driver of inclusive growth is somewhat contrary to some of the recent literature and the popular press (see e.g., Ford, 2015). These tend to blame too rapid technological innovation for income inequality and jobless growth, warning that technological innovation is skill-biased, disproportionately driving up the wages of the highly skilled workforce, and eliminating middle-skill intensive jobs, causing wage polarization (Brynjolfsson and McAfee, 2012). Frey and Osborne (2015) predict that up to 51 percent of current jobs in Germany may be lost due to technological innovation (e.g., automation) in the future, and Acemoglu and Restrepo (2017) warn, based on U.S. data, that each new robot can replace up to seven jobs. The present study does not share this pessimism and moreover supports the conclusion of studies such as those by Autor (2015) and Pfeiffer (2016), that the prediction of robots taking over human jobs is unlikely to materialize. In particular, Dauth et al. (2017b, p. 39) find that in Germany 'more robot exposed workers are even more likely to remain employed in their original work-

1 High inequality negatively affects growth and sustainable economic development (Berg and Ostry, 2011; Ostry et al., 2014) and may lead to economic, political and social turmoil (Stiglitz, 2012).
2 Der Spiegel, 12.03.2016: 'Die geteilte Nation'.
3 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'. This leads to the observation, or concern, that 'rich Germany has a poverty problem'.

FIGURE 1: **Inequality measures and poverty rate, 1991 to 2015**

Notes: At-risk-of-poverty rate is defined as '[p]ersons with less than 60 percent of median disposable income'.
Gini coefficient on scale between 0 (low inequality) and 1 (high inequality). Real incomes in prices of 2010.
Population: Persons living in private households. Equivalized annual income surveyed the following year. Equivalized with the modified OECD-scale (Grabka and Goebel, 2017, p. 55).
Market Income = Labor income, capital income, private transfers, imputed rent (fictive income advantages from owner-occupied housing).
Disposable income = Further contains benefits from social security, social transfers, direct taxes, social security contributions, obligatory health insurance.
Data source: Figures taken from Grabka and Goebel (2017), based on data from SOEPv32 (calculations of DIW Berlin),
Federal Statistics Office (Microcensus, EU-SILC).

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place', even though there are more robots per worker in Germany than in the US or any other European country.

The rest of this study is structured as follows. In Section 2 the core message is outlined and diagrammatically illustrated, with cross-references to the various sections, where the details of the specific arguments are elaborated. Section 3 shows that technological innovation has historically been a driving force for inclusive growth in Germany, and Section 4 documents that the effectiveness of technological innovation has declined in recent years. In Section 5 three broad reasons are discussed why technological innovation, despite high and rising expenditure on boosting innovation, is not stimulating labor productivity growth: (i) historical legacies, (ii) weaknesses in the education system, and (iii) entrepreneurial stagnation. In Section 6 evidence is provided to show that the decline in the effectiveness of technological innovation is an important factor for understanding rising income inequality. In Section 7 the main findings are summarized and various recommendations for policy and further research discussed.

2 Linking technological innovation and inclusive economic growth

For purposes of this study, growth is inclusive 'if and only if the incomes of poor people grow faster than those of the population as a whole, that is, inequality declines' (Anand et al., 2013, p.1). The first question to answer in this section is therefore: how is inequality defined?

Inequality is a complex term that implies a set of theoretical constructs, and there exist various ways to measure and express this concept empirically. While inequality is often associated with material or economic aspects, such as inequality in wages, incomes or wealth, it goes far beyond this. The concept must be extended to comprise non-material aspects such as equal access to opportunities, for example in education and employment, and the prospect of social mobility.

Here, however, to provide a tractable analysis given the lack of sufficient and consistent data on non-material equality in Germany, we will define and measure inequality by the distribution of incomes (wage and capital incomes) and wealth. As indicated in the introduction, all such measures have deteriorated in Germany over the past thirty years. Primarily, this study focuses on *income* inequality, measured by changes in the distribution of wage and rental (capital) incomes over time.

If inequality increases within a society, or remains at persistently high levels over time, it may have negative economic and social consequences that merit countervailing measures. Inequality may lead to a set of negative externalities that cause economic, political and social turmoil (Stiglitz, 2012). In contrast, nations with a more equal society are more likely to grow and develop economically[4] (Birdsall and Londoño, 1997).

4 While too much inequality is highly problematic, some inequality is also unavoidable, and even desirable. Some level of inequality is considered necessary to provide incentives, and stimulate development. Forced complete equality can threaten personal freedom. Additionally, institutions suffer from efficiency losses due to a 'leaky bucket' of bureaucracy or administration in the distribution process (Keeley, 2014).

The second and the central question addressed here is: how can the link between technological innovation and inequality be characterized in Germany?

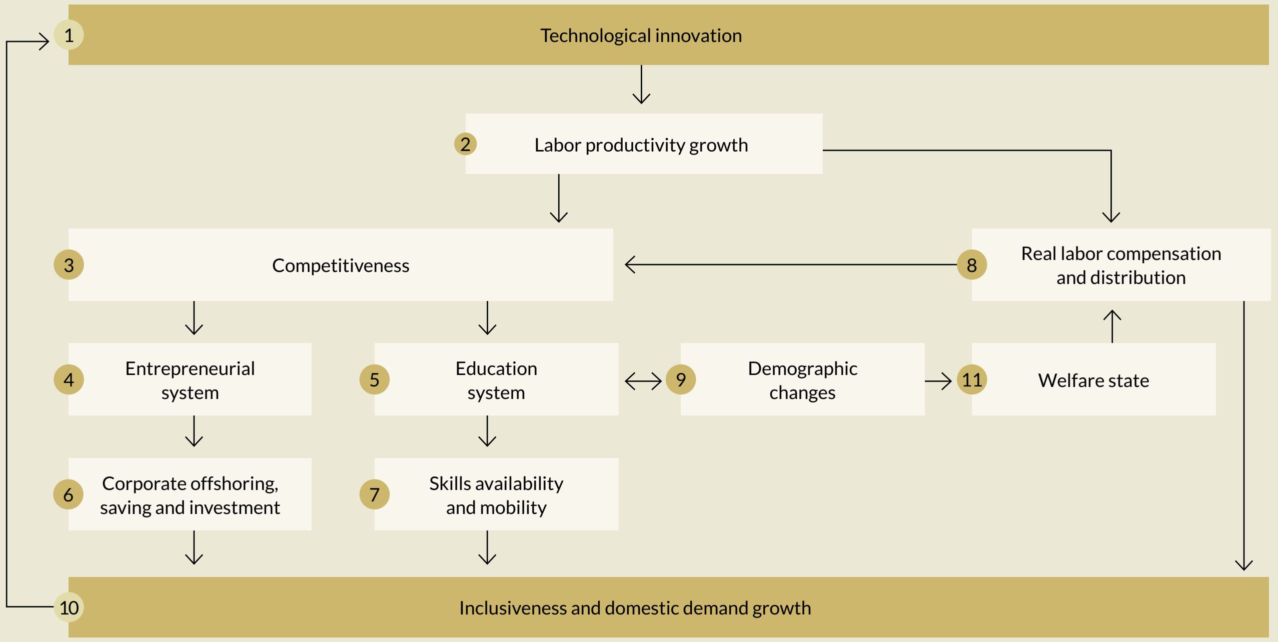
There are increasing concerns that too rapid technological innovation is responsible for rising inequality. This study argues that this is not the case in Germany – rather, it is the lack of effective technological innovation that triggers responses by government and the corporate sector, contributing to rising inequality, on top of demographic pressures. The argument can be explained with the help of Figure 2.

Technological innovation drives labor productivity growth [Box 1 to Box 2], which is a fundamental aspect of endogenous growth theory. The extent of labor productivity growth, in turn, determines the economy's competitiveness [Box 3], as well as the real compensation of labor, and how it is distributed [Box 8]. Germany's key challenge lies in declining labor productivity growth. This study documents that this decline has been consistent, even in the face of an increased spend on innovation. Labor productivity growth was five times slower in 2013 than in 1992. This decline is inconsistent with a scenario of rapid technological innovation, or with technology replacing human labor. As Yglesias (2015) and Dauth et al. (2017b) point out automatization and digitalization do not appear to lead to massive job losses. In Germany, declining labor productivity growth was exacerbated by the negative productivity shock from unification.

The problem caused by this decline is that real compensation of labor will, over the long run, only grow in line with labor productivity growth. In Germany real wage growth has indeed been sluggish and declining, and was even around zero and negative during the mid-2000s when stagnation in labor productivity growth set in. This slower wages growth implies that domestic demand will also grow slowly [Box 10].

A comprehensive literature studies the impact of labor productivity growth on wage distribution, accounting for ris-

FIGURE 2: **The channels from innovation to inclusiveness**



Source: Authors' own creation.

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ing wage inequality as the outcome of skill-biased technological change (SBTC) (see e.g., Acemoglu and Autor, 2011). Goldin and Katz (2010) explain that the wage premium of workers with the skills to use the new technology continues to rise if their supply fails to keep up with demand, due to the speed of innovation and technology diffusion. A more unequal distribution of incomes will result in an overall decline in domestic demand growth [Box 10]. While there is some evidence of a rising wage premium due to SBTC in Germany, this study concludes that it has been insignificant for income inequality, and has not been the major threat to jobs and incomes. To be more specific, there is little evidence that technology is generally replacing human workers with machines and robots, and especially not at the high skilled level (Marin, 2014; Dauth et al., 2017b).

A decline in labor productivity will put the competitiveness of the economy [Box 3] under pressure, and will cause the corporate sector (the entrepreneurial system) to respond by, for instance, offshoring production to locations with lower wages or higher productivity[5] and, furthermore, by increasing corporate savings, thereby investing less in fixed capital. This study presents evidence that this has occurred in Germany in recent years. Today large corporations hold substantial amounts of cash, equivalent to 20 percent of the country's GDP, instead of investing in capital or breakthrough innovations. The significant decline in corporate fixed capital investment, in turn, further decreases the effectiveness of technological innovation, because it delays the distribution and spread of technology throughout the economy, given that new technology is most often embodied in the capital that laborers use. The net result has been that profits grew faster than labor wages, leading to a decline in the relative share of labor in national incomes, with top incomes also rising out of proportion, as Piketty (2013) explains.

The extent to which the corporate sector engages in the above-mentioned adjustments towards better competitiveness will partly depend on the success of the educational system to deliver workers with those skills in demand, and ones that can 'travel' between different sectors. If the education system is too specialized and does not deliver the right kind of skills, the wage gap will grow faster via SBTC, but also via rising forms of insecure and low-wage employment. As a consequence, growth will be less inclusive and domestic demand will grow slower.

5 The offshoring of production refers to the allocation of parts of the supply chain, within the production process, to other countries.

Fears of reduced competitiveness not only elicit a response from the corporate sector, but also from government. Fearing that the country's international competitiveness would be weakened, government also contributed towards the reduction of real labor compensation from the mid-1990s. The so-called Hartz reforms were the central policy response in this regard. As a result various benefits of the social welfare state were reduced or abolished. Self-employment and forms of irregular and part-time employment on low(er) wages increased, while labor unionization rates fell. The rate of working- and 'at-risk-of-poverty' doubled from 4.8 percent to 9.6 percent between 2005 and 2015. Thus, although unemployment fell after peaking in 2005, income inequality did not (Biewen and Juhasz, 2012). The authors ascribe this outcome, at least partially, to the fact that the rise in employment was largely due to more self-employment together with part-time working and marginal forms of employment.

At the same time as the above pressures on real labor compensation, certain skills became scarcer due to demographic changes and the nature of the education system. The relatively specialized nature of higher education in Germany hampered the mobility of skills between sectors. More elderly workers and pensioners may accentuate reduced productivity, which reduces consumption growth and leads to an upward pressure on the wage premium. The overall effect leads to reduced domestic demand growth [Box 10], and greater inequality in incomes and wealth (i.e., reduced inclusiveness of growth).

Whereas the stagnation in domestic demand could have led to policy responses to stimulate demand, such as expanding government consumption and investment, and encouraging fixed investment by corporations, Germany ignored these owing to the benefits of the euro exchange rate, which favors the country's exports. The euro, it has been argued, induces the 'hyper-competitiveness' of the German economy, as evidenced by the fact it has the largest current account surplus worldwide. Hence, corporates and government could partly ignore the decline in domestic consumption. The ability to shift production to meet foreign demand through exporting and move to offshore production resulted in German firms reducing their demand for low-skilled labor while increasing their demand for high-skilled labor, driving the wage premium upward (Becker and Muendler, 2015). In this regard, Felbermayr et al. (2014) document that by 2003 exporting firms in Germany paid what can be labeled an 'exporter premium', resulting in wages 11 percent higher on average. The authors also find that the export premium has become a significant contributor towards wage inequality only since 2003, ascribing this to an indirect effect of the Hartz labor market reforms and the decentralization of collective bargaining in the late 1990s and stating that 'wage flexibility has increased sharply in Germany due to the documented decline of collective bargaining agreements. As such, company characteristics [...] such as export status have a stronger effect on paid wages' (Felbermayr et al., 2014, p. 37).

This rise in income inequality was exacerbated by two features related to a poor innovation performance: (i) good management skills were in relative short supply, leading to a rise in CEO wages; (ii) the scarcity of management skills resulted in an increasing divergence in firm-level productivity growth, which, in turn, produced high productivity frontier firms vs. low productivity laggard firms. A lack of management skills further contributed to a more sluggish diffusion of technological innovation across the economy, making innovation less effective.

The conclusion of this study is that Germany needs more and better innovation that will reboot labor productivity. While it is highly competent in traditional and medium-technology industries, such as automobiles and machine tools, it has failed to acquire the innovation lead in semiconductors, computing, 3D-printing, nanotechnology, robotics or molecular biology – the drivers of what has been named the 'fourth industrial revolution' by the World Economic Forum. 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 patents). The top 20 patent applicants in nanotechnology have not included a single German firm since 1970. In all of these fields, German firms are lagging behind those from the United States, Japan, South Korea, and increasingly also China. Germany has been, until recently, a technology leader in solar photo-voltaic (PV) energy. By now, however, most of the solar PV production has 'moved out of Germany' to China: almost 50 percent of the 100, 300 workers in Solar PV manufacturing in Germany lost their jobs in just one year (2013). Because these new technologies now fundamentally affect manufacturing, Germany's critically important manufacturing sector is facing the threat of ending up as 'a sub-sector of the IT sector in the US'.

To boost innovation in Germany, this study argues, a fundamental change is required in the national innovation system. In Section 3 we describe how Germany has traditionally established an excellent system of innovation: between 1850 and 1913, when Germany experienced its remarkable industrialization, the unique collaboration between industries, government and higher education institutions created the 'triple-helix' system, which remained largely intact after the Second World War. The system's earlier success, however, may be starting to work against delivering the type of effective innovation that is now required. An appropriate industrial innovation policy, supported by diversification of the higher education sector, is necessary instead. Such an industrial innovation policy will require a change in the approach and organization of the public sector in this regard, raising the question posed by Mazzucato (2015, p.125): '[h]ow should public organizations be structured so that they can accommodate the risk-taking and explorative capacity needed?'

This study does not answer this question, although an answer will eventually have to be delivered if sustained and inclusive growth in Germany is to resume in future. In the meantime, the social welfare state is central (see diagram [Box 11]). In particular, compensatory social welfare policies, including redistributive taxes and transfers and active labor market measures, remain the first line of defense against rising income and wealth inequalities and dealing with the challenges thrown up by changing demographics.

3 Technological innovation and inclusive growth in Germany: A tale of two periods

In this section Germany's experiences over the period 1850 to 1913 are compared with the post-World War II period (1950 to present). This is useful for a number of reasons: first, the relationship between technology, growth, and social outcomes tends to be persistent and institutions can have long-term effects – outcomes therefore often have historic roots. Second, it allows one to evaluate the impact of the national innovation system and to identify structural breaks. Third, a historical perspective makes strikingly clear that innovation-driven growth has been inclusive over a long span of time.

The historical overview underlines two points: first, technological innovation has historically been an important source of inclusive growth in Germany, based on a series of remarkable breakthrough product innovations in the late 19th and early 20th centuries that laid the foundations for virtually the entire modern German economy. During this period the German social welfare state, the world's first, was established. And second, in the period after the Second World War, technological innovation became less effective, focusing on incremental process innovations, accompanied by an increase in inequality over the past two decades. In the remainder of this section the key features of these periods in terms of innovation-inequality linkages are discussed.

3.1 The period of rapid innovation and inclusive growth: 1850 to 1913

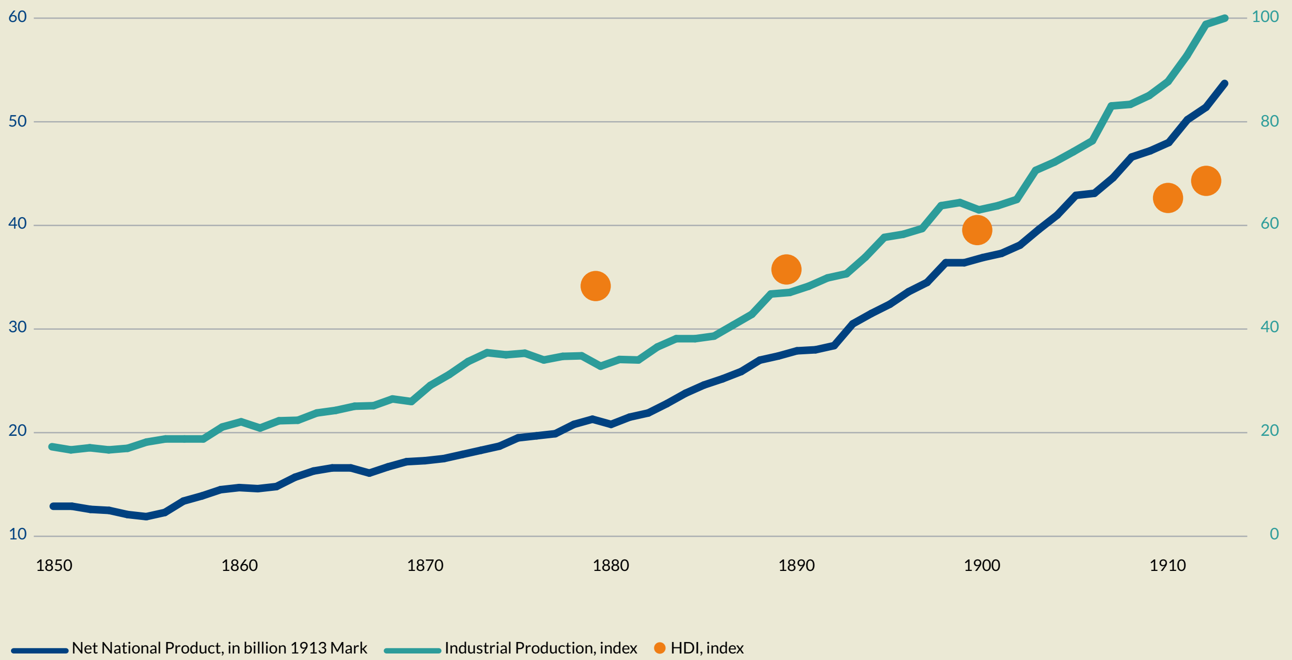
Germany's system of technological innovation came into being between 1850 and 1913. This was the period of Germany's industrialization (Beise and Stahl, 1999),[6] and coincided with the 'first era of globalization' (Twarog, 1997) and the 'second industrial revolution'. In fact, the innovation system supported and drove rapid industrialization, with Germany specializing in fields that were characteristic for the 'second industrial revolution', such as chemicals, automobiles and electricity. This development was accompanied by inclusive growth as shown by the Human Development Index (HDI) which rose from 48.3 (in the period 1871 to 1880) to 68.6 in 1912 (see Figure 3). As Twarog (1997) summarizes, 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. During this time, however, income inequality did not worsen (Williamson, 1995).

Innovation played an important role in driving this inclusive growth. A large growth component over this period was that in total factor productivity (TFP), a frequently used indirect indicator of technological progress. Burhop and Wolff (2005, p. 640) find that TFP contributed 63.9 percent to total net national product (NNP) growth between 1851 and 1913. Without the myriad of (radical) technological innovations that the system produced during this period (see Table 1), German industrialization and economic development would not have been as successful.

What made these radical technological innovations possible? This is a pertinent question, as 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 up to and including 1860. A century later, however, Germany had not only caught-up and transformed, but had also become the world's leading innovator. Most economic historians agree that Germany's performance was powered by the rise of its education and scientific sectors, and in

6 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.

FIGURE 3: **Economic take-off and industrialization in Germany, 1850 to 1913**



Notes: The industrial production and the HDI are indexes with a range from 0 (lowest) to 100 (highest). The industrial production data is indexed to 100 for the year 1913.
Data source: Authors' own compilation based on `compromise' data for the net national product (in billion 1913 marks) and industrial production data from Burshop and Wolff (2005, pp.651-653), and HDI data from Twarog (1997, p.322).

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particular by the collaboration among educational and research institutions, private entrepreneurs and government.

In the subsequent discussion our study focuses respectively on (i) the education and science establishment; (ii) the entrepreneurs and the business community; and (iii) the government, describing how their collaboration created the so-called 'triple-helix' model of innovation and development (Mroczkowski, 2014).

As far as the education and scientific research establishment is concerned, Watson (2010) traces significant institutional contributions to Frederick the Great's establishment of the Berlin Academy of Arts and Science in the 18th century, as well as to a 'revolution' in learning and reading. As the author documents, by the year 1800 around 270 reading societies existed in Germany, with literacy rates in Prussia and Saxony amounting to the highest in the world.[7] In subsequent decades, between 1790 and 1840, German scholars, such as Wilhelm von Humboldt, re-created German universities as research institutions – heralding the modern research university – that differed from earlier universities in their 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).[8]

Science and engineering were pre-eminent in the best of these universities. Moreover, the 19th century also saw the rise of polytechnics and technical universities (Technische Hochschulen), where engineering and applied sciences were paramount. These institutions were widely accessible, and mostly attended by the educated and rising middle classes of that period (Watson, 2010). The first steps were taken 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 the instigation of the chemical industry, renamed the Max Planck Institutes after the Second World War. This

7 By 1800, Germany's adult literacy rate was 35 percent and it was publishing 116 million printed books per year, only lagging behind France and the United Kingdom (Buringh and van Zanden, 2009).

8 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'.

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

Source: Authors' own compilation.

'industrial research system', influenced as much by entrepreneurs and businessmen as by the government and scientists, was a first of its kind worldwide (Grupp et al., 2005).

The scientific breakthroughs at universities and polytechnics were quickly taken up and applied for commercial purposes by German entrepreneurs. An early example was 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 engineer-entrepreneurs such as 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 telecommunications 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 these (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 Hoechst, introducing famous inventions such as the aspirin. The chemical and pharmaceutical industries led the way to the establishment of private industrial research laboratories with their main purpose inventing and applying 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 facility 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 list of radical inventions by engineer-entrepreneurs during the late 19th and early 20th century is remarkable (Table 1). The legacy of these innovations has 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 others.

The system that allowed them to become innovative, leading global firms has endured and was adapted over time to maintain their dominance in manufacturing, hence in the machinery, tools, automotive, and electrical engineering industries. As shown later in this study, however, the shift has been towards more incremental, rather than the radical innovations they pioneered during the 'second industrial revolution'. In the period after 1950, and particularly after 1980, Germany lost its global pre-eminence in generating radical innovations by failing to contribute to the sectors that defined the 'fourth industrial revolution'. Many of the innovations driving this new industrial revolution, such as in ICT, originated outside Germany, in particular in countries such as the United States, Japan, and South Korea.

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 changes in 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, owned by 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 national and state governments (i.e., the *Länder*) support universal education, but they also provided what many saw as the spark for Germany's industrialization through the promotion of the country's railway system (Fohlin, 1998). The railways created big 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, thereby improving the competitiveness of all industries and both internal and external trade (Kopsidis and Bromley, 2016). By 1913 the largest employers in Germany were state-owned enterprises such as the Prussian-Hessian Railway (more than 500,000) and the Deutsche Reichspost (more than 300,000) (Labuske and Streb, 2008). Since a degree was a requirement for many government jobs, the higher education system experienced a huge boost, and confirmed its importance as a central pillar in the development of the economy and civil society.

Mechanical engineering and specifically machinery manufacturing were given an important impetus by the railways, and at the same time, by 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 mechanical engineering industry between 1870 and 1913. By the latter date, exports of machinery were the single largest category of exports from Germany that also rated top exporter in this industrial sector. The beginning of Germany's manufacturing export model can thus be traced back to this era.

The mechanical engineering industry was also highly innovative, with half of the most inventive firms of that time located in this sector (Labuske and Streb, 2008). Many of them are still prominent in Germany, for instance 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 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 biggest value acquisition in Europe at that time.

More generally, the creation of the German Empire in 1871 centralized government and further increased the economic freedom and entrepreneurship that had already started in the late 18th century by reducing the control of various industry and trade guilds that were stifling competition and innovation (Ogilvie, 1996; Kopsidis and Bromley, 2016).[9]

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[10] and improve the allocation and distribution of technology (Meyer-Thurow, 1982; Burhop and Wolff, 2013).

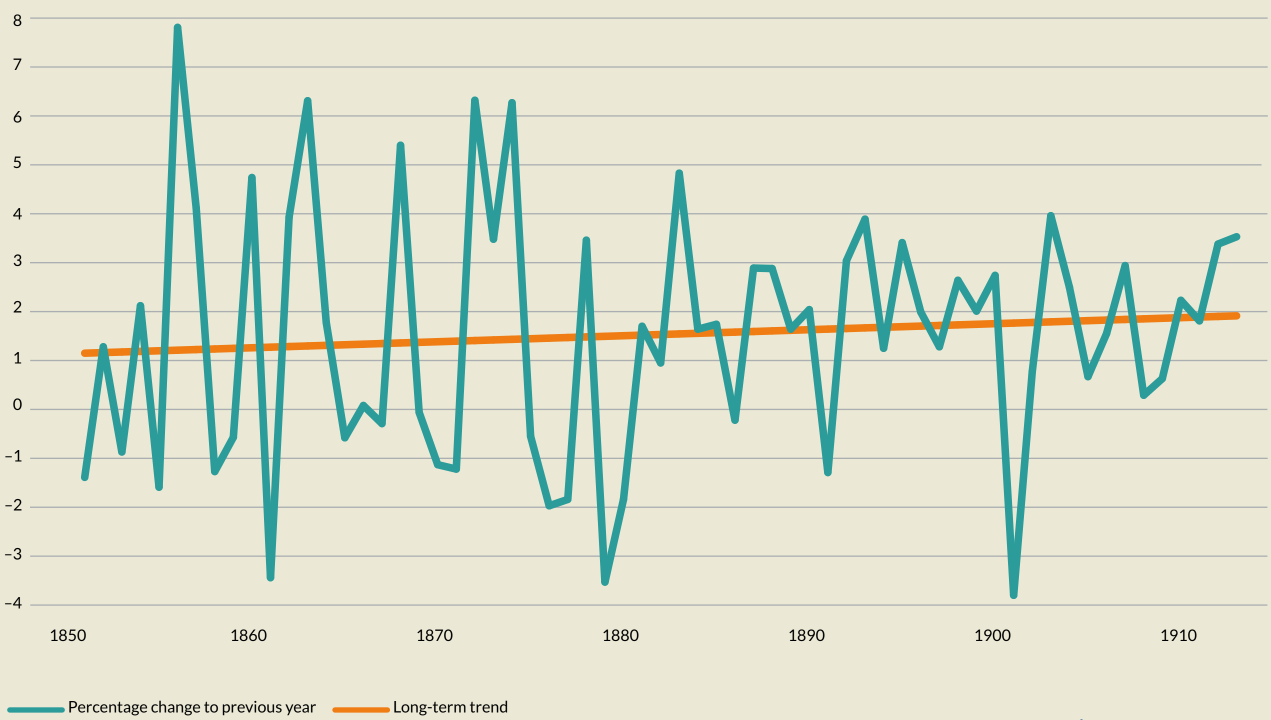
It should be noted that rather woeful historical events also affected the government's capacity to foster innovation and growth. France's reparation payments (around 5 billion Francs) after the Franco-Prussian War led to a huge inflow of money into the newly established German Empire in the years after 1871. The government, repaying loans to entrepreneurs and businesses that had supported it to finance the war, reinvested these funds on a massive scale in commercializing innovations and in expanding 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 the creation of the German Empire, 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, especially towards the end of the 19th century, when big joint stock credit houses 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 self-funding, credit cooperatives, and (outside of Prussia) monies from private bankers that funded entrepreneurial ventures, and the states that financed the railways' expansion (Edwards and Ogilvie,

9 Ogilvie (1996, pp. 286–287) describes the Luddite 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).

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

FIGURE 4: **Per capita GDP growth in Germany, 1850 to 1913, in percent**



Source: Maddison Project

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1996). The banking system as a whole developed in tandem with the industrial sector during the latter half of the 19th century.

Finally, an important 'social innovation' during the German Empire was the establishment of the world's first welfare state (the German *Sozialstaat*). This was deemed necessary for social stability, and moreover was 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 injury at work (1884) and old-age pension (1889) contributed to social inclusiveness. Williamson (1995) concludes that income inequality hardly changed in Germany during the period 1850 to 1913 despite the rise in top incomes, partly because the wages of low-skilled workers increased faster than in other industrial countries.

As indicated in Figure 3, using the Human Development Index (HDI), incomes, literacy, and life expectation all improved significantly, showing that growing industrial production and a higher net national product were accompanied by a rise in HDI. Moreover, as Figure 4 shows, economic growth accelerated during this period – which is in stark contrast to the post-1950 period when it decelerated.[11]

The lesson of this period is that technological innovations, supported by appropriate social protection, could be consistent with fast economic growth that was moreover inclusive – it did not lead to growing income inequality, and instead strongly contributed to human development for the population as a whole.

3.2 Wirtschaftswunder, declining innovation and rising inequality: 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 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).

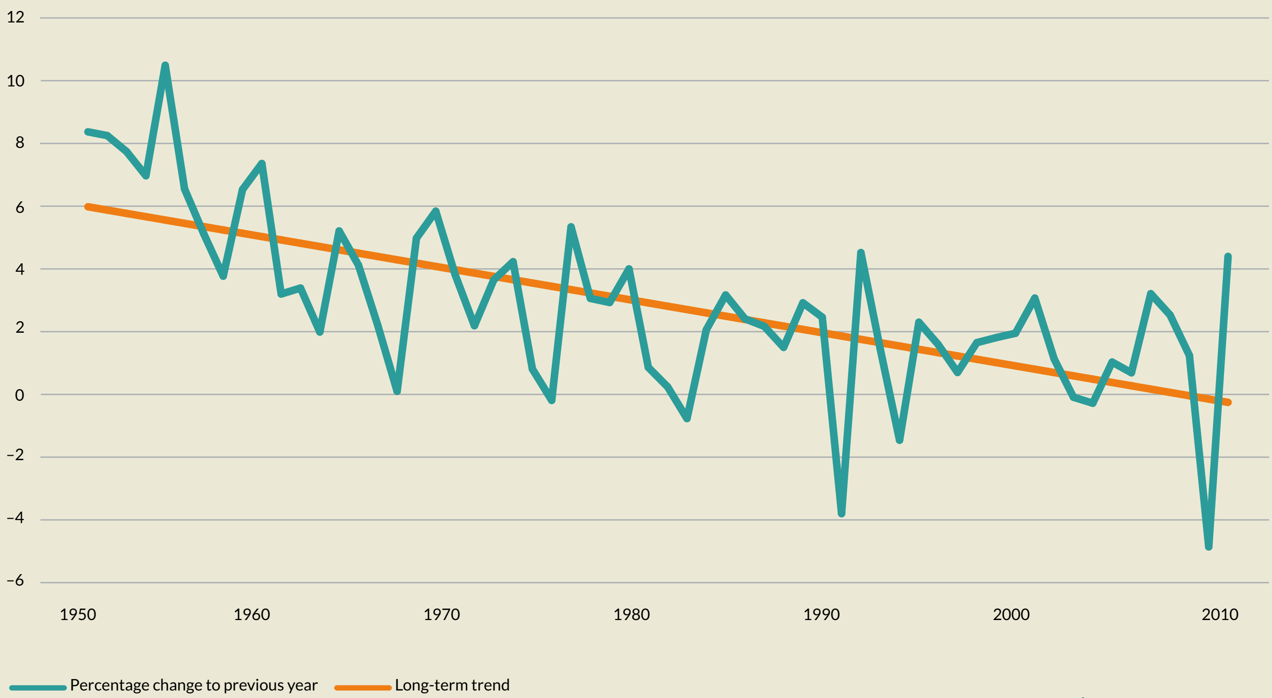
Grupp et al. (2005) depict historic innovation patterns in Germany from 1850 until 2000. They use total scientific expenditure as a percentage of total government expenditure as an indicator for innovation. Scientific spending includes R&D, training and teaching costs, and the costs of maintenance and 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 unification. R&D expenditure amounted to just 2.4 percent in 2004 (see also Figure 9 in Section 4.2). When comparing this trend with data on TFP growth for the post-war period, it can be seen that this peaked in the 1970s after which it declined.

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

Economic growth accelerated in terms of per capita GDP over the period 1850 to 1913. Between 1850 and 1869 average growth amounted to 1.6 percent a year. Between 1870 and 1899 it increased to 2.5 percent, and in the period 1900 to 1913 accelerated even further to 2.8 percent (see Figure 4). In sharp contrast, the period 1950 to 2010 experienced a deceleration in per capita economic growth. Initially though, between 1950 and the mid-1970s, average annual GDP per capita growth amounted to 5.0 percent. During this period West Germany experienced its *Wirtschaftswunder* (economic miracle). Growth was driven by reconstruction under the Marshall Plan and the introduction of social market policies, including the model of *Mitbestimmung* (co-management) in which workers obtained representation on the supervisory board (Comin et al., 2016). Growth, however, subsequently declined to an average 2.0 percent between 1975 and 1990, and further to 1.0 percent between 1990 and 2010 (see Figure 5). During

11 Although income inequality remained stable and the HDI improved during this period, the country still faced many social hardships, including the use of child labor and urban poverty.

FIGURE 5: **Per capita GDP growth in Germany, 1950 to 2010, in percent**



Source: Maddison Project

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this latter period Germany was described as the 'Sick Man of Europe'.

Audretsch and Lehmann (2016) point out that even before unification German 'competitiveness began to sag', and that while everybody had expected a 'peace dividend' after it and the end of the Cold War, this never materialized, because the unification 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 was 40 to 70 percent of that of West German workers. This shock occurred just as the country was 'exposed to new global competition' post-Cold War (ibid., p. 4).

What have been the reasons for this secular decline in productivity in Germany since the 1970s? Most scholars point to the nature of the innovation system. According to Breznitz (2014), the German system 'got stuck' at producing primarily incremental innovations in existing (and old) industries, rather than radically innovating and creating new industries and markets. Meyer-Thurow (1982) states that a major goal of R&D expenditure by individual companies was to prevent new firms/competitors entering the market rather than creating new markets. Erixon and Weigel (2016, p. 59) describe the strategies of large German corporations as being essentially 'defensive', in that they 'favor the allocation of resources according to a rentier formula; and it crowds out innovations'. As an example, Meyer-Thurow (1982, pp. 380–381) conducted a case study of the pharmaceutical giant Bayer AG and concluded 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 strategy of choice for large corporate giants, but also for the *Mittelstand*,[12] although for different reasons. The model of incremental

12 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). 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.

innovation adopted by the *Mittelstand* is to remain internationally competitive on the basis of quality, not costs. Today more than 70 percent of Germany's exports are from *Mittelstand* firms. 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 in the output of specific products of exceptional quality with a focus on customer needs, in the context of a growing globalization of the world economy in the 20th century, a focus on exports overseas gave these *Mittelstand* firms the chance to make use of economies of scale. Over time, many of these firms became world leaders in their field, being described as Germany's 'hidden champions' (Simon, 2009). In 2015, the top 20 'hidden champions' had a turnover of over EUR 7 billion and employed more than 72,000 (see Table 3 in the Appendix). Fear et al. (2015) argue that the success of *Mittelstand* firms is not so much driven by their innovative abilities, as by doing 'good business': their focus on customer needs and quality, reliable products and services.

As outlined before, while Germany today is a leader in traditional and medium technology industries such as automobiles, printing press and machine tools, it is not one 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*'[13] (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 have not included a single German firm since 1970.

This section concludes that the decline in Germany's innovativeness, from a world leader in breakthrough innovations to a country where incremental process innovations dominate, makes inclusive growth more difficult to achieve, particularly given slow growth in domestic demand and the imperative to remain internationally competitive. Hence, policy measures have been taken to reduce the real cost of labor and thereby improve the economy's competitiveness and reduce pressure on fiscal resources. Whereas in the past technological innovation promoted inclusive growth, it is becoming less effective. The following section documents this decline in more detail.

13 The term *Industrie 4.0* is ascribed to Henning Kagermann, head of the German Academy of Science and Engineering (Acatech) (The Economist, 2015).

4 Documenting the decline in German innovativeness

This section substantiates the conclusion that the German economy's innovativeness has declined over the past half century. This may appear counter-intuitive given that Germany's investment in stimulating technological innovation is large and growing. For instance, in 2014 the country spent more than EUR 80 billion on R&D, an increase of 66 percent on 2000. But various pieces of evidence are here presented, using different measures of 'innovation', to show a consistent picture of Germany generating less and less effective innovations, despite channeling significant amounts of investment into this area of economic activity.

4.1 Exhibit 1: A growing gap between applied and granted patents

This first piece of evidence is derived from patent data, a frequent 'output' indicator of innovation. An important distinction lies between patent applications and patents granted. The difference rests in the ratio of successful (granted) patents to applications (see Figure 6). The recent trend in Germany has been a reduction in the ratio of patents granted to 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,[14] and this has coincided with the period in which income inequality rose.

In so far as the decline in successful (granted) patent applications reflects one in innovativeness, the broad reasons are discussed in the next section. It can however be noted that patents are far from being a perfect measure of innovativeness, warranting some caution in making strong conclusions. For instance, patent offices may simply be getting more stringent, or the growth in the number of applications might not be quality-driven, but the inclination to submit applications may have increased over time.

14 Germany also experienced a decline in the quality of its patents granted at the USPTO relative to the United States between 1980 and 2011 (Kwon et al., 2017).

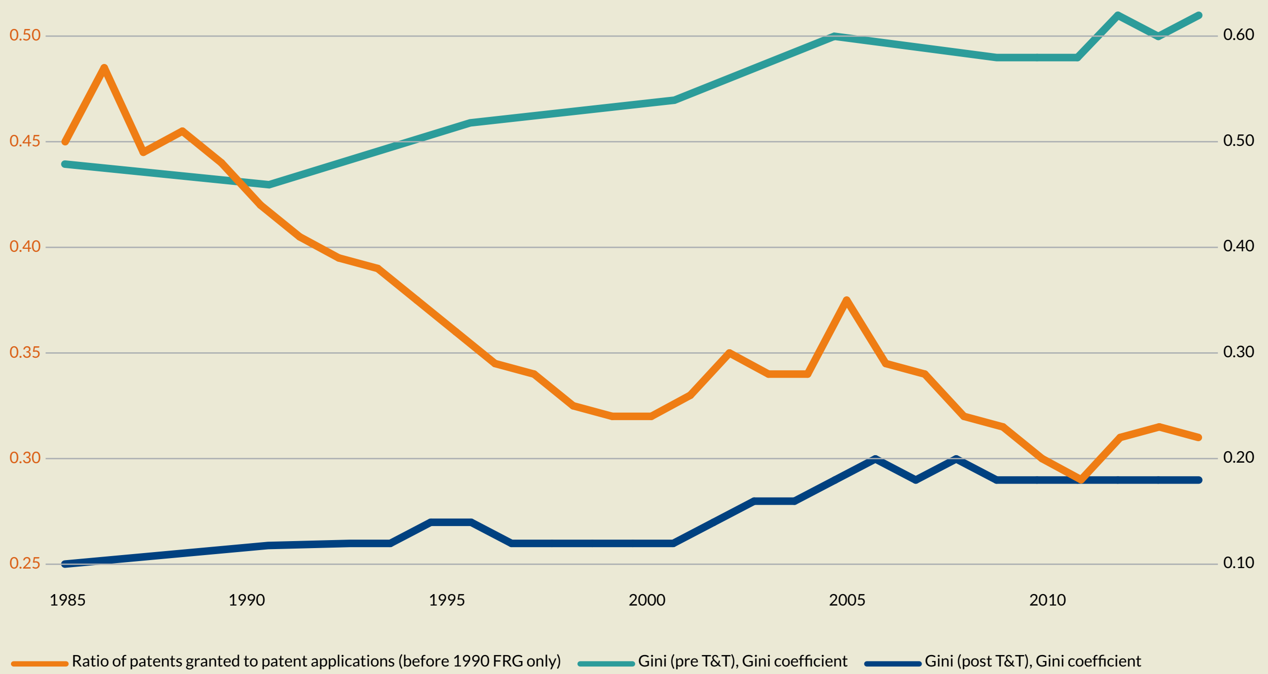
4.2 Exhibit 2: Declining rates of growth in productivity

The second piece of evidence derives from data on labor productivity and total factor productivity (TFP). TFP growth has been declining in Germany since the 1970s, down to a rate of only 0.5 percent per annum over the past ten years (OECD, 2016). As the OECD (2016, p. 6) notes, TFP growth has been on a long-term decline since the 1970s. Over the period 1996 to 2005 it averaged 0.4 percent, which makes Germany 34th out of 37 OECD countries. Only Portugal, Italy and Spain did worse.

Figure 7 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 rate experienced from 2001 to 2010, at just 0.4 percent. Recently annual TFP growth has seen a moderate increase, up to an average of 0.7 percent between 2011 and 2014, on a par with the decade from 1991 to 2000.

The 1960s were thus, at least as 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

FIGURE 6: **Ratio patent applications to patents granted and the Gini coefficient, 1985 to 2014**



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

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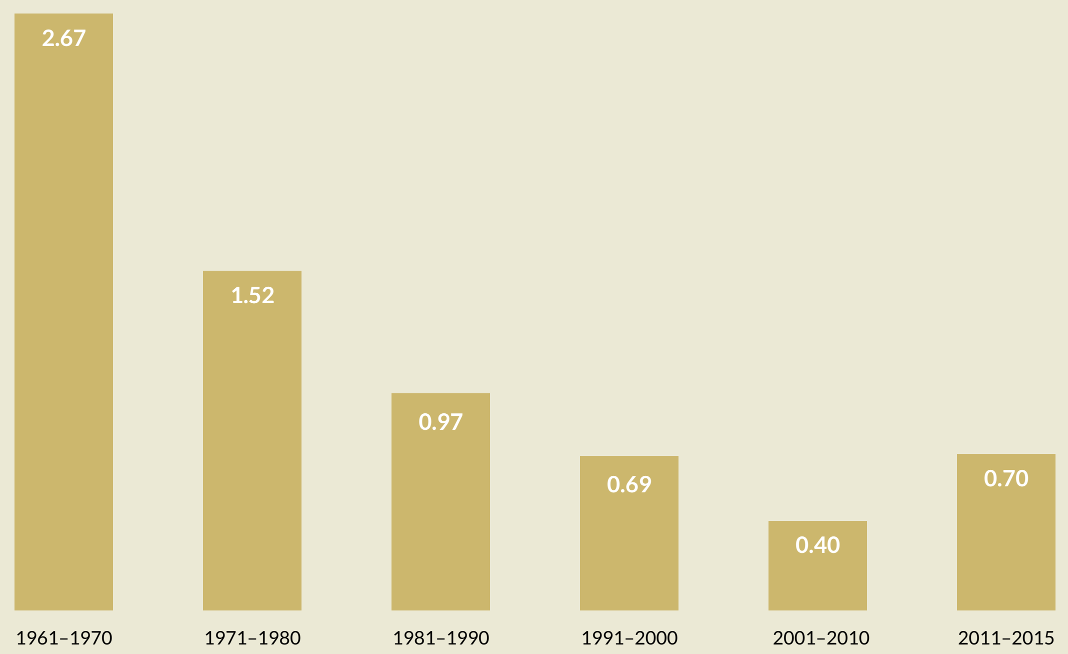
FIGURE 7: **Average annual TFP growth, 1960 to 2015, in percent**



Source: European Commission AMECO database online.

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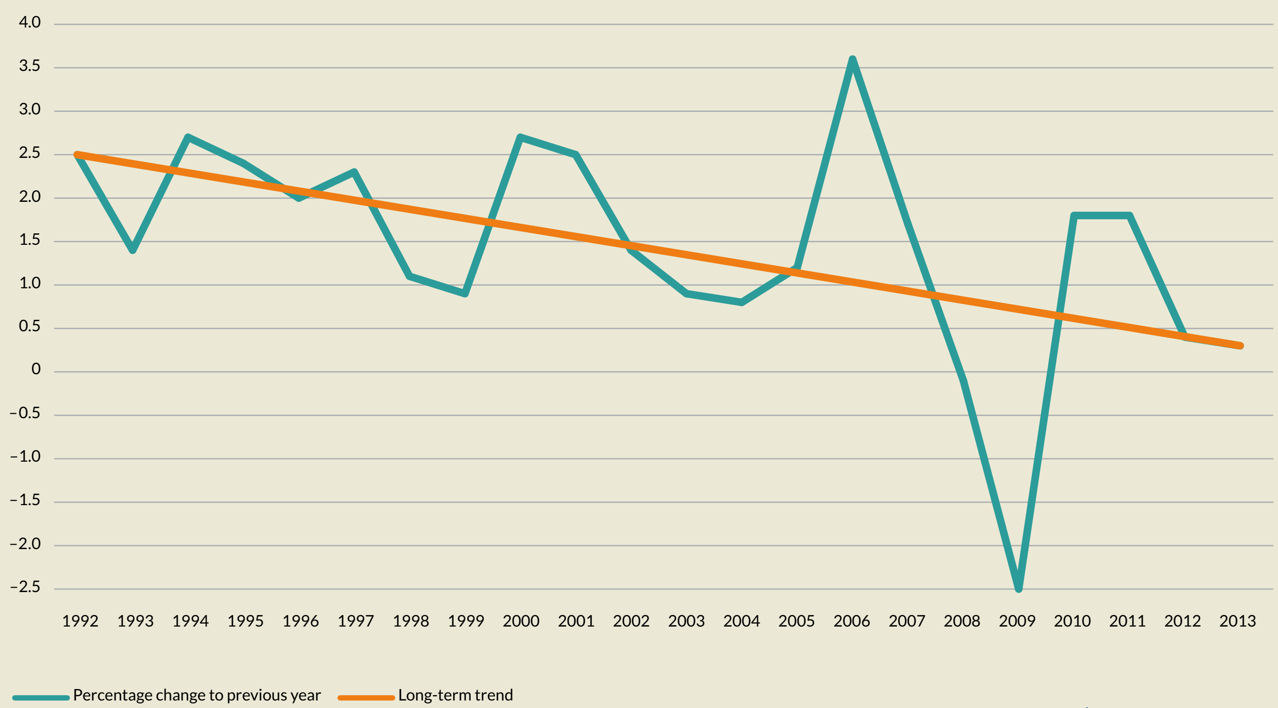
FIGURE 8: **Percentage change in real labor productivity (output per hour worked), 1992 to 2013, in percent**



Source: European Commission AMECO database online.

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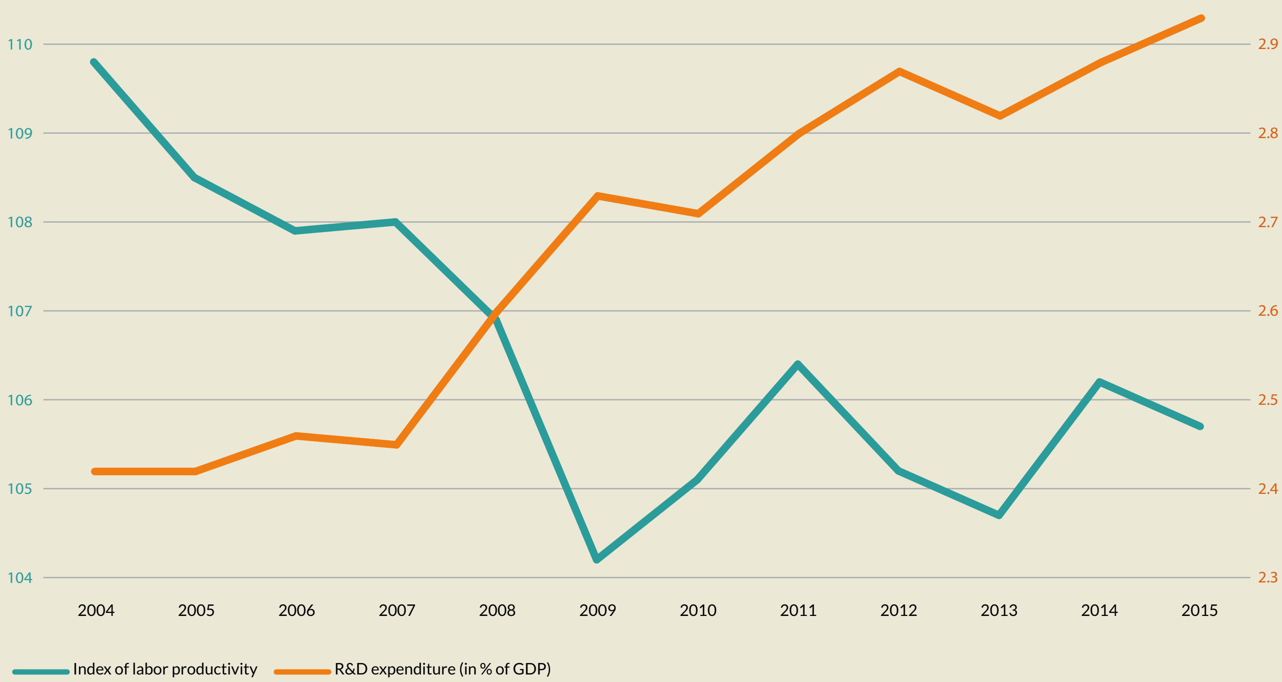
FIGURE 9: **Labor productivity per person employed and R&D expenditure, 2004 to 2015**



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

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reflect the relatively slower growth in high(er) skills acquisition in Germany over this period. Baumgarten (2013, p. 5) finds that 'German establishments invested more in technology during the 1980s than during recent years, showing that while 34 percent of firms invested in ICT in 1996, only 29 percent did so in 2010.' Thus, the decline in labor productivity occurred in spite of the rising share of GDP spent on R&D. Innovation expenditure has become less effective.

Figure 8 further shows that the percentage change in real labor productivity per hour worked has been on a longterm decline since the 1990s. Labor productivity growth rates were five times lower in 2013 than in 1992. Figure 9 contrasts the index of labor productivity, showing that it has overall declined since 2004 (relative to the EU 28), despite an upward blip after the Great Recession in 2008/2009, with R&D intensity, defined as gross domestic expenditure on R&D. This increased considerably over the same period, especially from the mid-2000s, peaking at almost 3 percent in 2014.[15] The figure makes clear that R&D expenditure (innovation), since 2004 at least, has not contributed to raising labor productivity relative to other European countries.[16]

4.3 Exhibit 3: Labor hours worked, productivity and labor compensation

From 1950 the annual hours worked by the average German worker declined from just over 2,400 hours to less than 1,400 by 2015. This decline has historical roots, having started as early as under the German Empire.[17] In fact, Germany has experienced the fastest fall in annual average hours worked per employee compared to the United Kingdom, France, and the United States (see Figure 10). This sharp decline can be explained by the growing power of unions, by higher incomes (raising the value of leisure), and also by the low (and even declining) levels of inequality in Germany during the 20th century. The latter is an interesting point given the conclusion by Huberman and Minns (2007), that hours of work will decline more rapidly in more equal societies, because of the lower opportunity costs of working more.

This decline in working hours is also based on increasing productivity over time, rendered possible by technological innovation and capital investment. This is why, even though average annual hours worked substantially declined over recent decades, employment and wages have grown. Wages, however, have grown increasingly more slowly and, furthermore, by less than labor productivity. In fact, labor productivity growth has been slowing down – which stands in contrast to the view that robots replace humans in the workplace. As Yglesias (2015) points out, following substantial replacement of humans by robots, one would expect the labor productivity of those still with jobs to surge.

As Figure 10 and the previous section make clear, labor productivity is not increasing fast enough to lend credence to the idea that robots are taking over. Notably, Dauth et al. (2017b, p. 1) find that there is 'no evidence that robots cause total job losses' in Germany, in spite of the fact that the number of robots per workforce in Germany exceeds that of the United States and other European countries.[18]

A final piece of evidence in this regard can be shown by comparing average annual growth in worker compensation with growth in GDP per worker (see Figure 11). Since 1991, GDP growth per worker has generally exceeded any increase in worker compensation – hence, a proportionately larger share was directed towards capital, consistent with the finding of higher income inequality over this period – except for the most recent period 2011 to 2015, when workers received proportionately more than their GDP share.[19]

The period 2011 to 2015 was also the period most intensely affected by the 'fourth industrial revolution' technologies *(Industrie 4.0)*, such as robotics. Clearly, these technologies are not consistent with higher income inequality in the data (yet). This finding is the opposite of what would be

15 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) counters these arguments, concluding that '[f]or the mismeasurement hypothesis to explain the productivity slowdown […] current GDP measures must be missing hundreds of billions of dollars in incremental output'.

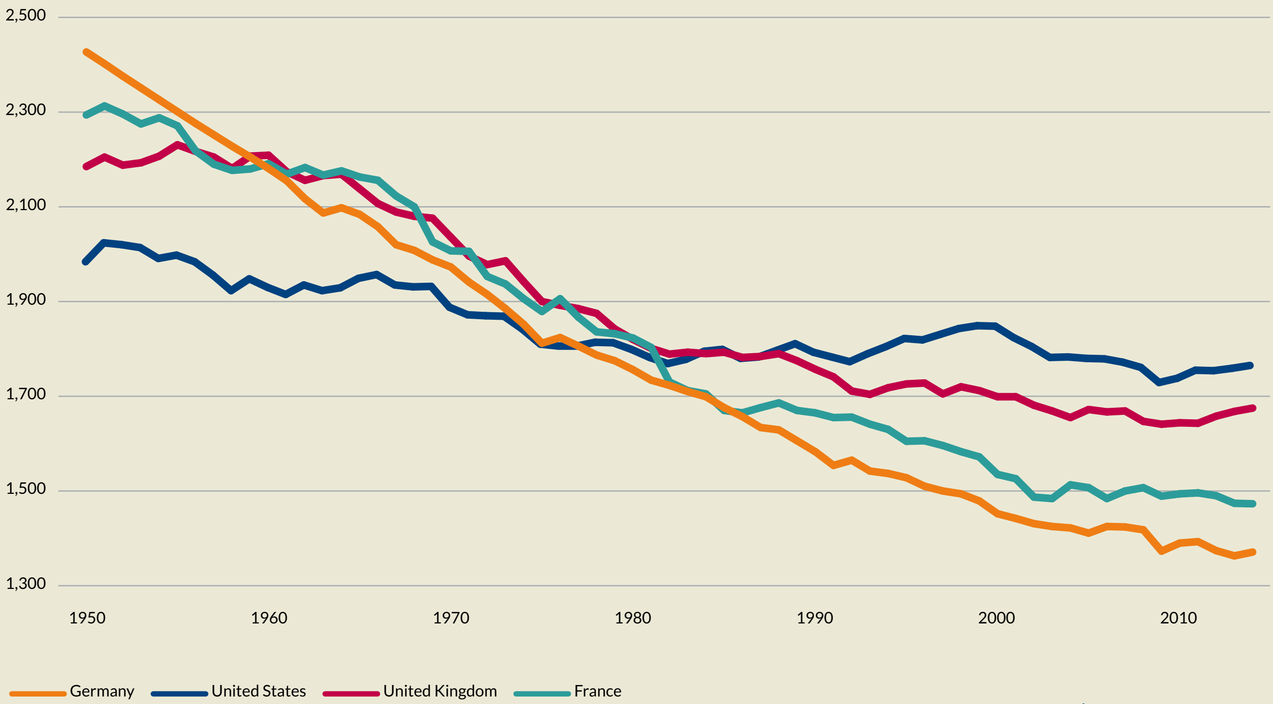
16 Bloom et al. (2017, p. 46) similarly find that research productivity declined in the United States over the period 1930 to 2000, stating that '[j]ust to sustain constant growth in GDP per person, the US must double the amount of research effort searching for new ideas every 13 years'.

17 In 1870 the average worker worked for almost 68 hours per week in Germany. By 1913, this had fallen to 57 hours, and by 2000 to only 41 hours (Huberman and Minns, 2007).

18 The authors do find however that robots cause reduced employment in manufacturing: not through job losses for incumbent workers, but by restricting jobs for new labor market entrants. The robots, in contrast, even help incumbent workers to maintain their jobs (Dauth et al., 2017b).

19 Based on OECD data, average wage growth was particularly low from the mid-1990s onward, and even 0 or negative during the 2000s. Only since 2010 has average wage growth started to rise again.

FIGURE 10: **Average annual working hours, 1950 to 2014**



Source: Penn World Table 9.0.

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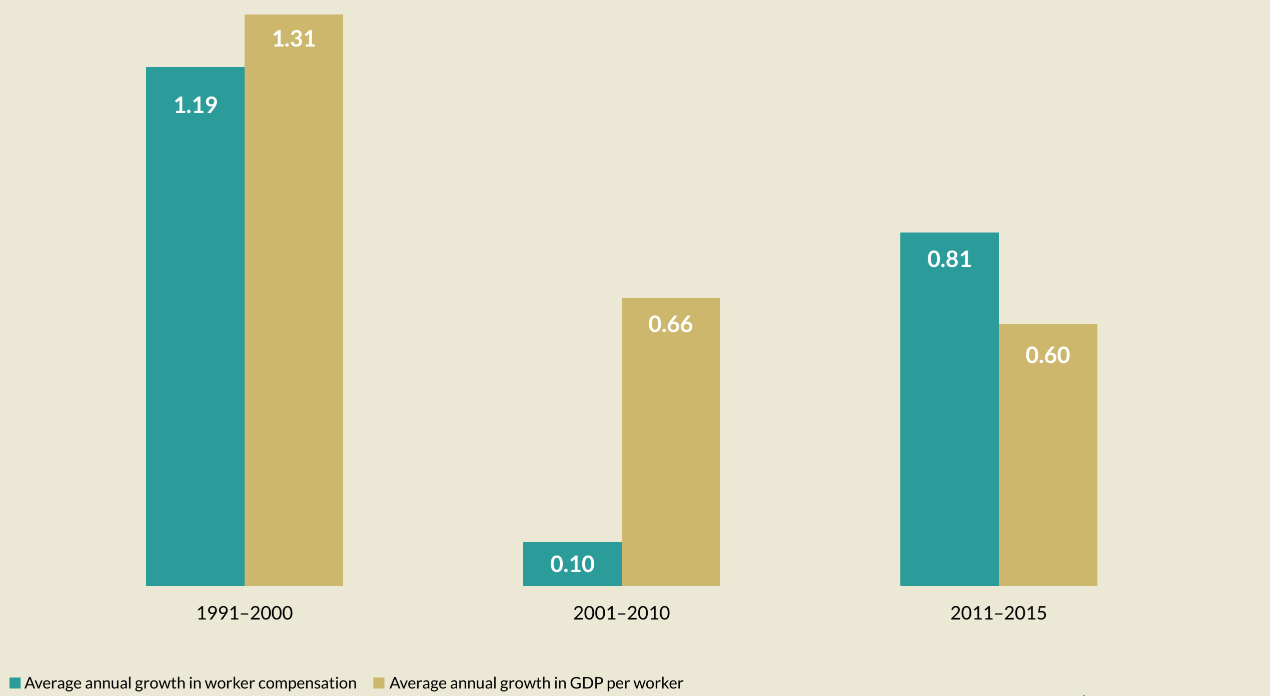
FIGURE 11: **Average annual growth in worker compensation and GDP per worker, 1991 to 2015, in percent**



Source: European Commission AMECO database online.

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expected if technological growth was 'too fast' for workers to adjust, or if robots were indeed taking over people's jobs.

4.4 Exhibit 4: The relative scarcity of venture capital investment

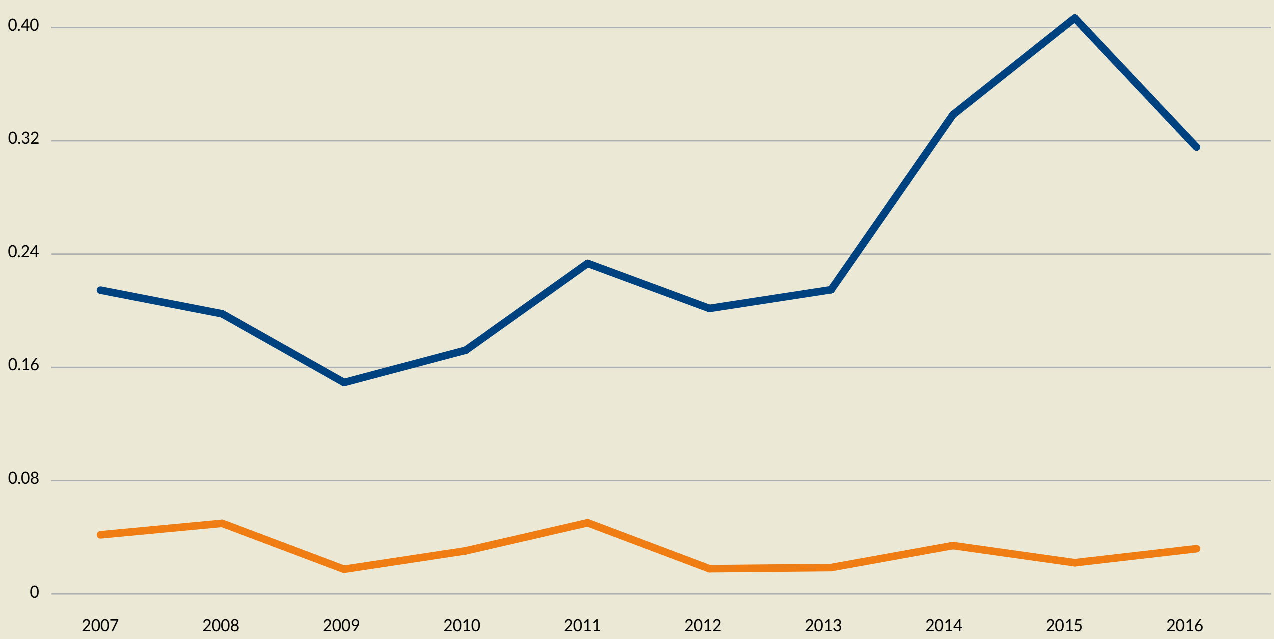
Venture capital (VC) investment is sometimes used as an indicator of innovation, since it is generally employed to finance high-tech start-ups, particularly in the ICT industry. Fohlin (2016) describes how the VC market expanded in the United States in the late 1970s in tandem with the ICT revolution. The location of VC investments also gives an indication of where radically innovative firms operate. Florida and King (2016) estimate the total value of VC investment worldwide at USD 42 billion in 2012. Of this, only 13.5 percent was invested in Europe; and within Europe, Germany's share was relatively small, behind the United Kingdom, France, Denmark, and Russia. The authors report, for instance, that among the top ten 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 does not stand out in terms of VC – on the contrary, it is lagging behind, compared to the United States, China, and other emerging market regions. Consider, for instance, Figure 12, where VC investment is compared between the United States and Germany, in percent of GDP, between 2007 and 2016. The graph indicates that there has been a surge in VC investment in the United States since 2013, reaching more than 0.4 percent of GDP by 2015, which amounted to almost 20 times the proportion of VC investment in Germany.

In 2014, the VC investment in only two US city-regions (San Francisco and New York) was already ten times the overall VC investment in Germany. Other city-regions, such as Beijing, have also experienced more than double the VC investments compared to Germany as a whole, as Figure 13 indicates. Moreover, data show that the volume of VC investments by non-member companies 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

FIGURE 12: **Venture capital investment in the United States and Germany, 2007 to 2016, in percent of GDP**



Source: Authors' own compilation based on data from Statista.

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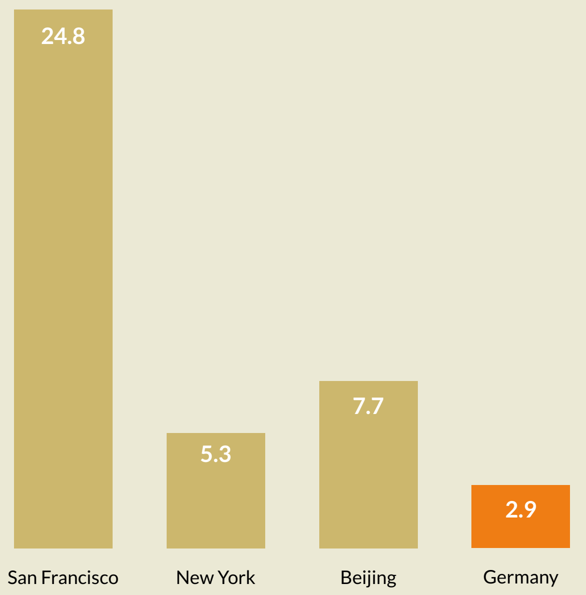
FIGURE 13: **Venture capital investment in selected world cities and regions, 2014, in billion USD**



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

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identified two decades ago. Audretsch and Lehmann (2016, p. 5) quote 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 are from the United States (42 percent) and Japan (30 percent).

5 The causes of decline in German innovativeness

Promoting itself as the *Land der Ideen* (Land of Ideas), Germany invests heavily in stimulating technological innovation. Despite this investment and effort, the impact of technological innovation on labor productivity growth continues to decline. The previous section offered four pieces of evidence that, separately and collectively, strongly support the idea of a decline in the effectiveness of innovation. The question arises why this has been declining – particularly, why has productivity been declining despite the rise in R&D spending? Only by understanding the causes of this decline can policy interventions be designed that have the potential to revive the contribution of technological innovation to inclusive growth. Three main reasons are discussed in this section: first, the historical legacy and institutional context, as Germany lost a large portion of its intelligentsia during and after the Second World War; second, weaknesses in the education system; and third, entrepreneurial stagnation.

5.1 Historic legacy and institutional context

Fohlin (2016, pp. 18-19) identifies the Second World War as representing a structural break in Germany's innovativeness, with a subsequent decline due to a combination of factors, including war destruction, the effects of the Cold War, the division of the country until 1990, and the subsequent costs of unification. Given 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'. 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 had 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.

A further institutional feature that may have contributed to the decline in innovation is the drop in union density over the past three decades. In Section 6 (below) the study shows that unionization reached a peak in 1991 and subsequently declined. This may have contributed to the slower and poorer diffusion of technologies. In this regard Addison et al. (2013) find evidence that unionization has been beneficial for innovation in the past, because the participation of workers in management helped new technology adoption and diffusion. Over the more recent past, however, the power of unions has diminished.

5.2 Lack of diversity and innovativeness in the education system

The decline in innovation can also be traced to the country's education system.[20] Two main problems are identified: first, it may be too specialized and intertwined with

20 The weaknesses of a generally much-praised education system have been reflected in the relatively poor and, at times, even declining position 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. Its score in the 'Index of Cognitive Skills' declined from 0.56 to 0.48 between 2012 and 2014.

the current industrial structure; and second, it may be 'un-entrepreneurial' and too bureaucratic.

One 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 exports of goods in 2016; 28 percent of its labor force was employed in industry, consisting of manufacturing, mining and construction 2015.[21] 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 the typical *Mittelstand* manufacturing businesses.[22] 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'.

As indicated in Table 2, Germany's tertiary education enrolments 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 enrolments 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. By way of contrast, Germany has the lowest percentage of tertiary students enrolled in education programs in health/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.

The overall conclusion from this table is that, compared with other high-income OECD countries where manufacturing has traditionally played an important role, Germany's tertiary student population is more heavily specialized in engineering and manufacturing right up to today. It is less diverse compared with the United States, where most students are in fields such as health and welfare, arts and humanities, business and law, and social sciences. Germany, however, also has proportionally more students in ICT technology programs than in any of these countries, which should be a positive attribute in terms of future labor market demands. It has been also argued, however, that it is precisely jobs in ICT, such as in programming and coding, that can most easily be performed by computers rather than humans.

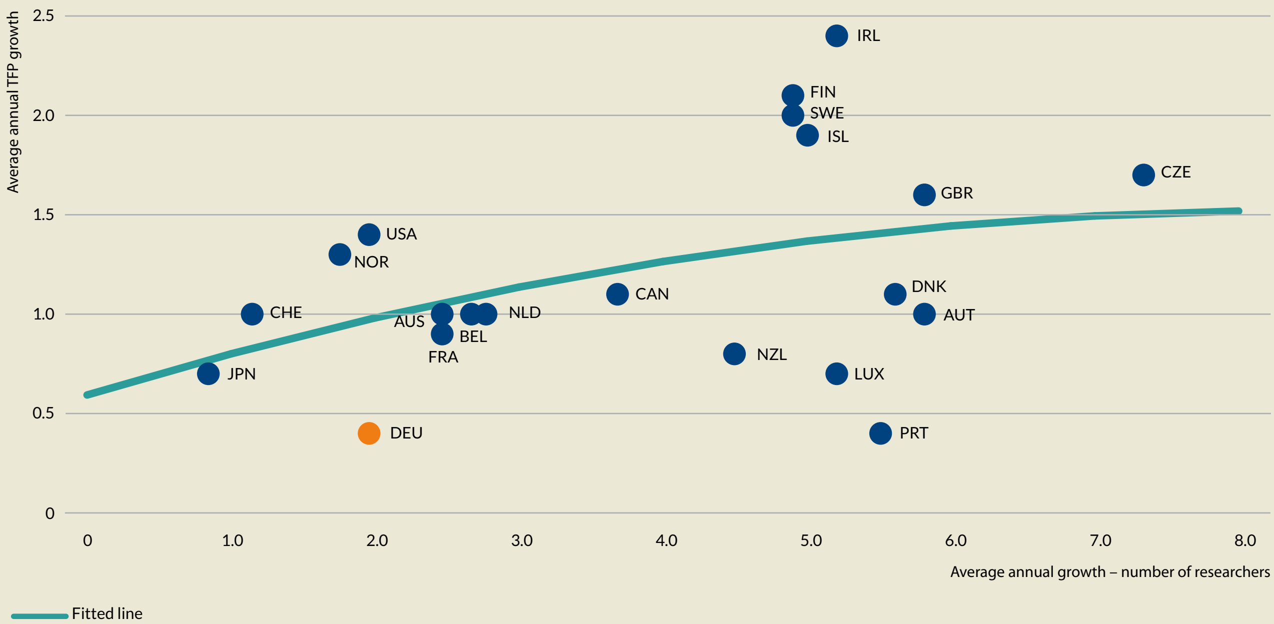
21 Data source: World Development Indicators.
22 'Most skills acquired, in either manufacturing or in agriculture, travel very poorly to service occupations' (Iversen and Cusack, 2000, p. 327).

TABLE 2: **Comparison of tertiary education enrollment by field, 2014**

Percentage of students in tertiary education enrolled in 2014	DEU	FRA	ITA	GBR	USA
Engineering, Manufacturing and Construction	21.00	11.93	17.03	9.20	7.65
Information and Communication Technologies	6.18	2.71	1.36	4.09	3.76
Business, Administration and Law	22.42	27.78	20.97	17.72	17.03
Natural Sciences, Mathematics and Statistics	10.20	6.51	6.71	14.59	6.03
Services	2.15	3.16	2.34	1.54	7.01
Arts and Humanities	13.48	13.33	15.24	16.12	17.47
Health and Welfare	6.94	15.91	15.53	17.00	18.24
Social Sciences, Journalism and Information	7.09	9.12	12.39	8.87	10.47
Agriculture, Forestry, Fisheries and Veterinary	1.58	1.14	2.63	1.04	0.64
Unspecified Fields	0.11	5.38	0.72	2.38	4.10

Source: Authors' own compilation based on the UNESCO Education Database.

FIGURE 14: **Growth in R&D researchers and TFP growth in selected OECD countries, 1996 to 2005, in percent**



Notes: Growth in R&D researchers refers to 1996 to 2005, with the following deviations: AUS, CHE (1996-2004); FIN, NOR, NZL, SWE (1997-2005); AUT (1998-2005); LUX (2000-2005).
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).

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Owing to the tendency to produce relatively more specific and uneasily transferable skills, the German government has increasingly *de facto* opted to encourage workers to exit the labor market through early retirement on a pension (an expensive manner to deal with the challenge), as well as self-employment (labor market deregulation). The result of both has been greater wage dispersion – and thus income inequality. In addition, it has driven up the uncertainty of employment, lowered the quality of jobs while increasing wage poverty, added to income inequality, and put the fiscal position of the state under pressure – the social welfare system relies heavily on transfers (Seeleib-Kaiser, 2001). This, overall, offers a possible explanation for the current 'malaise' and feeling of living in a divided society referred to in the introduction.

As well as being relatively specialized, the German education system may not able to keep up the 'production' and 'delivery' of the highly skilled workers needed in the R&D sector. Figure 14 plots the relationship between growth in the number of R&D researchers and TFP growth in selected OECD countries between 1996 and 2005. It shows that Germany had one of the lowest levels of growth in R&D researcher numbers – 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.[23]

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 in any way innovative. 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'.

23 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.

5.3 Entrepreneurial stagnation

A third broad reason for the decline in the effectiveness of innovation is what can broadly be described as entrepreneurial stagnation.[24] This does not refer to a general lack of entrepreneurship, nor of business firms in the economy. It means that entrepreneurship has not been as effective in producing and commercializing radical breakthrough innovations in recent times compared with earlier periods. The two main reasons for this phenomenon 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, reflecting discrepancies in management capabilities.

First, there is growing recognition that the essentially settled 19th century industries are dominant and entrenched, and have the potential to 'shift resources towards themselves' (Fohlin, 2016, p. 19). The effect has been to put the focus on incremental innovations, resulting in a decline of the quality of technological breakthrough innovations.

Second, concerns have been rising that, more recently, a growing gap between leading and lagging firms has emerged in terms of innovation, with a resulting spread in company-level productivity. This 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). One of the outcomes of this rising productivity gap is greater wage and income inequality (Bloom, 2017).

The increase in the proportion of lagging firms is also reflected in a declining number of firms investing in innovation,[25] in the declining start-up rate of new firms since 1990,[26] and in the small share of firms (only 1 percent)[27] aiming to grow (Henrekson and Sanandaji, 2017).

Figure 15 depicts the growing gap in productivity between leading and lagging firms since the 1990s. It 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'.

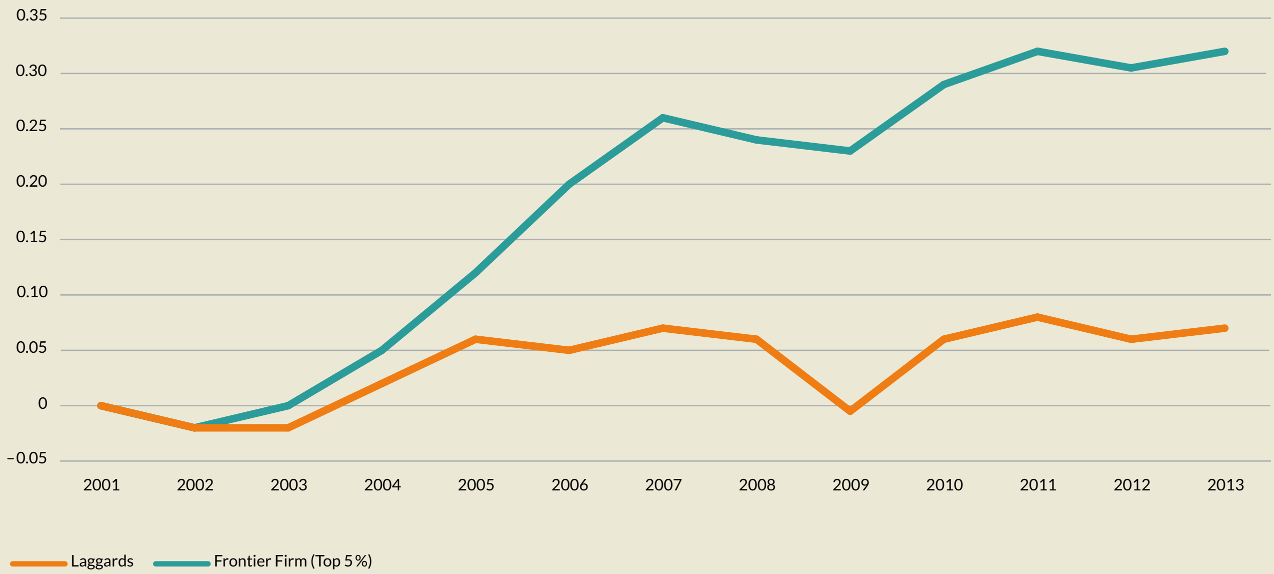
The European Commission (2017) says existing evidence suggests that the impact of research and innovation (R&I) investment on productivity growth[28] has been declining in general in Europe, and not just in Germany. It ascribes this as due to 'obstacles to the diffusion of innovation from productivity-leading companies' (ibid., p. 4). Hence, a lack of technology diffusion may be contributing to both the decline in productivity and the rise in income inequality. Inter-firm pay inequality might therefore present one reason 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'.

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, relatively poor management performance in German firms, especially in *Mittelstand* companies.[29] Broszeit et al. (2016) find, using the German Management and Organizational Practices (GMOP) data set, that (i) German company-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 a particular 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).

What may be the reasons for the comparative lack of management quality? According to Fohlin (2016, p. 21), this may reflect the lack of business school education in that 'the post-war German education system provided essen-

24 Naudé (2016) argues that Europe is more generally in an 'entrepreneurship crisis', which is also echoed by Henrekson and Sanandaji (2017).
25 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.
26 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.
27 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)
28 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.
29 Cooper et al. (2017) suggest another (related) reason, namely that the greater labor market flexibility introduced by the Hartz reforms that has helped the country maintain high employment rates has done so at the price of declining firm productivity. The reason for this is that the specific practice of 'short-time work' has hindered the reallocation of workers from less to more productive firms.

FIGURE 15: **Widening labor productivity gap – frontier vs laggard manufacturing firms (value added per worker), 2001 to 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 productivity in 2013 compared to 2001. See details in Section 3.3 of Andrews et al. (2016).
Source: Andrews et al. (2016) based on the recent update of the OECD-Orbis productivity database (Gal, 2013).

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tially no counterpart to the United States' business school education'. It may also reflect a lack in both quality and quantity of entrepreneurship.

Other potential reasons are the dominance of large firms in comparatively 'old' industries (e.g., machinery, automobiles, and energy) and the lack of venture capital (European Commission, 2017). Andrews et al. (2016) further identify a 'decline in the contestability of markets' as one of the reasons for the slower diffusion of technology. They recommend competition policy to address this shortcoming. Watzinger et al. (2017, p. 4) argue in their study that competition policy is beneficial for innovation, citing the example of Bell Labs (a U.S. research and scientific development company) 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'. Finally, as Erixon and Weigel (2016, p. 27) note, 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 a slower process. Figure 16 illustrates the precipitous decline in net fixed capital investment in Germany since 1991.

In conclusion, entrepreneurial stagnation in Germany is characterized by the defensive strategies of large incumbent firms and rather weak management practices. These result in a decline in fixed capital investments and a lower ability of lagging firms to learn from and catch up with 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 with each other and/or newcomers. As a result, the diffusion of technology has become sluggish, and with it labor productivity growth, too.

6 Declining technological innovativeness and rising income inequality

From the previous sections it can be concluded that the decline in technological innovativeness has caused labor productivity growth to stagnate: a potential reason for the rise in income inequality. The link, however, is neither direct nor automatic. In this section we argue that slow productivity growth combined with demographic change has caused policymakers and the corporate sector to reduce real labor compensation, and thus erode the social welfare state. It is further noted that, unlike in the United States, income inequality in Germany has not been caused by globalization or financialization of the economy.

6.1 Demographic changes, demand stagnation and labor markets

Germany is characterized by low fertility rates and an aging population.[30] The average age of the German population increased from 38.3 in 1991 to 41.8 in 2009 (Fritsch et al., 2015), with more than 31 percent of households receiving pensions (Drosdowski et al., 2015). This demographic shift has and will have both direct and indirect effects on income inequality.

As a direct effect, aging can lead to more income inequality, because there are more pensioners (who have, on average, lower incomes)[31] and a reduced workforce (with higher wages due to scarcity). Whether this occurs, and how far it impacts, remain questionable and can only be settled empirically.

30 This is generally the case for Western Europe. As the European Commission (2013) notes, by 2030 the EU-27 population will amount to approximately 522 million, of which 23 percent will be older than 65. UN-DESA (2015) estimates that 217 million people in Europe will be older than 60 by 2030. In Germany, an old and stagnating population means that the labor force will begin to shrink by 2025 to the extent that, all things being equal, there will be between 3 to 6 million fewer labor market participants in 2050 compared to 2012 (Faik, 2012).

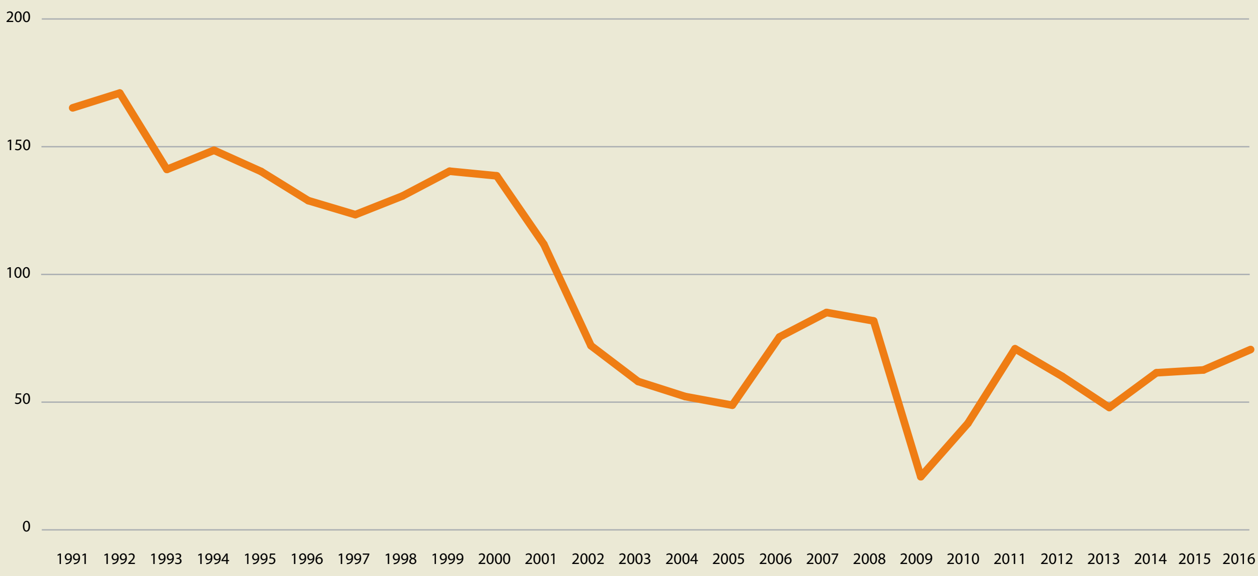
31 Households on pension receive on average 18 percent less than the average household (Drosdowski et al., 2015).

According to Drosdowski et al. (2015), 'most empirical findings so far show that income inequality increases with demographic aging'. Klemm and Weigert (2014) ascribe ten percent of the rise in income inequality since the 1990s to aging. Drosdowski et al. (2015) study these questions using a macro-econometric input-output model that predicts more income inequality in Germany as the population ages, with it accelerating after 2025 due to labor shortages. Faik (2012) similarly finds that demographic factors have been a significant determinant of income inequality, and that, moreover, the current trend in aging predicts 'a remarkable increase of German inequality by 2060' (ibid., p. 1).

Households having children later in life and less stable marriages have accompanied this demographic trend; furthermore, a significant increase in the number of single-parent households can be observed. According to the European Commission (2013), these changes in household structure explain 13 percent of income inequality in a country such as Sweden. In the case of Germany, Biewen and Juhasz (2012, p. 629) find that the decline in household size and the increase in single parent households have had a 'moderate' impact on income inequality.

Evidence further shows that 'assortative mating' is having an effect in Germany. This term refers to the phenomenon where couples with relatively similar educational and skills levels marry. It has been theoretically modeled and found empirically to drive higher income inequality over time (Fernández and Rogerson, 2001; Greenwood et al., 2014). Greenwood et al. (2014) find, using US Census Bureau data from 1960 to 2005, that 'assortative mating' has increased significantly and is, moreover, a significant driver of income inequality, as predicted by models such as Fernández and Rogerson (2001). They find that in the United States the Gini coefficient would amount to 0.34 instead of 0.43, if marriages were based on random matching instead of 'assortative matching' by 2005. Grave and Schmidt (2012) show, using German Microcensus data from 1976 to 2005, that 'assortative mating' has also

FIGURE 16: **Net fixed capital formation (in 2010 prices), 1991 to 2016, in billion EUR**



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

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significantly increased income inequality in Germany over the past three decades, contributing to wage polarization. Huber and Winkler (2016, p. 3) find similar evidence, using data from the GSOEP covering the period 1993 to 2008. Their results show that 70 percent of German workers ‘have the same educational level and 15 percent work in the same 2-digit industry as their partner’.

The demographic determinants of income inequality in Germany have been pertinent to the country’s debate on immigration. Most scholars concur that the recent influx may only have a short- to medium-term impact on meeting the requirements for skilled labor in the German economy (Drosdowski et al., 2015). It may, however, also lead to higher income inequality. The European Commission (2013) observes that migrants to Europe infrequently bring the required skills and are not always effectively integrated into labor markets. Hence, they are ‘over-represented in low-skilled occupations and self-employment’.

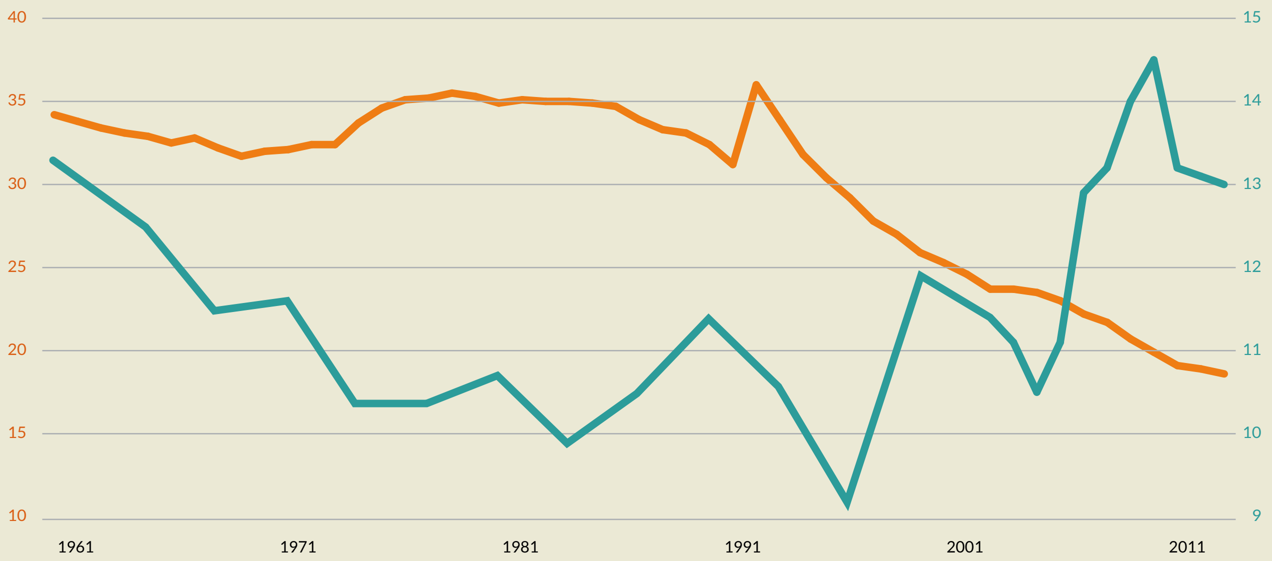
Blau and Kahn (2012) point out that migrants may increase the supply of low-skilled labor, thereby reducing wages for all low-skilled workers, so that wage inequality rises. Card (2009) argues that migrants tend to be concentrated in the ‘tails of the skill distribution’, i. e., they tend to be either low-skilled workers or highly skilled, so that an increase in a country’s immigrant population may be accompanied by an increase in income inequality. Edo and Toubal (2015) therefore argue for selective immigration policies towards attracting highly skilled workers, coupled with flexible labor market arrangements. They find evidence from French data, between 1990 and 2010, that such a policy could reduce the relative wages of the highly skilled – i. e., reduce the skills premium, and hence lower income inequality.

Finally, if spending decreases with age and the elderly save more than the remainder of society, demographic changes can also contribute to rising income inequality. In this case, the government and corporate sector’s response can be to seek reductions in real labor compensation to maintain export competitiveness.

6.2 Erosion of the social welfare state

The erosion of the social welfare state can be traced back at least to the period following the oil crisis of the 1970s. Seeleib-Kaiser (2001) discusses the SPD’s *Ökonomisch-politischer Orienterungsrahmen für die Jahre 1975 bis 1985* (economic-political orientation framework for the years 1975 to 1985), which set out the claim that the social welfare state, established after the Second World War and underpinning the *Wirtschaftswunder*, was now threatening the international competitiveness of German firms. The unification process of the 1990s delayed many proposed policies for cutting back on the welfare state (ibid.).

FIGURE 17: **Union density and top 1 percent income, 1960 to 2011**



Notes: Top 1 % Income = Pre-tax national income share held by given percentile group. Pre-tax national income is the sum of all pre-tax personal income flows accruing to the owners of the production factors, labor and capital, before taking into account the operation of the tax/transfer system, but after taking into account the operation of pension system. The population is comprised of individuals over age 20. Union Density = Aggregate membership of active union members, as a proportion of wage earners in employment.
Series until 1990 covers West Germany (with West-Berlin)
Source: OECD (Union density) and World Wealth & Income Database (Top 1 share).

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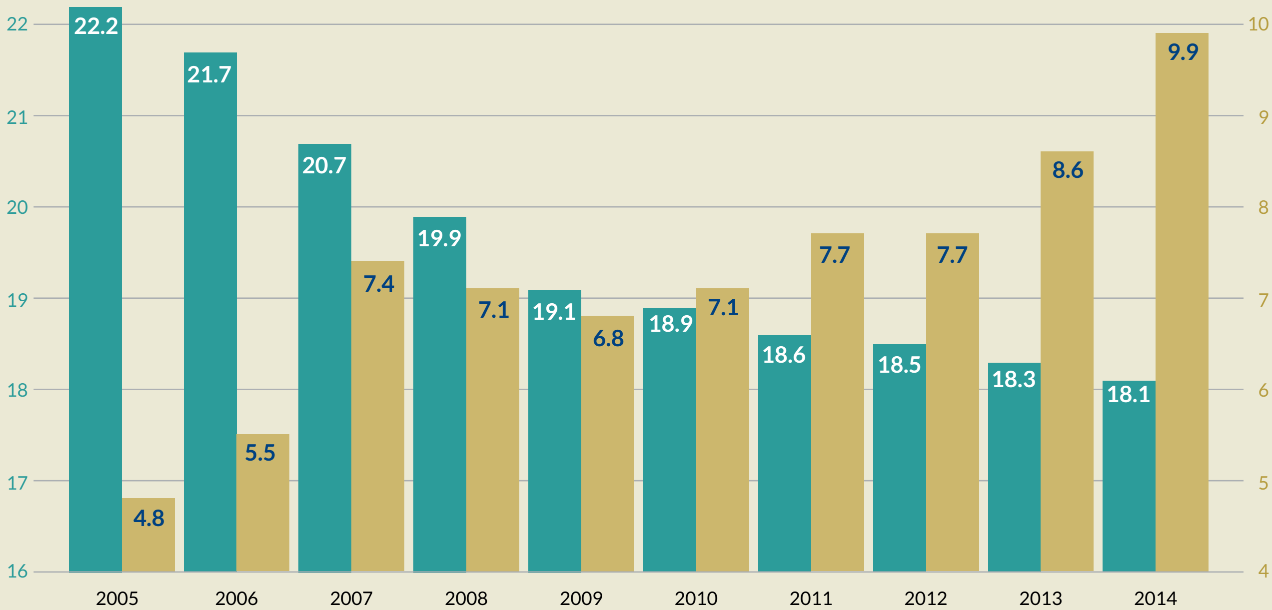
FIGURE 18: **Union density and in-work at-risk-of-poverty rate, 2005 to 2014, in percent**



Note: As defined by Eurostat, the risk-of-poverty threshold is set at 60 % of the national median equivalised disposable income (after social transfers).
Source: OECD (union density) and Eurostat (in-work at-risk-of-poverty rate).

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Between 2002 to 2005 then, a series of fundamental reforms were implemented, the so-called Hartz IV reforms (Felbermayr et al., 2014). These included various labor market reforms and further contributed to the decentralization of collective bargaining power from the late 1990s. As a consequence of these reforms, 'wage flexibility has increased sharply in Germany due to the documented decline of collective bargaining agreements' (ibid., p. 37). As The Economist (2017) points out, because workers in Germany value employment security to a large extent, they are willing to accept lower wage growth in return.

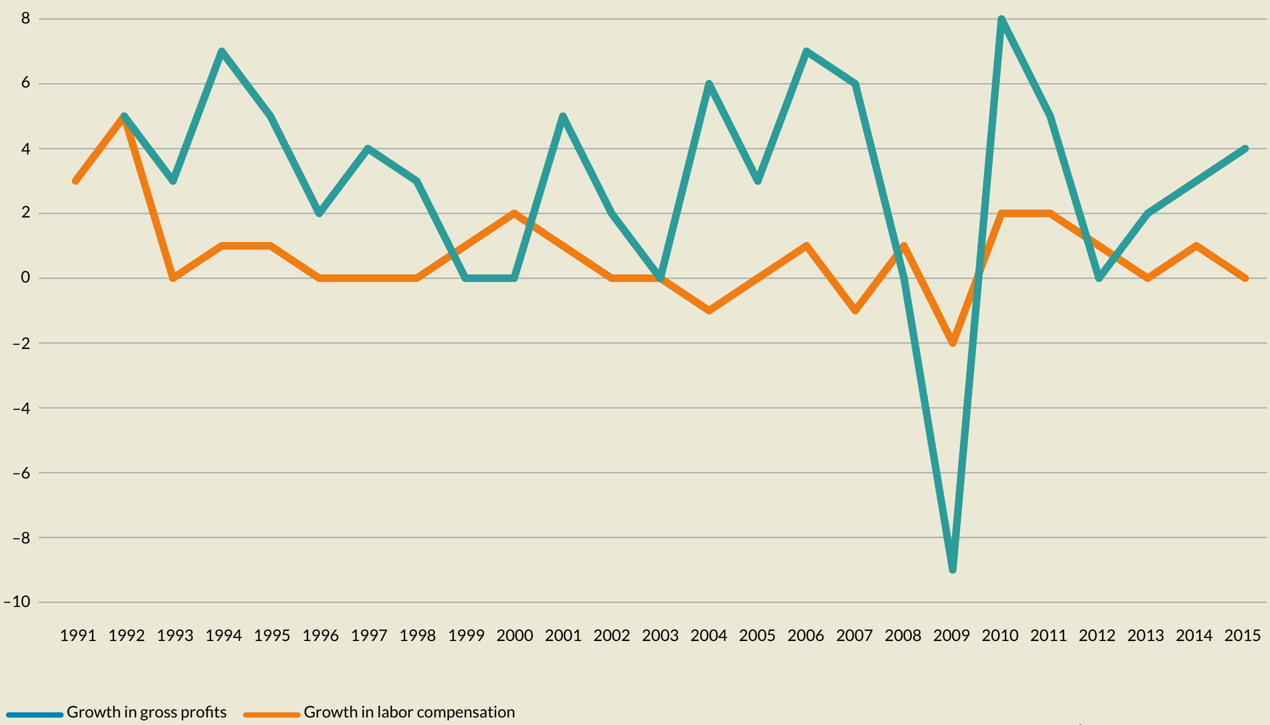
The decline in collective bargaining that followed the Hartz IV reforms is reflected in the decline in union density. Figure 17 shows that union density has significantly declined since its peak in the late 1970s, and moreover that it has been accompanied by a significant rise in income inequality, as measured by the share of income earned by the top 1 percent.

Falling union density is also inversely related to the 'in-work-at-risk-of-poverty rate', as Figure 18 shows. This suggests that one reason for the increase in income inequality may be found in the increased income share of the top 1 percent, and the simultaneous increase in the prevalence of the working poor, as low-skilled workers accept pay-cuts. In fact, the rate of working and being poor almost doubled from 4.8 to 9.6 percent in Germany between 2005 and 2015 (OECD, 2016).

Between 1996 and 2010 the share of workers covered by industry-level wage agreements declined from 77 to 53 percent, and of those covered by any form of collective agreement from 82 to 62 percent (Felbermayr et al., 2014). According to Baumgarten (2013, p. 5) this decentralization of wage bargaining has been one reason for the rise in wage inequality, because it primarily lowered the relative wages of 'workers in the lower part of the earnings distribution'. Felbermayr et al. (2014) point out that particularly wages in the 20th percentile have declined significantly, driving a wider skills premium. Using data for the period 1996 to 2010, the authors decompose wage inequality and find that 50 percent of the increase in wage inequality can be explained by the decline in collective wage bargaining.

Figure 19 furthermore shows that since around 2000 the growth in profit rates has substantially exceeded that in labor compensation, meaning that the functional distribu-

FIGURE 19: **Growth in gross profits and labor compensation, 1991 to 2015, in percent**



Source: European Commission AMECO database online.

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tion of income will, *ceteris paribus,* worsen. It also shows the dramatic impact of the global financial crisis on profits, and their very rapid recovery afterwards.

In addition to the Hartz reforms that reduced social security benefits, a cut in the top marginal tax rate from 53 percent in 1999 to 42 percent in 2007, was introduced (Biewen and Juhasz, 2012). The Hartz reforms were followed by an increase in self-employment, rising from 8 percent in 1991 to 11 percent of the labor force in 2009. The proportion of the self-employed in the service sector increased from 36 in 1991 to 53 percent in 2009. This was an important mechanism for reducing unemployment and for accelerating the structural shift in the German labor market, away from manufacturing towards more (skill-intensive) services (Fritsch et al., 2015).

More self-employment in a country is generally associated with higher income inequality. This is because the distribution of earnings among the self-employed tends to be quite diverse, with a few high-income and many low-income earners (OECD, 2011). Frick and Grabka (2009) indeed find that the self-employed in Germany are on average wealthier than wage-earners, with the average wealth of a self-employed person with more than ten employees amounting to approximately EUR 1.1 million in 2009 – a sum approximately ten times higher than the average wealth of a wage earner.

6.3 Inequality is different in Germany than in the United States

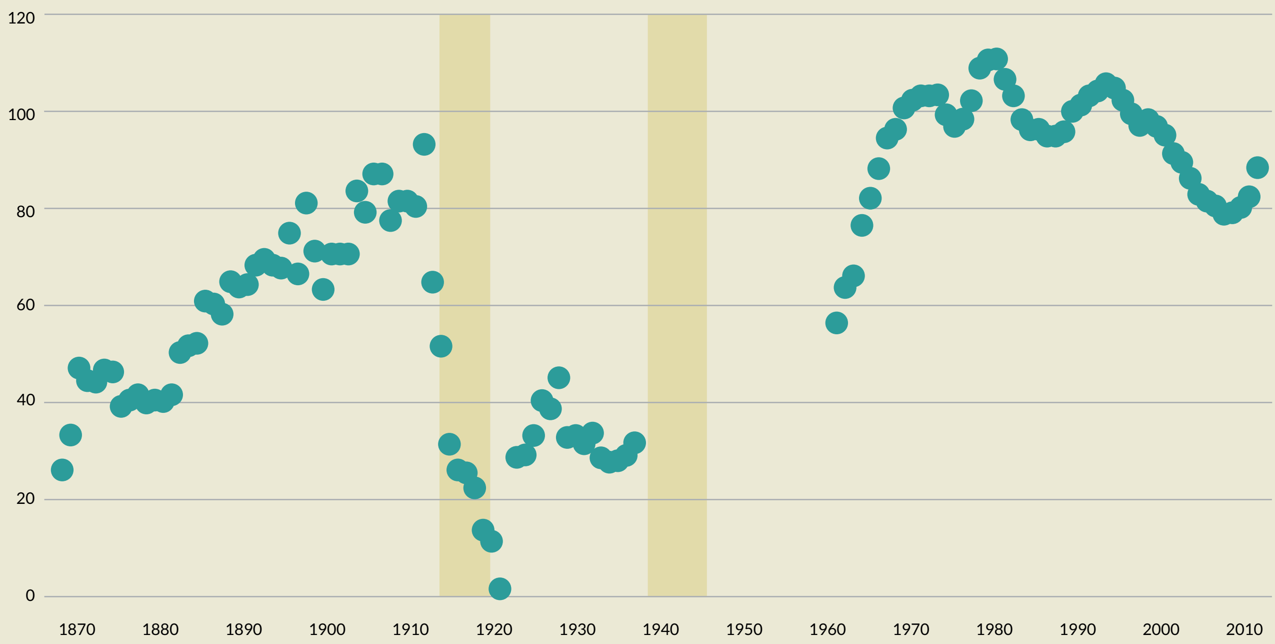
Finally, before summarizing and putting forward some policy recommendations for inclusive growth in Germany, it can be pointed out that the patterns and determinants of income inequality are different in Germany with respect to the United States. The issue of rising inequality is very topical in the United States, and has been the subject of a growing literature, wherein the globalization and financialization of the US economy have been two of its major drivers. It can be asked whether or not these determinants may also be relevant for Germany. This sub-section shows that this is not the case. This has two implications: first, caution is advised in terms of avoiding financialization in Germany in the future and second, the predictions about and analysis of the replacement of human jobs by robots, such as by Acemoglu and Restrepo (2017), are based on US data and experience, and therefore perhaps not as relevant for Germany. Indeed a recent German study shows no evidence that robots are causing total job losses in the country (Dauth et al., 2017b).

Since the mid-1970s the United States has experienced significant increases in income inequality, but also in unemployment and job polarization, especially in the manufacturing sector. Today, the US manufacturing sector contributes only around 12 percent to employment, compared to roughly 23 percent in Germany. The reasons for this de-industrialization and the accompanying rise in wage inequality are largely due to globalization and financialization. The impact of globalization occurred through the offshoring of manufacturing, which 'exported' jobs to China and other Asian countries (Baily and Bosworth, 2014). The financialization of the economy occurred as a result of deregulation, which drew away the 'best and brightest' from production into financial services, where relative wages started to outpace those in other industries from the late 1970s (Philippon and Reshef, 2012), contributing to the demise of labor unions and collective bargaining, and the rise of the shareholder economy (Lazonick, 2013; Lazonick and Mazzucato, 2013). Lazonick (2013) describes the term 'financialization' as the making of economic decisions that are not based upon production considerations, but (financial) share price information. In the United States resources have been massively diverted from physical production (manufacturing) towards the financial sector. This has generated higher income inequality by shifting income increasingly from labor to capital sources.

Are globalization and financialization equally responsible for higher inequality in Germany? This study argues that this is not the case. On the contrary, globalization has had a positive influence on jobs and equality. As documented by Dauth et al. (2017a), employment in manufacturing declined much less in export-oriented industries – in fact, employment has remained remarkably constant since the 1990s in these industries. Germany manages a large trade surplus[32] on its current account, in contrast to the United States, which manages a large trade deficit. During the 1990s, furthermore, large German firms internationalized successfully by moving parts of their value chain to Eastern and Central European countries, thereby remaining globally competitive (Veugelers, 2013; Marin, 2016). Dauth et al. (2017a) also find that the expansion of service sector employment in Germany did not primarily occur because of workers re-allocating out of manufacturing, but rather because of jobs being created for new labor

32 Germany, in fact, has the largest trade surplus of any country, reaching a record of USD 300 billion in 2016 (Dubner, 2017).

FIGURE 20: **Real house price index, 1870 to 2011, 1990 = 100**



Note: Shaded areas indicate periods of World Wars.
Source: Figure and data taken from Knoll et al. (2017).

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market entrants and the former unemployed. They conclude that (ibid., p. 3), '[u]nlike in the case of the US, globalization therefore did not speed up the manufacturing decline in Germany, but it even retained those jobs in the economy.'

Financialization is also not a major contributor to income inequality in Germany. At present, its scale is not as extensive as in the United States and the United Kingdom. Since 2001 there has been a corporate de-leveraging in Germany following the abolition of government guarantees for *Landesbanken*,[33] and a further de-leveraging after the 2008 financial crisis (Veugelers, 2013). The share of profits and property incomes in the gross national income (GNI) has remained stable, between 22 to 24 percent and only six percent of the top one percent's income is derived from the financial sector (Niehues, 2015). Other authors point to the rather limited rise in the CEO compensation in Germany, due to the unique *Mittelstand*, where supervisory boards play an important part in corporate governance. The financialization of an economy often goes hand in hand with a property boom, which can be also ruled out in the case of Germany. As Figure 20 shows, real house prices have even been declining during certain periods.

Although the financialization of the economy has not been a cause of rising income inequality in Germany so far, it may become more pronounced as a future source. Caution is necessary, since there are indeed signs that financial capital sources of income are becoming more important (Dell, 2005; Frick and Grabka, 2009; OECD, 2011).

33 The Landesbanken are a group of state-owned banks of a type unique to Germany. They are regionally organized and their business is predominantly wholesale banking.

7 Summary, recommendations and concluding remarks

7.1 Summary

Technological innovation has been central to Germany's economic success. During the period 1850 to 1913 the country's economic rise, from an industrial 'backwater' to an industrial powerhouse, was made possible by a remarkable and historically unparalleled series of radical innovations. These included technologies such as the internal combustion engine, aspirin, radar, the diesel engine, and others. The provision of supporting social welfare, first introduced during this period, including unemployment and pension insurance, health and employment protection, helped to ensure that the growth sparked by these innovations was to a large degree socially inclusive: income inequality did not increase and indicators of human development improved consistently. The technological breakthrough innovations of the late 19th and early 20th centuries, led, moreover, to the rise of a number of firms that would become global household names. Firms such as Siemens, Bosch, ThyssenKrupp, Bayer, and BASF were among those founded during this period. These firms and others would later provide a basis for the *Mittelstand*-led *Wirtschaftswunder* of the 1950s and 1960s.

The *Wirtschaftswunder,* however, could not be sustained. Average annual per capita growth started to decline in the 1970s. In the post-war era, Germany's industries were largely focused on incremental rather than on radical innovations. In fact, the country lost its leading edge as a generator of radical innovations during the 'third industrial revolution', and was overtaken as a leading innovation country by the United States, and later by Japan and South Korea. The manner in which the country responded to the potential loss of its international competitiveness had significant implications for income and wealth inequalities.

Inequality started out at low levels after the Second World War,[34] and even declined in the early subsequent decades, but began to rise again, particularly during the 1990s. At the same time, Germany lagged behind the United States, Japan, and South Korea in terms of radical innovations in key new industries such as semiconductors, nanotechnology and robotics. This was moreover a period during which the social welfare state began to erode, partly as a response to reduced impact of technological innovation on labor productivity growth. The outcome was rising income and wealth inequalities.

This study therefore argues that it is not 'too much' technological innovation that is causing rising income inequality in Germany, through skill-biased technological change, but the opposite – a declining impact of technological innovation on labor productivity growth. Fearing that this declining impact would undermine the economy's international competitiveness, real labor compensation was progressively curbed from the mid-1990s. This occurred *inter alia* through the government's erosion of the social welfare state, as well as offshoring and reduced fixed capital investment by the corporate sector. The outcome was rising income and wealth inequalities. Between the mid-1990s and 2010 the rise in wage inequality was faster in Germany than in the United States, the United Kingdom, and Canada. This study identified three reasons why technological innovation has become less and less effective: (i) historical legacies, (ii) weaknesses in the education system, and (iii) entrepreneurial stagnation.

7.2 Recommendations

First, a focus should be set on revamping the German technological innovation system, although this might be diffi-

34 The two World Wars of the 20th century have had a leveling effect on economic equality by destroying wealth, infrastructure, and social and political structures (Piketty, 2013).

cult to implement: the recent historical evidence suggests that it has become rather entrenched. It may be difficult for the government and industry to significantly alter the nature of the country's innovation system over the short- to medium-term. Innovation policies, for instance policies to spur R&D and commercialize intellectual property in important new industries, are not expected to lead to quick results. This does not mean, however, that there is nothing the government can do to invigorate the innovation system into delivering more breakthrough innovations, particularly in the areas underpinning *Industrie 4.0*. This study can recommend, following Mazzucato (2015), that a 'mission-driven' industrial policy, aiming to 'stimulate development of markets and activities for those things which at present are not done at all' could be useful in this regard. Many of the current *de facto* 'industrial-policy' initiatives, such the *Energiewende* (energy transition)[35] are focused on incumbents instead of focusing on 'things that are not done at all' or in which the country is lagging.[36]

Moreover, such a shift in industrial policy will also require a change in the approach of public sector organizations towards innovation policy. One important point to bear in mind is that, as Coad and Rao (2008) pointed out, 'an innovation strategy is even more uncertain than playing a lottery, because it is a game of chance in which neither the probability nor the prize can be known for sure in advance'. Hence, the public sector must be prepared to occasionally fail, and to act entrepreneurially. For Mazzucato (2015, p.125) this raises the question, '[h]ow should public organizations be structured so that they can accommodate the risk-taking and explorative capacity needed'? Answering this question falls outside the scope of the present study, although an answer will be increasingly required if sustained and inclusive growth is to resume in Germany in future.

A second recommendation is to focus on the social welfare system as the most important tool for inclusive economic growth in the short-run. Social protection, fiscal redistribution, and active labor market policies (ALMP)[37] will provide the most appropriate measures to stop income and wealth inequalities from further widening in the upcoming years. These could include the creation of more government jobs, more redistributive taxation,[38] and a stronger collective labor and union movement. Fears that stronger unionization will be detrimental to innovation in Germany's case are, so far, unfounded. On the contrary, Addison et al. (2013, p. 6) do not find any proof that unionization has delayed innovation in the past and even find some evidence that unionization benefited innovation. This positive impact of unionization on innovation may be due to the participation of workers in managing the 'adoption and spread of new technologies'.

It can further be suggested to consider new and innovative forms of social protection schemes. These could include, for example, a form of Universal Basic Income (UBI)[39] or a negative income tax, although there are many justifiable objections to such schemes. The many objections, reinforced by the practical difficulties, make them unlikely to be implemented in the near future. A global wealth tax could further support redistribution and thereby lower inequalities, and may, moreover, be used to finance innovative social protection schemes. A global wealth tax, however, is equally unlikely to be implemented. The search for other policy measures will certainly continue, as for example in a recent proposal by the European Union and Bill Gates that

35 In *'Industrieland Deutschland'* (Germany as an industrial nation) the major industries such as automobiles, machines, chemicals and electro-technology are all energy-intensive. The cost of energy is an important determinant of their competitiveness. The current approach to energy is contained in the *Energiewende* of 2010, which aims to steer the country to certain targets of energy consumption, greenhouse gas emissions, and the use of renewable energy by 2050. Policy support for renewable energies started in 1991 with the *Stromeinspeisungsgesetz* (Law on the Sale of Electricity to the Grid); in 2000 the *Erneubare Energien Gesetz* (Renewable Energies Act) was introduced, and more recently the decision was taken to phase out the use of nuclear energy by 2022 (Rutten, 2014).

36 In recent years there have been increasing calls for so-called 'inclusive innovation policies' (e.g., Planes-Satorra and Paunov, 2017, p.17), referring to policies that 'aim to remove barriers to the participation of individuals, social groups, firms, sectors and regions that are under-represented in innovation activities'. More research is needed to clarify whether and how such inclusive innovation could also lead to more effective innovation, i.e., innovation that raises labor productivity in Germany.

37 These policies amount to about 1 percent of GDP at present, compared to 2 percent in Denmark, where they have been found to be effective. Zollner et al. (2016) evaluate a range of entrepreneurship promotion programs (including bridging allowances and start-up subsidies) within Germany's ALMP and find that they had 'high success rates as well as high cost efficiency'. This recommendation resonates with the evaluation of the German social welfare system by Snower et al. (2009, p.155) who identify as a crucial problem 'a lack of adaptability and versatility [of the labor force] in the presence of the reorganization of production and work in response to technology-driven globalization processes' which requires state support to allow these laborers to 'turn themselves into winners through their own efforts'.

38 The concern is whether higher tax rates would discourage entrepreneurs (who are typically among the highest income earners), which, in turn, could lead to less job creation. A welfare-maximizing top tax rate should thus balance the potential reduction in job creation with the increased ability to provide transfer payments. Brüggemann (2016) provides model estimates, using US data, which shows that a welfare-maximizing top marginal tax rate would be 82.5 percent.

39 A UBI is a payment to every adult citizen, irrespective of labor market status or income. A number of UBI schemes (or *Bedingungsloses Grundeinkommen*) have also been proposed for Germany (Haywood, 2014).

TABLE 3: **Overview policy recommendations and examples for Germany**

Policy recommendation	Examples
Stimulate the industrial-innovation system to raise productivity growth	• Promote R&D in new and lagging sectors. • Expand active labor market policies. • Improve contestability of markets. • Implement industrial policies and venture capital funding for raising real investment. • Improve labor market mobility.
Strengthen the social welfare system	• Develop innovative social protection schemes. • Ensure a progressive tax-transfer system. • Strengthen the power of unions.
Diversify the education system	• Promote diversification of skills. • Enhance lifelong learning. • Expand managerial and entrepreneurial competencies.
Align immigration policies, integrate working parents, postpone retirement	• Attract appropriately skilled immigrants. • Better integrate the existing stock of immigrants. • Promote technologies that will help postpone retirement.

Source: Authors' own creation.

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robots should be taxed.[40] Such social protection measures may also help stimulate innovation in Germany, as a more equal distribution of economic growth will boost domestic demand.

It is widely accepted that social protection and fiscal redistribution should be reformed – not only because of the challenges of potential technology-induced unemployment (whether real or not), but also because of demographic changes and the resulting pressure on public finances.

Third, a reform of the education system remains fundamentally necessary, not only to deliver the scientists and entrepreneurs that can spearhead future innovation-led growth, but to allow skills to be more transferable and less specialized than at present. As the labor intensity of Germany's manufacturing sector continues to decline, it will become more necessary for the workforce to be better adapted (with diversified skills) to reallocate to the service sector. Herein lifelong learning,[41] as well as managerial and entrepreneurial competences, are essential components.

A possible reason for the lack of relative managerial competences in Germany may be the dominance of the economy by a number of large incumbent firms, most of them with historic roots in the pre-war area and the lack of contestability in markets. Thus, as a complementary policy, increasing competition in the economy, and stimulating fixed capital investment by these large incumbent firms is a further recommendation.

Finally, it is also essential to align immigration policies with the country's growing shortage of educated workers. Attracting appropriately skilled immigrants, better integrating the existing stock of immigrants,[42] integrating working parents in the economy, and postponing retirement through more flexible work practices, are further policies that can be recommended.

An overview of the policy recommendations outlined in this section, including a set of examples, is summarized in Table 3.

40 A difficulty, however, lies in the definition of a 'robot'. For this and other reasons the EU recently rejected a proposal to consider a tax on robots. Guerreiro et al. (2017) show that if the cost of automation falls to the extent that full automation occurs, it is in fact not optimal to tax robots.

41 Gries et al. (2017) present a theoretical model of population aging and skill-biased technological change to show that 'well-designed education policies can substitute for simple social transfers', and that this is especially the case for lifelong learning which helps aging workers to find and keep employment.

42 After the United States, Germany has become the most significant international destination for migrants. According to Daley and Kulish (2013, p. A1), however, 'Germany's experience with integrating foreign workers in the past […] has proved difficult […]. A recent study found that more than half of the Greeks and Spaniards who came to Germany left within a year'. The Bertelsmann Stiftung (2014, p. 31) notes 'a worrisome trend with regard to acceptance of diversity'. Their indicator of 'acceptance of diversity' has declined consistently in Germany since the mid-1990s. The report recognizes that more needs to be done with integration, stating that '[i]ntegration is needed – not only of immigrants, but of anyone who is different'.

7.3 Concluding comments: What if the 'fourth industrial revolution' is different?

Technological innovation has historically contributed to inclusive economic growth in Germany. But will this also be the case in the near future, given that many are claiming that the technologies which characterize *Industrie 4.0* are different? The fear is that they will replace human labor instead of complementing it, unlike previous technologies (Ford, 2015). Germany may be particularly vulnerable for two reasons: first, about 23 percent of its labor force is employed in industry, which presents the sector that will be most affected by the 'fourth industrial revolution'; and second, since the Second World War the United States and other countries have overtaken Germany in terms of producing the radical (product) innovations that are driving the new industrial revolutions. If disruptive technologies, in which Germany lacks any leading innovative position, replace many of these jobs over the next two decades, it could well result in further increasing income and wealth inequalities.

The vulnerability of Germany is compounded by the fact that the reallocation of the workforce from manufacturing to other sectors, such as services, may be difficult because of the more limited transferability of skills in the economy. The German education system is excellent in forming skilled workers for specialized areas based on its economic structure. Whereas this has been a recipe for past successes, it may become a liability in the future. Unlike the United States and the United Kingdom, Germany has a less diversified education system with proportionally more tertiary education students in engineering and science than in services, social sciences, and other sectors. The German system has also become slow to adapt, is perceived as bureaucratic, and lacks entrepreneurial dynamics. Hence, it may have difficulties in providing for the 're-skilling' of the labor force and in attracting the necessary high-skilled workers. The outcome may well be that the skills premium in the labor market will continue to rise, as certain skills become scarcer, also as more and more people exit the labor market on reaching retirement age. Thus, income inequality may also rise in future via this channel.

These concerns need not become reality. There are two reasons to be optimistic: first, there is no consensus that the 'fourth industrial revolution' will indeed lead to the huge job replacement and unemployment rates that some predict, and that have made headlines. Many leading scientists suggest that the impacts will not be as radical and that tasks rather than jobs will be affected; and moreover, that new markets and new business models will result in many new jobs being created (see e.g., Autor, 2015; Pfeiffer, 2016). As Autor (2015, p. 26) concludes, the distinction between tasks and jobs is important; although automation will affect tasks, it may not affect jobs to the same extent, and even raise the demand for jobs that contain different combinations of tasks including problem-solving skills: '[w]hile some of the tasks in many middle-skill jobs are susceptible to automation, many middle-skill jobs will continue to demand a mixture of tasks from across the skills spectrum'. For Germany, unlike several other countries, the rise of the 'fourth industrial revolution' in newly emerging countries potentially offers many opportunities as a supplier of inputs, materials, services, and technologies. It may even result in less need or incentives for German companies to outsource or offshore their manufacturing or assembling to countries with low-cost labor. The potential of the 'fourth industrial revolution' may well be that Germany in particular, and Europe more broadly, will experience a 're-shoring' of manufacturing. This, in turn, could lead to fewer jobs being exported, and hence result in more inclusive economic growth.

Second, German policy makers, industry associations and academics are well aware of the potential threats and opportunities, and a number of prominent policy initiatives in recent years are explicit and well-crafted attempts to ensure that manufacturing remains competitive, continues to provide jobs, and improves its innovativeness. Among these are active labor market policies, which consist, for example, of policies to encourage entrepreneurship. A recent evaluation of these measures finds them to be successful overall (Zollner et al., 2016). The long-term competitiveness of Germany's manufacturing sector will depend more than ever on the extent to which the required skills (termed '21st century skills') will be available in the economy. The effectiveness of higher education and its collaboration with business and government in the 'triple-helix' model will become more important, both for the incremental innovations that are needed to absorb and utilize the new technologies originating elsewhere, as for the more radical innovations that will be required to assume a leading global role as producer. Germany fortunately has much experience with the 'triple-helix model' which served it well during its industrialization phase in the 19th century. It can serve it well again, for its (re)industrialization in the 21st century.

In conclusion, this study stresses the need for further research, focusing on future opportunities and on assessing the impact of new technologies rigorously, as well as on the elaboration of new policy instruments to steer innovation, such as the EU's new directives on pre-commercial innovation procurement and innovation partnerships.[43]

The argument that the 'fourth industrial revolution' may be significantly different from previous ones, with less scope for compensatory employment creation, should – despite the optimism – still be taken seriously; just as the social, political and ethical implications of artificial intelligence have to be given more attention by policy makers and scientists. Germany cannot afford to be complacent about any trend that affects employment in its manufacturing sector. The remote but real threat is that, given Germany's lagging position in radical new ICT innovation, its manufacturing industry will ultimately become 'a sub-sector of the IT sector in the US' (Malmer and Tholen, 2015, p. 53).[44]

43 See, for instance, the 'EU policy initiatives on Innovation Procurement'.

44 The United States' Smart Manufacturing Leadership Coalition (SMLC) aims, with strong US government financial backing, to (re)capture the United States' global dominance in manufacturing.

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Appendix

TABLE 4: **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**

Source: Authors' own compilation.

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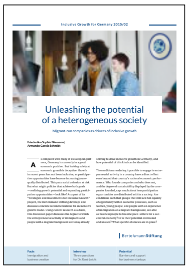

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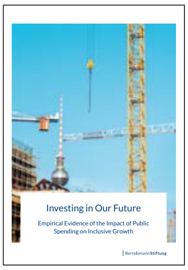

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