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Automation and the Future of Work in Germany: A Summary of Research and Policy Recommendations

Laura D'Andrea Tyson

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By Laura D'Andrea Tyson
Distinguished Professor of the Graduate School, Haas School of Business
Co-Founder, Berkeley Roundtable on the International Economy
Organizer, Work and Intelligent Tools and Systems (WITS)
University of California, Berkeley

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Introduction

Automation and the digitalization of work are having significant effects on the German labor market and are challenging policymakers to modernize the existing and proven instruments of Germany's distinctive "social market" economy. The COVID pandemic has accelerated the pace and scope of these technological changes and intensified their effects on work and the labor market. To inform the modifications in policies and institutions necessary to achieve the goals of Germany's social market system it is necessary to understand these effects.

This report focuses on how automation, broadly defined to encompass a variety of technologies including robots, software, digital systems and platforms, and artificial intelligence, is changing the size and composition of employment, the level and distribution of wages, and the educational and skill requirements for different kinds of work. The report is based both on research by German and international scholars and organizations and on interviews with economists, policy-makers and business and labor leaders in Germany.[1]

When possible, the German experience is compared with the experiences of other advanced industrial countries that have access to the same automation technologies but that differ in their labor market policies and institutions. Like all technological progress, automation technologies have the potential to increase productivity and economic output, lift living standards, improve the conditions and returns to work, and enhance health and longevity. But whether nations realize this potential and how they share automation's "bounty" or economy-wide benefits among their populations are not technologically determined—they depend on policies, institutions and choices.

[1] This research was supported by the German Federal Ministry of Labour and Social Affairs (BMAS), Ewing Marion Kauffman Foundation, American Academy in Berlin, and Berkeley Roundtable on the International Economy.

I. Lessons from History and Economics

Technological change has been shaping human life and work for centuries. It has also been the main driver of economic growth and prosperity. Today, the world is in the midst of what is often called the Fourth Industrial Revolution characterized by the growing utilization of new digital technologies like cloud computing, robotics, the Internet of Things, advanced wireless technologies, artificial intelligence and machine learning. Digitalization is building on the breakthroughs of the Third Industrial Revolution in information and communications technologies (ICT) to empower increasingly intelligent machines and systems to transform work. Together these technologies are continuing to automate work, performing tasks previously performed by humans, a process that was underway even before the Industrial Revolution in the 18th and 19th centuries. The COVID19 pandemic is accelerating these trends and extending their scope.

History contains several lessons about the effects of automation on economic performance and labor markets. Automation increases the growth of productivity which in turn increases incomes and the demand for goods and services, and that in turn increases the demand for labor. Over time, automation, productivity growth and employment growth move together—there is no historical evidence of a tradeoff between them. Many existing jobs, occupations and economic activities are changed or displaced by technological changes, but many new ones are created.

In the long run there has been no "technological unemployment," because the **displacement** effect of automation has been offset by both the **productivity** effect which increases demand for labor in non-automated tasks and the **reinstatement** effect through which automation creates new tasks for labor (Acemoglu and Restrepo, 2019). History also indicates, however, that while the displacement effects of technological change can occur quickly, the productivity and reinstatement benefits often take decades to arrive and are not evenly distributed among economic activities, locations and workers. During the transition, there is considerable dislocation of jobs and workers and significant frictional and structural underemployment and unemployment. For some workers, the dislocation of jobs, occupations, industries and even communities can last a lifetime with long-term consequences and costs.

Economic theory also indicates that in the long run wage growth should be commensurate with productivity growth. But when the displacement effects of technological change are large, wage growth is likely to fall short of technology-driven productivity growth and labor's share of national income is likely to decline. Consistent with this prediction, during the last several decades, both average and median wage growth has decoupled from productivity growth and labor's share of national income has declined in Germany and in most advanced industrial countries, albeit to differing degrees (Berger and Wolff, 2017). The International Monetary Fund has estimated that about half of this decline was the result of labor-displacing technological change (IMF, 2017). A declining labor share of national income is mirrored in a rising capital share. And since capital returns are concentrated at the upper ends of the income distribution, this is one of several channels through which labor-displacing technological change increases income inequality.

Another channel is widening wage gaps between workers whose skills and occupations are displaced and those whose skills and occupations are enhanced by productivity gains or who assume new jobs and tasks enabled by new technologies. During the last half century, technological change has been both labor-saving and skilled biased, and this has been a factor behind the growth of wage and income inequality and the decline in labor's share of national income in advanced industrial economies (Autor and Salomons, 2018; OECD, 2018; MGI, 2017; Tyson and Spence, 2017; Autor, Levy, Murnane, 2003; Acemoglu, 2002).

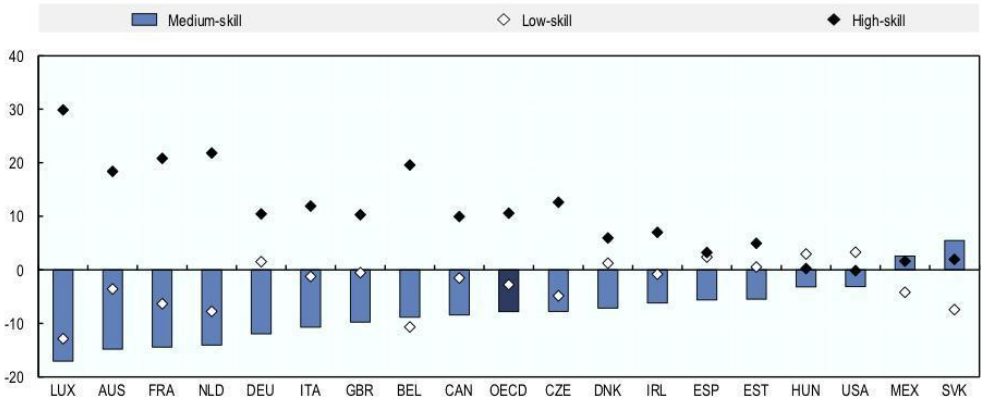
In its simplest formulation, skill-biased technological change (SBTC) increases the demand for skilled jobs and workers relative to non-skilled jobs and workers. During the last two decades, research has shifted from a simple skill-based approach to a task-based approach that focuses on routine-biased technological change (RBTC). Compared to the SBTC paradigm, RBTC better explains labor market polarization, the pattern of a decline in the share of middle-skill occupations and increases in the shares of both low-skill occupations and high-skill occupations that has occurred in advanced industrial countries (Goos, Manning and Salomons, 2014; Autor et al., 2003; Card and DiNaro, 2002; Hassel and Ozkiziltan, 2020). RBTC substitutes for humans in routine tasks and complements humans in non-routine tasks, resulting in falling demand for occupations with medium skill requirements that are routine intensive. Automation, as broadly defined in this report, has reduced the demand for workers with "middle" skills who perform routine tasks and increased the demand for workers with the "high" skills needed to perform non-routine technical and problem-solving tasks.[2] Sectors and occupations more specialized in routine-intensive tasks have experienced larger declines in labor's share in value-added (MGI, 2017, Autor, 2010 and 2019). Moreover, a recent study finds that automation and digitalization have become less labor-augmenting and more labor displacing in recent decades (Autor and Salomons, 2018). These trends have been strengthened by changes in business models and organizations necessitated by COVID19.

In the three decades prior to the onset of the pandemic, the evidence shows that RBTC did not reduce net employment—it was not net labor displacing—but it did contribute to the polarization of occupations and employment. RBTC is clear in the "polarization" of labor markets—a decline in middle skill jobs along with a rise both in high-skill jobs and to a smaller extent in low-skill jobs as shares of employment. Polarization in employment categorized by the skill levels of occupations is evident between the mid 1990s and the mid 2010s in the OECD figure below (OECD, 2019, Figure 3.3).

[2] For detailed definitions of low-, middle-, and high-skill categories, please see the Appendix Table 1. In summary: Autor and Petropoulos are nearly identical; OECD and MGI for Europe are identical, but comparable to Autor and Petropoulos; OECD for US is different because it is based on wages rather than occupations.

Figure 3.3. Jobs polarised in OECD countries between the mid-1990s and mid-2010s

Percentage-point changes in shares of working adults in each skill group



Note: Results at individual level for working adults (Box 3.1).
Source: OECD calculations based on LIS, ECHP and EU-SILC (Box 3.1).

Source: OECD, 2019.

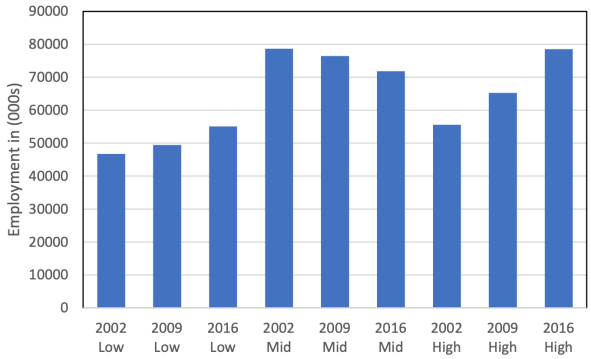
The 2020 OECD Employment Outlook (2020) updates the data on polarization for the advanced industrial countries. From the mid-1990s to the latest available period (2016-2018), the share of middle-skill occupations in total employment declined by more than 11 percentage points. During the same period, high-skill occupations grew by 9 percentage points and low-skill occupations grew by 3 percentage points. The employment share of middle-skill occupations declined because the number of jobs in low- and particularly high-skill occupations grew strongly, while the number of middle-skill jobs remained constant.

Consistent with the OECD, a recent study by McKinsey Global Institute (MGI, 2020) confirms continuing polarization of labor markets: in 16 European economies between 2000 and 2018 high-skill employment as a share of employment increased by 4 percentage points or 16 million workers and low-skill employment as a share of employment increased by 2 percentage points or 10 million workers while the share of middle-skill employment fell by 7 percentage points or 6 million workers. Both the OECD and the MGI estimates indicate that although automation has been “polarizing”, it has also been “upgrading” or “upskilling” in the sense that the decline in mid-skill employment has been largely offset by an increase in high-skill employment.

The upskilling of jobs in Europe has been facilitated and driven in part by a significant rise in the educational attainment of the European workforce (see Figures 4 and 5 below). Between 2002 and 2016, the share of tertiary-educated workers in total employment in the EU increased by 11 percentage points, while the share of workers with upper and post-secondary education declined by 1 percentage point and the share of workers with lower secondary education or less declined by 10 percentage points (Brekelmans and Petropoulos, 2020, p. 10). New entrants to the European labor market are more likely to be tertiary educated than 20 years ago and, therefore, relatively fewer people are starting their careers in middle-skill jobs (OECD, 2020). The OECD also finds that entrants with "typical" middle-skills are less likely to start their careers

in middle-skill jobs. Instead, they are more likely to begin in low-skill employment. In Germany and throughout Europe, the decline in middle-skill employment between the mid-1990s and mid-2010s was driven more by attrition (new labor market entrants entering middle-skill occupations at lower rates compared to older workers retiring from middle-skill occupations) than transitions (greater movement of middle-skills workers to different occupations and different skill groups, usually mid-career) (OECD, 2020).[3]

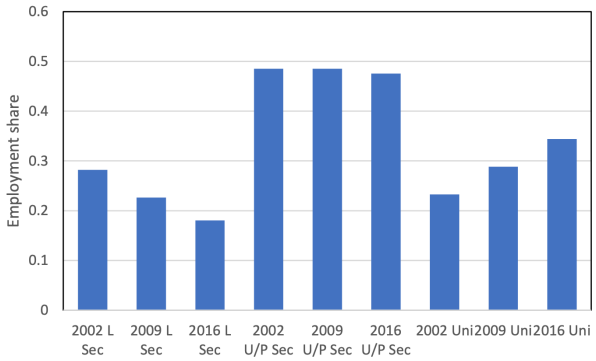
Figure 4: Number of low-, middle-, and high-skilled workers in selected EU countries for 2002, 2009 and 2016



Source: Bruegel. Note: The number of persons employed in each skill level is obtained by assigning the occupation of each respondent to the corresponding broad category defined in Table 1, these broad categories are then grouped into three skill levels for each given year. The data is weighted using EU-LFS sampling weights.

Source: Brekelmans and Petropoulos, 2020.

Figure 5: Employment shares at different levels of education for selected EU countries, 2002-2016



Source: Bruegel. Note: This figure refers to the educational attainment of the labour force dividing education in three categories outlined in Table 2. The employment share refers here to the share of the labour force with a given level educational attainment. The data is weighted using EU-LFS sampling weights.

Source: Brekelmans and Petropoulos, 2020.

[3] According to the OECD (2020, pg. 222): "Attrition is primarily driven by new cohorts of workers entering the labour force in middle-skill occupations at lower rates than previous cohorts. Transitions are changes in the career patterns of different occupational groups, in which workers reallocate to other skill groups (including possible spells of non-employment) during their careers at different rates than in the past. Transitions could include earlier cohorts who started their working lives in middle-skill jobs being laid off mid-career, for example, while attrition could take the form of young workers entering the labour market in different occupations. Attrition is about labour market entry, while transitions account for mid-career changes."

Recent research on the US and European Union has shown that polarization of jobs is linked to geography (Autor, 2019; Brekelmans and Petropoulos, 2020). In the EU, from 2002 to 2016, mid-skill jobs declined by 12 percentage points in cities and by 10 percentage points in suburban areas, compared to a decline of 7 percentage points in rural areas. Middle-skill jobs became 9 percentage points less common in cities compared to rural areas by 2016; the comparable difference was only 4 percentage points in 2002. The decline in middle-skill employment in cities and suburban areas was offset by increases in low-skill employment. Contrary to the overall upskilling of the EU labor force, there was down-skilling of less educated workers from middle- to low-skill jobs in cities and suburban areas. For tertiary educated workers, the geographic structure of occupations remained constant over time (i.e. most tertiary educated workers in low-skill jobs are in rural areas, whereas tertiary educated workers in high-skill occupations tend to be in cities).

Overall, given currently available automation technologies and the current trajectory of RBTC and polarization, the upskilling of tasks and employment are likely to continue, resulting in greater wage inequality as well as new educational and training requirements for workers.The economic and organizational effects of COVID pandemic are strengthening these trends (Chetty et al., 2020; Cowan, 2020; Montenovo et al., 2020; MGI, 2021).

II. Automation and Long-Term Trends in Labor Market Conditions in Germany

This section summarizes the effects of automation on long-term trends in Germany's labor market. Most of the evidence draws on research and results from the 3-4 decades prior to the onset of the COVID pandemic in 2020.

A. Quantitative and Qualitative Labor Market Indicators

In 2019, on the eve of the pandemic, the German labor market was performing well. The employment rate for the working age population had been steadily increasing for a decade, employment was at a record high and the unemployment rate was at a record low. As the OECD dashboard below shows, for the latest pre-pandemic year for which data were available Germany was outperforming most OECD countries, including the US, and the OECD average on both quantitative and qualitative measures of labor market performance. Germany was underperforming the OECD average on only three indicators: Germany had a higher "low-income" rate as measured by the share of employed workers earning less than two-thirds of median earnings; a larger gender labor income gap as measured by the per capita annual earnings of women compared to those of men and gender wage gap; and a higher share of workers in "high-strain" jobs.[4] Germany's low-income rate and gender labor income gap rate

[4] Job strain (% of workers in jobs with a combination of high job demands and few job resources to meet those demands):
Job strain is defined as jobs where workers face more job demands than the number of resources they have at their disposal. Taking into account of data availability, two types of job demands are identified: i)

reflect a multi-decade increase in part-time employment as a share of dependent employment (as distinct from self or independent employment). Between 1995 and 2019 the part-time employment rate in Germany was higher than the OECD average, hitting 22% in 2019 compared to the OECD average of 16.7%. In Germany as in other advanced economies, women account for a disproportionate share of part-time employment—37% in Germany compared to an average of 25% in the OECD in 2018. In Germany as in other advanced industrial economies, there is a wage penalty for part-time work: evidence from 1984 to 2010 finds that there was a 10% wage penalty for part-time workers in Germany (Wolf, 2014).

The German Labor Market: how does Germany compare? *Dashboard of Labor Market Performance for Germany, the OECD and the USA*				
	Indicator	**Germany**	**OECD**	**USA**
Quantity	Employment rate (2019)	76.7%	68.7%	71.4%
	Employment rate, m (2019)	80.5%	76.2%	76.5%
	Employment rate, f (2019)	72.8%	61.3%	66.3%
	Unemployment rate (2019)	3.2%	5.4%	3.7%
	Part-time employment (2019)	22.0%	16.7%	12.5% (2017, latest available)
	Broad labor market underutilization (2016)	21%	27.2%	25.7%
	Jobs at high risk of automation (2019)	18%	14%	10%
Quality	Earnings quality (2016)	26.5 USD	16.6 USD (2015, latest available)	18.5 USD
	Labor market insecurity (2016)	1.9%	4.9%	3.7%
	Job strain (2015)	28.5%	27.6%	25.8%
Inclusiveness	Low-income rate (2018)	17.8%	15.4%	24.1%

time pressure which encompasses long working hours, high work intensity and working time inflexibility; and ii) physical health risk factors, such as dangerous work (i.e. being exposed to noise, vibrations, high and low temperature) and hard work (i.e. carrying and moving heavy loads, painful and tiring positions). Similarly, two types of job resources are considered, namely: i) work autonomy and learning opportunities which include workers' freedom to choose and change their work tasks and methods, as well as formal (i.e. training) and informal learning opportunities at work; and ii) Social support at work which measures the extent of which workers receive social support from colleagues and supervisors. The composite Job Strain index, thus, refers to those jobs where the workers face one demand but have no resources, or face two demands but have one or no resource (OECD Stats).

	Low-income rate* (2015)	10%	10.9%	15.5%
	Gender wage gap (2018)	15.3%	13%	18.9%
	Gender labor income gap (2015)	42.6%	38.1%	39.5%
	Employment gap for disadvantaged groups (2016)	20.2%	24.7%	25.4%

Note: Employment rate: share of working age population (15-64) in employment (%). Part time employment rate: Part-time employment is defined as people in employment (whether employees or self-employed) who usually work less than 30 hours per week in their main job. Unemployment rate: share of persons in the labor force in unemployment (%). Broad labor underutilization: share of inactive, unemployed or involuntary part-timers (15-64) in population, excluding youth (15-29) in education and not in employment (%). Jobs at high risk of automation: Jobs are at high risk of automation if the likelihood of their job being automated is at least 70%. Earnings quality: gross hourly earnings in PPP-adjusted USD adjusted for inequality. Labor market insecurity: expected monetary loss associated with the risk of becoming unemployed as a share of previous earnings. Job strain: percentage of workers in jobs with a combination of high job demands and few job resources to meet those demands. Low income rate: The incidence of low pay refers to the share of workers earning less than two-thirds of median earnings. Low income rate*: share of working-age persons living with less than 50% of median equivalized household disposable income. Gender wage gap: the difference between median earnings of men and women relative to median earnings of men (full-time employees). Gender labor income gap: difference between per capita annual earnings of men and women (% of per capita earnings of men). Employment gap for disadvantaged groups: average difference in the prime-age men's employment rate and the rates for five disadvantaged groups (mothers with children, youth who are not in full-time education or training, workers aged 55-64, non-natives, and persons with disabilities; % of the prime-age men's rate).

The Hartz labor market reforms between 2002 and 2005 strengthened the growth of part-time employment in Germany through policies that fostered the creation of so-called “mini” and “midi” jobs, but the increasing share of part-time employment was already apparent before these reforms took effect (Carrillo-Tudela et al., 2018, Rothe and Wälde, 2017, Burda and Seele, 2016). OECD data show that part-time employment as a percentage of total employment increased gradually from the early 1990s to 2004, then jumped in 2005 and has risen gradually since. One study estimates that from 2005 to 2010, part-time work accounted for virtually all of the employment growth in Germany (Burda and Seele, 2016). Another study finds that the 2005 Hartz reforms increased part-time work by tightening restrictions on welfare benefits (Carrillo-Tudela et al., 2018).

The Hartz reforms also encouraged the growth of non-standard work in Germany. Non-standard work is an umbrella term that covers many forms of work including part-time work, temporary agency work; on-call work; temporary contract work; multi-party employment relationships; and gig economy work or freelance work by independent workers mediated through platforms. One study finds that of the 5.2 million unemployed individuals in early 2005 when the final phase of the Hartz reforms were implemented, more than 37% ended up in non-standard work arrangements, while only 9% transitioned from unemployment to full-time employment (Rothe and Wälde, 2017).

According to the most recent estimates, non-standard dependent employment makes up 28% of dependent employment in Germany (25% part time and 3% unstable employment pooled

across 2016 to 2018), compared to 22% across OECD countries (OECD, 2020).[5] Self-employed workers, including gig workers and platform workers, are not included in these estimates. Workers in such jobs still account for a small share, estimated at 1%-3% in a recent OECD study, of European and German employment (OECD, 2019).[6] Another recent study found that only 0.85% of the German working population has done platform work (Bonin and Rinne, 2017), while the share of active crowdworkers, defined as individuals who complete paid tasks via online platforms or online marketplaces, is 4.8% of the voting-eligible population, but only 3.4% earn income through this work (Serfling, 2018).[7]

In Germany as in the other advanced industrial countries, technological advances in computing power, cloud storage and sophisticated algorithms are enabling the growth of non-standard work, particularly gig or platform-mediated work and posing challenges to the traditional ways of financing, providing and safeguarding worker legal protections and social benefits through standard employment relationships.

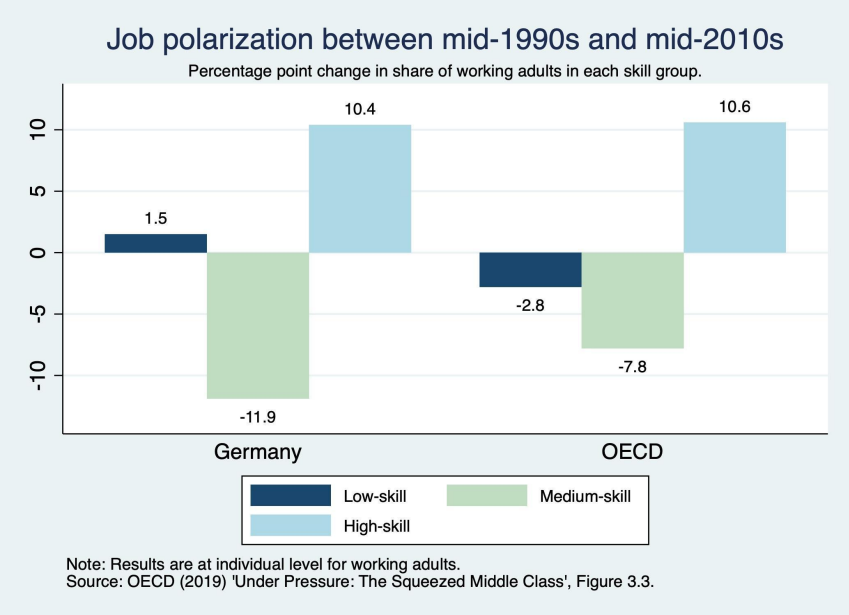
The OECD dashboard shows that in 2019 the share of jobs with a likelihood of automation of at least 70% was higher in Germany than the OECD average, in large part because manufacturing accounts for a larger share of employment in Germany (15% in Germany vs. 11% OECD average in 2019) and routine manufacturing jobs are at relatively high risk from automation (OECD, 2020). Driven by productivity gains propelled by technological and organizational changes, German manufacturing output has more than tripled while manufacturing employment has fallen sharply during the last forty years. The increase in manufacturing productivity has been accompanied by a shift from low-skilled to high-skilled workers (BMAS, 2017).

Robots have played an important role in productivity gains in the automotive industry in Germany, which is the fourth largest robot market in the world. In 2020, the number of industrial robots installed in Germany hit 230,000 mainly driven by robot use in the automotive industry (IFR, 2018).

The effects of automation on Germany's manufacturing sector are consistent with and reflected in the OECD data on the polarization of Germany's labor market shown below (OECD, 2019). Between the mid 1990s and the mid 2010s, the share of working adults in middle-skill occupations fell more in Germany than the OECD average while the share of working adults in high-skill jobs increased at about the same pace in both Germany and the OECD. Germany

[5] According to the OECD, "non-standard dependent employment refers to wage or salary workers who experience periods of part-time or unstable work. Self-employed workers and persons not in the labour force are not included. The OECD defines part-time employment as people in employment who usually work less than 30 hours per week in their main job. Unstable employment is defined here as a situation characterised by frequent transitions between employment and unemployment over a number of years."
[6] Additional research is needed on the size and composition of gig and platform work in Germany.
[7] According to the author, "To identify survey participants as crowdworkers, the following question was posed: "Do you complete paid tasks, that are conveyed via online platforms or online marketplaces?" [German: "Arbeiten Sie für bezahlte Arbeitsaufträge, die Sie über Online-Plattformen oder -Marktplätze vermittelt bekommen?"]

experienced a small increase in the share of workers in low-skill jobs, reflecting in part the growth in part-time employment in services, while the OECD had a small decrease.



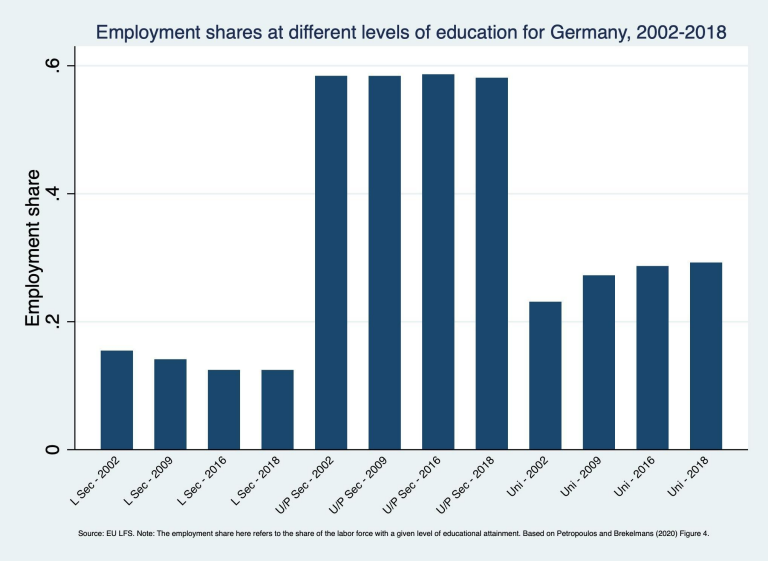
Source: OECD, 2019.

In Germany, as in other OECD countries, the workforce has become more educated over time, with the share of workers with only a primary or lower secondary education declining and the share of workers with a tertiary education increasing (Brekelmans and Petropoulos, 2020). The share of workers with a tertiary education increased from 20% in 1992 to nearly 30% in 2018 (based on our analysis of EU LFS annual data). The polarization of employment and the upskilling of occupations caused by RBTC have been accompanied and facilitated by the increase in the educational attainment level of the German workforce. In fact, the OECD Employment Outlook (2020) finds that from the mid-1990s to the mid-2010s there was an increase in the likelihood that middle-educated workers, both men and women, would be employed in high-skill occupations. In contrast, in most other OECD countries, middle-educated workers were less likely to hold high-skill jobs in the mid 2010s than in the 1990s. In Germany the rise in the employment share of middle-educated workers in high-skill occupations was almost as large as the rise in their share of employment in low-skill occupations (OECD, 2020).

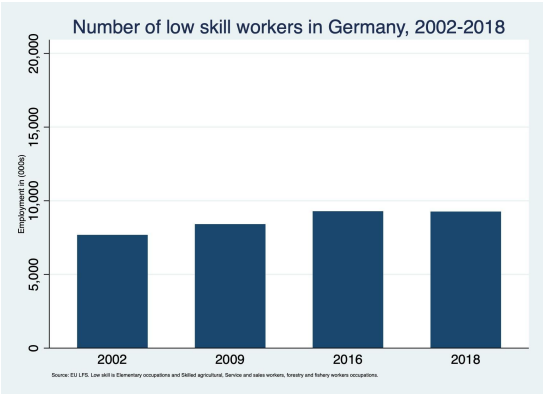
B. Trends in Educational Attainment Levels and Wages

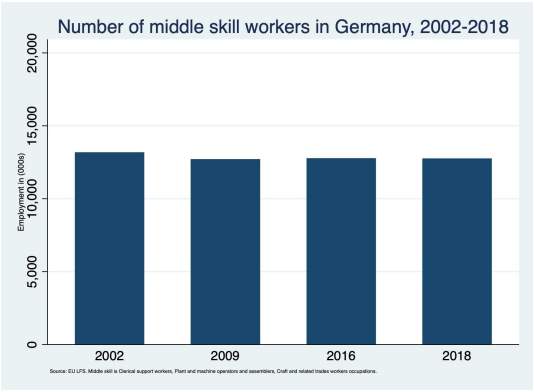
In Germany, as in other OECD countries, both employment rates and unemployment rates vary significantly by education. Employment rates rise with educational attainment, increasing from 61% for adults with below upper secondary education to 89% for adults with tertiary education in Germany (2018). Unemployment rates fall with educational attainment, declining from 8.5% for adults with below upper secondary education to 1.8% for adults with tertiary education. For young (15-34) vocational education and training graduates in Germany, the employment rate is

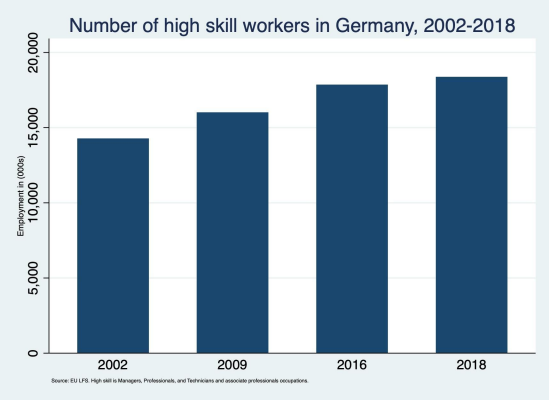
91% and the unemployment rate is 3%, compared to 69% and 9% respectively for young graduates with general upper secondary/non-tertiary education (OECD, 2020, Figure 5.4). Pronounced differences in employment and unemployment rates by education level are a persistent feature of labor markets in Germany and other advanced industrial countries. These differences were evident in the Great Financial Recession and recovery through 2019 and they are apparent in the recession/shutdown caused by COVID. . Job losses have been larger for workers with lower levels of education. Surveys from mid-April 2020 show that as a result of COVID, nearly one-third of all German workers usually employed were working from home, with low-earning workers 35% less likely to work from home than high-earning workers (OECD, 2020 and 2020, Figure 1.17), and low-earning workers 50% more likely to have stopped working than high-earning workers.



Source: EU LFS Database. Based on Figure 5 in Brekelmans and Petropoulos, 2020.







Source: EU LFS Database. Based on Figure 4 in Brekelmans and Petropoulos, 2020.

Wages also vary by education. In Germany and other OECD countries the wage benefit to higher education has been trending upward (OECD, 2019; Alda et al., 2020, pg. 11). In Germany in 2017 tertiary degree holders ages 25 to 64 could expect to earn 169% of the wages received by those with only upper secondary education for part-time or full-time employment. The comparable figure for the OECD average is 157% (OECD, 2019, pg. 84, Table A4.1). Tertiary educated workers in Germany represent just 12% of those with earnings at or below half of the median, and about 25% of tertiary educated workers earn more than twice median earnings, compared to only 5% of those with upper secondary or post-secondary non-tertiary education and 2% of those without upper secondary education (OECD, 2019, pg. 92, Table A4.2).

Germany's vocational education and training systems (what the OECD calls post-secondary non-tertiary education) also provide earning advantages: adults who complete this level of education earn 11% more for part-time or full-time employment than those with upper secondary education. Young (16-35) apprenticeship graduates in Germany earn 46% more than those whose highest qualification is at the academic upper secondary level (OECD, 2018, Figure 3.2). Among young employed graduates of vocational education and training in Germany, 44% are in middle-skill occupations, compared to 35% in high-skill occupations and 21% in low-skill occupations (OECD, 2020, Figure 5.8). Comparable OECD figures are 45% middle-skill, 20% high-skill and 35% low-skill. Unlike most OECD countries, in Germany higher employment rates among vocational education and training graduates persist into later adulthood, however, after age 45 the advantage disappears.

Differences in earnings between female and male full-time workers persist across all OECD countries. A gender-wage gap remains for each level of education in Germany, but becomes less pronounced for below upper secondary education (20%) and for those with upper secondary or post-secondary non-tertiary education (14%) (OECD, 2019, pg. 93). Consistent with the OECD average, in Germany tertiary-educated women earn about 75% of the earnings of men with the same level of education. Although young women tend to be more likely to complete higher education than young men (OECD, 2019, pg. 50), the net financial return on

investing in tertiary education for a woman in Germany, on average, is less than two-thirds of the return for a man (OECD, 2019, pg. 98). Across OECD countries, on average, the net financial return to tertiary education for women is about 15% higher than in Germany. The large gender-pay gap in Germany, relative to other OECD countries, is the result of several interrelated factors including the relatively large share of women in low-wage service jobs or part-time employment, child care policies, discrimination and implicit biases, and social norms (Economist, 2020). However, gender-pay differences nearly disappear when looking at the former East Germany (Fuchs et al., 2019, pg. 17) and full-time workers under 30 (Schrenker and Zucco, 2020). The increase in the gender gap after age 30 may reflect the reduction of women's working hours compared to men's working hours at that age, which is around the age of the birth of first children for many women. Recent research confirms that the gender pay gap in advanced economies reflects in part a sizable and persistent childhood penalty on female wages—the loss in wages that women experience as a result of bearing children (Kliff, 2018).

C. Productivity, Wages and the Labor Share of National Income

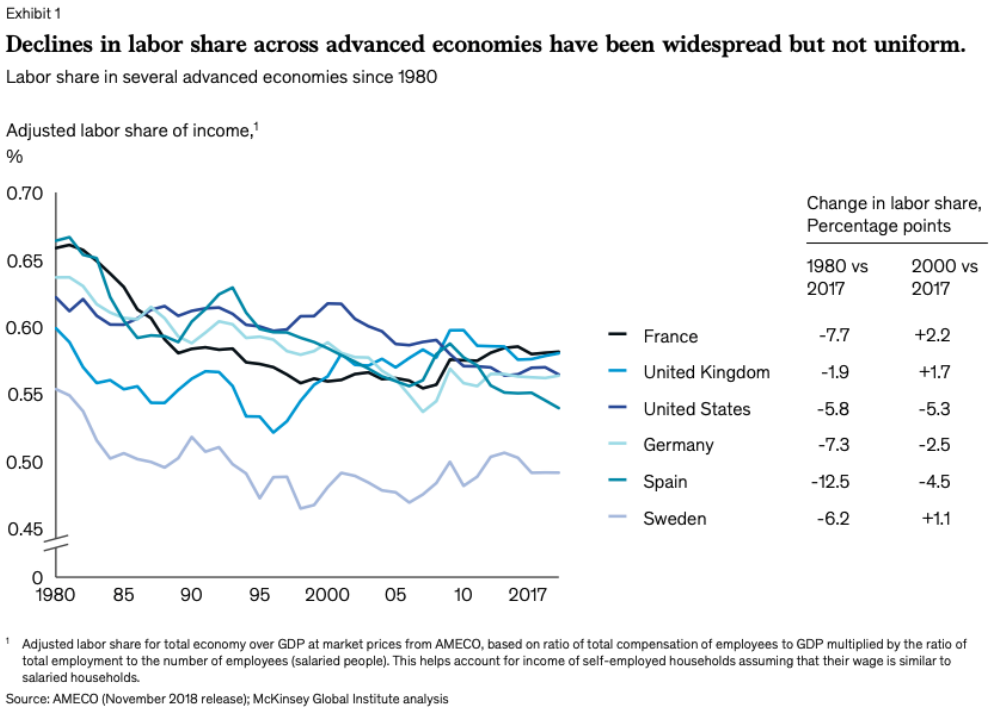
In Germany, as in other advanced economies, productivity growth is a major determinant of real wage growth. Labor productivity growth, measured per hour worked, in Germany declined sharply from 2.46% between 1985 and 1995 to 0.95% between 2004 and 2016, a period when productivity growth slowed throughout the advanced economies as a result of the Great Recession and slow recovery. All sectors, including manufacturing and its sub sectors with the exception of transport equipment, experienced the 2004-2015 slowdown in productivity growth in Germany. The major driver of the slowdown was a reduction in capital deepening—the growth of capital per hour worked—as a result of weak business investment. Over the entire 1991-2016 period, productivity growth was strongest in information and communications at an average annual rate of 4.2% and in manufacturing at an average annual rate of 2.5%. According to recent research, Germany's worker training systems and the high-productivity workplaces they foster, have contributed to Germany's relatively strong productivity growth in manufacturing and in most manufacturing subsectors (Baily, Bosworth, Doshi, 2020).

Overall the German economy caught up to the US level of productivity in the 1990s and has since then remained very close behind. The productivity gap is most pronounced in the IT sector. It is also important to note, however, that *productivity per worker* is lower and has grown more slowly than *productivity per hour* in Germany because of a significant decline in the average number of hours worked in recent years. In 2018, the average German worker worked more than 400 hours less than the average US worker. As a consequence, output per worker in Germany in 2017 was only 74% of the US level. As a matter of policy, Germany is choosing to share productivity benefits from automation with workers in the form of reductions in working hours (Baily, Bosworth, Doshi, 2020).

Over the last several decades in Germany as in other advanced economies real wage growth has been slower than productivity growth, and there has been a sizable gap between the two (see figure below). The gap or decoupling has been larger for the median wage than for the average wage, reflecting widening wage inequality.

Source: OECD Economic Indicators. Author's calculations based on Kuegler et al., 2018 Figure 2 Panel A. The figure compares GDP per hour worked as a measure of labor productivity and CPI-deflated total labor compensation per hour worked.

Decoupling has contributed to a drop in labor's share of national income which as noted above has been falling to differing degrees in advanced economies since the 1980s (see MGI graph below). The share in Germany experienced a long decline from the early 1980s through the financial crisis, hitting a trough in 2007 and recovering slightly thereafter. By 2017, the share was about the same as in 2004 but remained far below its peak in the early 1980s.



Source: MGI, 2019, pg. 5.

There are many theories for why the labor share of national income has been declining and why wage growth and productivity growth have decoupled in advanced industrial countries and there are many interrelated factors at work (Pak and Schwellnus, 2019, Table 1; De Serres and Schwellnus, 2017, Tables 5 & 6). A recent OECD report identifies both macroeconomic factors including technological change, globalization, minimum wages and the decline in collective bargaining coverage, and microeconomic factors including weakening competition in product and labor markets and inter-firm differences in productivity, profits and wage (Schwellnus et al., 2018). RBTC along with policy-driven reductions in the prices of capital goods has encouraged labor displacing investment, reducing labor's share of national income. The spread of digitalization and the emergence of superstar firms with substantial market power and low labor shares have also played a role as has the globalization of supply chains, made possible by technological changes in information, communications, and logistics. RBTC has facilitated and incentivized globalization based on labor arbitrage and both have contributed to the polarization of employment, the decoupling of wage growth from productivity growth, and inequality (Tyson and Spence, 2017).

In Germany, country-specific institutional factors and policies also contributed to the declining labor share through the Great Recession and its modest recovery thereafter. Following German unification, real wages grew more slowly than productivity, and Germany's cost competitiveness particularly in manufacturing strengthened. Real wage growth was restrained in the middle of the wage distribution (50th percentile) and there was a dramatic drop in real wages at the lower end of the wage distribution (15th percentile). The increasingly competitive global environment in which German firms found themselves after unification, including new opportunities for them to move production and employment to lower-cost locations to the east, increased their bargaining power with unions and works councils which in turn agreed to wage restraint to preserve jobs (Dustmann et al., 2014). Wage moderation may have also been influenced by the threatened job displacement effects of technological change especially as a result of the capital intensification/robotization of production from the early 1990s to the outbreak of the Great Recession. A decline in collective bargaining coverage among employees also contributed to the declining labor income share and rising wage inequality during this period (Bundesbank, 2018).

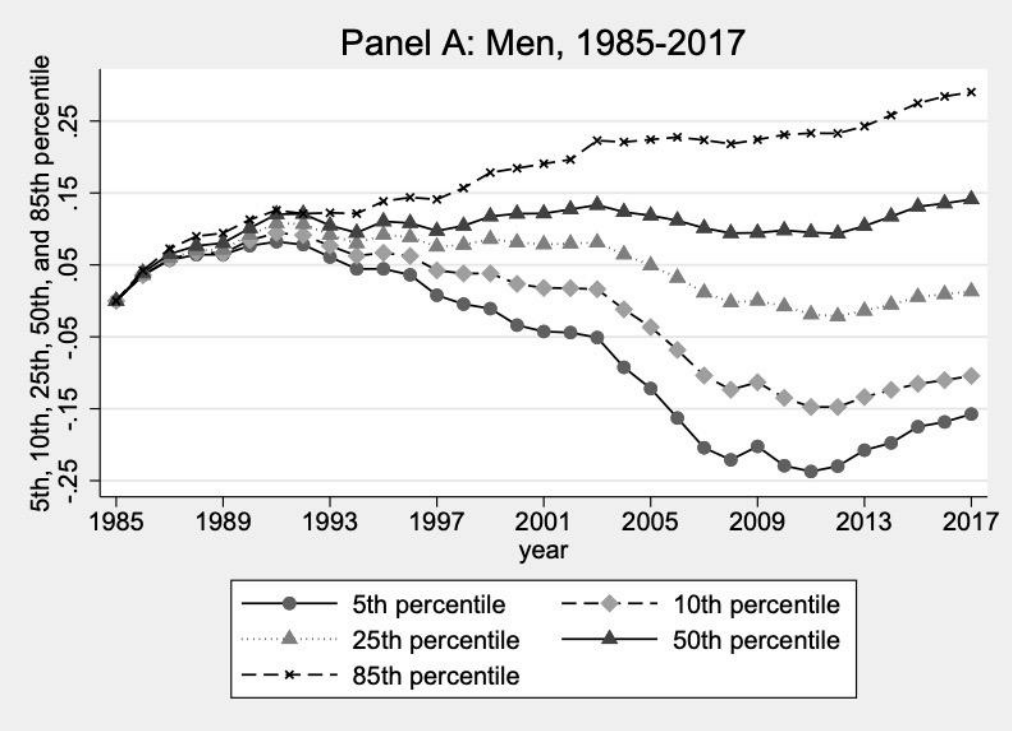
D. Automation and Wage Inequality

1. Overview of Wage Inequality Trends[8]

Between the mid 1980s and the mid 1990s, wage inequality (as measured by both the standard deviation of wages and the Gini coefficient) among full-time workers was largely unchanged in Germany.[9] In the mid 1990s, however, wage inequality began to increase driven by strong wage

[8] This report focuses on wage inequality, which contributes to but is distinct from overall income inequality. For an overview of income inequality in Germany from 1871 to 2014, see Bartels (2019).
[9] Unless otherwise indicated, wage inequality measures in this section refer to full-time employment and exclude part-time employment and non-standard employment.

increases at the top of the wage distribution, stagnation in median real wages, and significant declines in real wages at the bottom of the distribution (Felbermayr et al., 2014, Figures 1 and 2).[10] These trends persisted through 2007; between 1995 and 2007 the real median wage showed little improvement while wages for the bottom decile fell by 13% and wages for the top decile increased by 10% (Kügler et al., 2018). These trends began to change following the Great Recession. As the recovery gained momentum in Germany, strong economic expansion and a tighter labor market strengthened the position of unions, leading to favorable wage negotiations (Dustmann, 2020). Consistent with this explanation, Kügler et al. (2018) attribute a significant share of wage growth for the 10th and 50th percentiles to higher union wage demands after 2010. Additionally, Bosch and Weinkopf (2012) and Bosch (2018) argue that the implementation of new or higher industry-specific minimum wages established through employer associations, unions, and government contributed to wage growth during this period. As Figure 4 shows, beginning in 2010, wage growth strengthened across the wage distribution with wages for the bottom decile increasing at a faster pace than median wages or wages for the top decile.



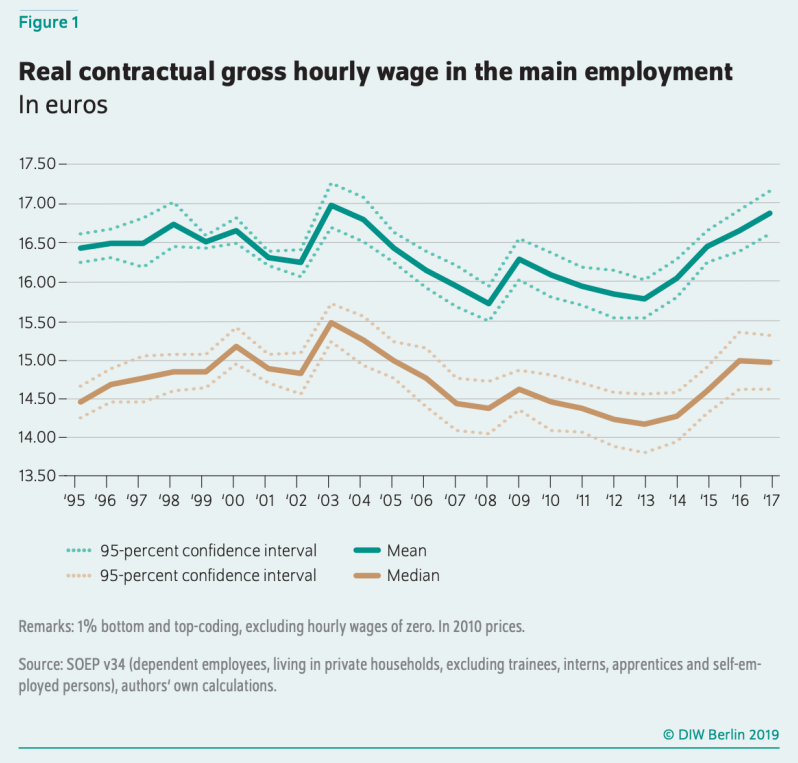
Notes: The figure shows the indexed (log) real wage growth of the 5th, 10th, 25th, 50th, and 85th percentiles of the wage distribution. Panel A refers to the period between 1985 and 2017, with 1985 as the base year. Wages are indexed to 2015 price levels. Spells are duration and full-time probability adjusted. Sources: SIAB 7517 of the Institute for Employment Research in Nuremberg; taking full-time workers in West Germany and between the ages of 21 and 60 into account.

Source: Christian Dustmann presentation, September 2020. The overall trend is the same when women are included (see: Figure 4 in Kuegler et al., 2018).

Wage growth for the bottom decile was fueled by the introduction of a statutory national minimum wage in 2015, the first time the government directly set a wage floor by law that provided coverage for designated categories of workers across the economy. Research confirms that the introduction of the minimum wage increased the wages of low-wage workers

[10] It is important to note that trends in wage inequality between East and West Germany were similar, although the level of inequality has been lower in East Germany than in West Germany.

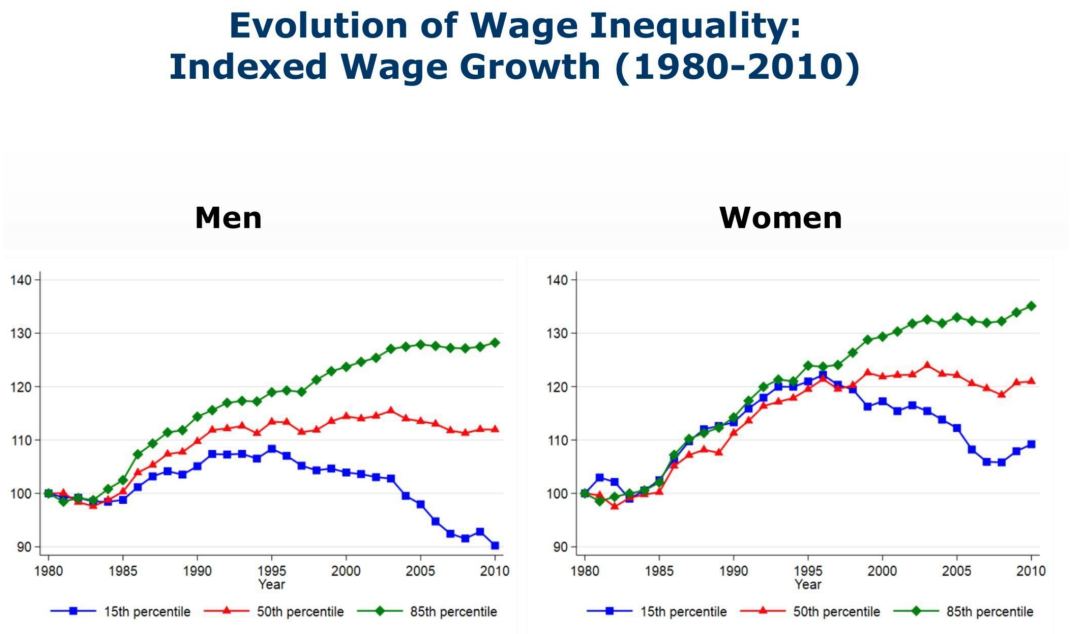
relative to wages of high-wage workers without reducing the employment of low-wage workers (Dustmann et al., 2020). Overall wage inequality increased between the mid-1990s and 2010, due to strong growth in wages at the top, stagnation in wages at the 50th, and significantly slower wage growth below the 50th percentile with the most dramatic slowdown in wage growth for the 5th and 10th percentile. After 2010, wages grew more rapidly across the entire wage distribution, but wage inequality persisted, with growth in wages at the top outpacing growth in the bottom 50th percentile. Another measure of wage inequality is the gap between the growth of the median and average wage. A recent study also shows that between 1995 and 2017 the gap between the real hourly median wage and the real hourly average wage was persistent between the two estimated at about 2 euros in 2017 (DIW Berlin, 2019).



Source: DIW Berlin, 2019.[11]

As noted above, there is a persistent gender wage gap in Germany but according to OECD data, it declined from 27% in 1992 to 15% in 2018 (OECD, 2020). Wage inequality trends between the mid 1990s and 2010 by gender show similar results: rising wages for the 85th percentile and stagnant wages at the 50th percentile. Overall wage inequality is somewhat larger for men than women.

[11] This is likely a lower-bound estimate of wage growth in the period 2004-2008. From DIW Berlin (2019): "Overall, wage growth was weaker in the SOEP than in the Vierteljährliche Verdiensterhebung (VV), the quarterly earnings survey of the German Statistical Office. Gross monthly wages without special payments for full-time employees from 1995 to 2003 rose at virtually the same level in both data sets. From 2004 to 2008, wage growth in the SOEP was below that of the VV. Since 2008, wage growth in both data sources has only differed slightly. See German Statistical Office, Durchschnittliche Bruttomonatsverdienste, 2019 (in German; available online)."



Source: Alexandra Spitz-Oener presentation at the American Academy in Berlin, December 2019.

2. RBTC, Institutional Changes and Wage Inequality

There are numerous often interrelated factors including changes in the personal characteristics of the workforce, such as age, education, gender, cohort and industry; changes in technology and globalization; and changes in institutions, labor market policies, and macroeconomic conditions behind wage inequality trends in Germany and other advanced industrial economies. **Despite a growing body of research, it is important to note that there is no consensus about the relative importance of these factors. Moreover, evidence on the "direct" effects of RBTC on wage inequality, as distinct from its indirect effects through related factors including education, sector, occupation, and firm-level profitability, is limited and inconclusive.**

While RBTC is a widely accepted explanation of the polarization of tasks and jobs in Germany and advanced industrial economies, the polarization of employment is not necessarily associated with the polarization of wages or other measures of wage inequality. While higher and to a lesser extent lower skill jobs/occupations have increased relative to middle-skill ones, consistent with the polarization of employment, wages have not polarized but they have become more unequal over time, with wages for higher-skill jobs/occupations growing faster than those at both the middle and low ends of the wage distribution (OECD, 2019).

The remainder of this section summarizes the findings of recent research on the effects of automation, education, institutions and policy changes on wage inequality trends in Germany.

a. Wage Inequality and Education

Section 2 summarized the evidence on the role of educational differences on wage differences and wage inequality. As noted in that section, the share of college-educated workers has been increasing in Germany and the education premium in wages for workers with tertiary degrees compared to wages for workers with lower and upper secondary degrees has also been increasing. Moreover, the wages of college graduates show greater dispersion than the wages of workers with secondary degrees, so ceteris paribus, the higher the share of college graduates in total employment, the larger is wage inequality. SBTC has affected wage inequality by education by increasing the demand for workers with tertiary degrees compared to those with lower levels of education. The fact that the wage premium for workers with tertiary education has increased even as their number and their share of total employment have grown indicates that the increase in demand for such workers has outpaced the increase in their supply. In the race between the demand for workers with the skills and education required by SBTC and the supply of such workers, demand has been winning, driving up both the wages and the employment of workers with the requisite skills.

In the US, new evidence on the race between education and RBTC suggests that the college wage premium is no longer the largest driver of overall wage inequality (Autor, Goldin, Katz, 2020). The study finds that increased educational-wage differentials account for only 38% of the increase in wage inequality from 2000 to 2017, compared to 75% from 1980 to 2000. Although wage inequality increased at a similar rate during the two periods, the more recent period saw increased wage inequality *within* educational groups, rather than *between* them. In particular, wage inequality grew among college educated workers, while there was almost no change in wage inequality for non-college educated workers since the 2000s.

Relative to the US, Germany has fewer tertiary educated workers as a percentage of the working-age population and slower growth in tertiary educational attainment (OECD, 2019). Thus, dissimilar to the latest findings for the US, it is likely that the college education premium will continue to play a significant role in wage inequality in Germany as SBTC and RBTC increase the demand for college-educated workers relative to their supply.

Other recent research confirms the importance of education and labor market experience in wage inequality trends in Germany (Biewen, Fitzenberger, Lazzer, 2017). For men, the most important individual variables behind wage inequality are changes in education especially at the upper end of the wage distribution and changes in experience and labor market histories (incidence of part-time work and work interruptions) especially at the lower end of the wage distribution. For women, the most important variables are age/experience and labor market histories.

b. Revisiting the German Wage Structure (Dustmann et al., 2009)

This study confirms widening wage inequality at the top and bottom of the German wage distribution between 1975 and 2004. Wage inequality began to increase in the 1980s mostly in the top half of the wage distribution as measured by the 90/50 wage gap. Beginning in the early 1990s, wage inequality also started to increase in the bottom half of the wage distribution as measured by the 50/10 ratio. The authors conclude that

RBTC was a major driver of widening wage inequality in the top half of the wage distribution while institutional changes, most important the decline in union coverage, were the main factor behind widening wage inequality in the bottom half of the distribution. The paper shows the growing polarization of Germany's labor market as measured by the relative growth of jobs at the median wage (50th percentile), the bottom (15th percentile) and the top (85th percentile.) Consistent with predictions about SBTC's effects on employment and wages, they find that employment and wage changes were positively correlated for occupations above the median wage and negatively correlated for those below. This asymmetrical pattern reflects SBTC's effects on increasing demand for labor in non-routine tasks in which technology complements human skills and decreasing demand for labor in routine tasks in which technology substitutes for human labor. The authors find that changes in workforce composition (cohort effects) as measured by changes in the education and age/experience of workers, explain some but not all of the increase in upper-tail inequality and cannot explain the path of lower-tail inequality.

Overall, the authors conclude that technological change was an "important driving force behind the widening of the wage distribution particularly at the top." They find that the major driver of lower-tail inequality was a sharp decline in union coverage and to a lesser extent an increase in the supply of relatively low skilled workers following reunification. The decline in union coverage explains about 28% of the rise in inequality at the lower end of the wage distribution but only 11% at the upper end.

c. From Sick Man of Europe to Economic Superstar: Germany's Resurgent Economy (Dustmann et al., 2014)

This study examines the increase in wage inequality in Germany between 1990 and 2008, measured by wage growth at the 15th, 50th and 85th percentiles. Real wages at the 15th percentile fell from the mid 1990s through 2008; real median wages stagnated through 2000 when they began to fall while real wages at the 85th percentile grew strongly throughout the period. The authors identify a sharp decline in union coverage and the increasing decentralization of the wage-setting process from industry-level agreements to firm-level agreements and sometimes even individual-worker agreements as driving forces behind overall wage restraint reflected in the stagnation of wages at the 50th percentile and real wage declines at the bottom 15th percentile. **The authors argue that increasing competitive pressures on German industry, combined with new opportunities for German firms to shift their production to lower cost locations in newly liberalized eastern European countries, forced unions and works councils to cooperate with their employers to limit wage demands, sacrificing wage increases in order to maintain employment.**

Research by Jens Südekum also finds that the wage effects of automation (robots) in local labor markets in Germany reflect voluntary wage restraint by unions/works councils (Südekum, 2019 and 2018). He finds that works councils/unions responded to the significant expansion in the deployment of robots in German manufacturing in the mid 1990s by accepting lower wages or lower wage growth to secure job stability. More recently, research by Gerhard Bosch and Jutta Schmitz-Kießler (2020) explores the role

of unions and works councils in shaping Industry 4.0. **Overall, the evidence indicates that wages do not fall at firms as they deploy robots. Instead both productivity and wages rise at such firms, although the productivity gains are larger than the wage gains. Consistent with economic theory, investment in robots and other capital equipment increases worker productivity and wages rise to reflect the productivity gains.**

d. Productivity Growth, Wage Growth and Unions (Kuegler et al., 2018)

This paper documents both the decoupling of wage growth from productivity growth and increasing wage inequality at the bottom of the wage distribution in Germany between 1995 and 2007/2008. The authors attribute these trends to wage restraint by unions in response to threats of job loss from increasing global competition, a decline in union coverage, and the decentralization of the union wage-setting process from sectors to individual firms (as a growing number of firms opted out of sectoral wage agreements). The decline in unionization coverage from nearly 80% in 1995 to about 55% in 2015 was particularly pronounced between the mid 1990s and the early 2000s when aggregate wage growth was particularly sluggish and wages at the bottom of the wage distribution dropped significantly. As the decline in union coverage slowed after 2010, aggregate wage growth, including at the bottom of the wage distribution, increased. **Concern over the drop in real wages at the lower end of wage distribution and eroding collective bargaining coverage for such workers led to the introduction of a statutory minimum wage in 2015. This marked a departure from the social market economy model in which wage determination was left to voluntary negotiations between employers and workers.**

e. Increasing Wage Inequality in Germany: What Role Does Global Trade Play? (Felbermayr et al., 2014)

This paper documents the rise of both upper tail and lower tail wage inequality for full-time workers between the mid 1990s and 2010, with wages rising at the 80th percentile, falling at the 20th percentile and stagnant at the median. In 2008, median wages were approximately at the 1997 level. A significant share of the rise in wage inequality during this period took place in conventional skill groups; personal characteristics of workers, including age, education and gender explained only about 20% of the rise. Wage inequality trends were broadly similar in East and West Germany during this period, but the level of inequality was noticeably lower in the former than the latter. Wage inequality (measured by standard deviation) increased across all skill levels with the lowest level of inequality among low-skilled workers and with wage inequality among highly skilled workers showing the largest increase over the period.[12] Increasing inequality among highly skilled workers was a significant factor behind the overall rise in wage inequality.

The paper confirms the importance of a "collective bargaining wage premium," as measured by the percentage supplement to the wages of an employee in a

[12] Skills are measured by education level: low-skilled workers have at most a high school education and no vocational training; highly-skilled workers have university diploma or technical college diploma.

company with a collective bargaining agreement over the wages of a comparable employee in a company without such an agreement. This supplement increased between the late 1990s and 2010 hitting about 19% by the end of the period. The paper finds that the most important factor behind rising wage inequality during this period was the decline in collective bargaining coverage that was particularly important in the lower range of the wage distribution and explained about 43% of the overall inequality increase. Aside from changes in collective bargaining, the growing share of highly-skilled and experienced workers, who traditionally exhibit higher wage dispersion compared to other workers, were important factors behind growing wage inequality. Neither technological change, as measured by investment in new technologies, nor globalization, as measured by exports, were found to have increased wage inequality during the period.

f. Polarization and Rising Wage Inequality: Comparing the U.S. and Germany (Antonczyk et al., 2018)

This study documents and compares polarization of employment and rising wage dispersion for all education/skill groups in the US and Germany between 1979 and 2004. The results are consistent with an SBTC explanation of the polarization of employment in both countries. The trends in wages favor higher-education workers in both countries, although rising skill premia are more important in the US than in Germany. Although there are similarities in wage inequality trends in both countries, differences in the timing and the patterns indicate that SBTC alone cannot explain these trends. In Germany the rising wage premium between medium and low-education workers is entirely due to cohort and aging effects and there is no evidence of wage polarization. Episodic changes reflecting changes in institutional factors including the decline in collective bargaining and changes in minimum wages are partly reflected in cross-country differences in cohort effects. In Germany, for example, the decline in collective bargaining coverage and the decentralization of wage setting over time may have lowered the wages of less skilled workers in the youngest cohorts whose entry wages were less protected as a result of these changes.

g. Wage Inequality and the Minimum Wage

In 2015 an hourly minimum wage of 8.50 euros, about 48% of the median wage, was introduced to increase wages at the bottom of the wage distribution and to contain the growth of lower-tail wage inequality. According to the OECD's international comparison of the ratio of minimum wage to median wage, in 2015 the ratio for Germany (0.48) was higher than for Spain (0.37) and the US (0.36), but lower than France (0.62) and the UK (0.49). When the minimum wage was introduced, about 15% of workers earned an hourly wage of less than 8.50 euros, suggesting that the increase directly affected about 4 million jobs (Dustmann et al., 2020; Bruttle, 2019). Workers younger than 18 years of age, apprenticeships, interns, voluntary workers and the long-term unemployed were exempt. Despite large differences in wage levels across regions, the minimum wage was set at a uniform national level. On average affected workers were paid about 6 euros before the minimum wage was introduced (Bossler and Schank, 2020). Since 2015, the minimum wage has been increased, hitting 9.35 euro at the beginning of 2020. In 2019,

nearly 2 million jobs benefitted from the minimum wage increase, and by April 2019, 3.5% of all jobs in Germany (1.4 million jobs) were paid the statutory minimum wage (Statistisches Bundesamt, 2020).

Recent research finds that the minimum wage has significantly increased the wages of low-wage workers relative to the wages of workers located higher in the wage distribution and has reduced lower-tail wage inequality without any discernible effect on either the unemployment rate or the employment rate of low-wage workers (Dustmann et al., 2020). Wage and employment trends for high-wage workers have also not changed in response to the minimum wage. Another study concludes that the minimum wage accounts for about half of the decrease in wage inequality between 2010 and 2017 (Bossler and Schank, 2020).

The minimum wage has resulted in a reallocation of low-wage workers from smaller lower-paying firms to larger higher-paying ones. The reallocation is the result of the movement of these workers to firms that pay higher wages or a wage premium for the same types of work, and have more full-time jobs, a more skilled workforce, lower levels of staff turnover and higher labor productivity. Some small firms, especially those with fewer than 3 workers and those located in regions where wages for low-wage workers were significantly lower than the minimum wage, were put out of business. For many displaced workers, the movement to higher wage firms has required a significant increase in commuting time.

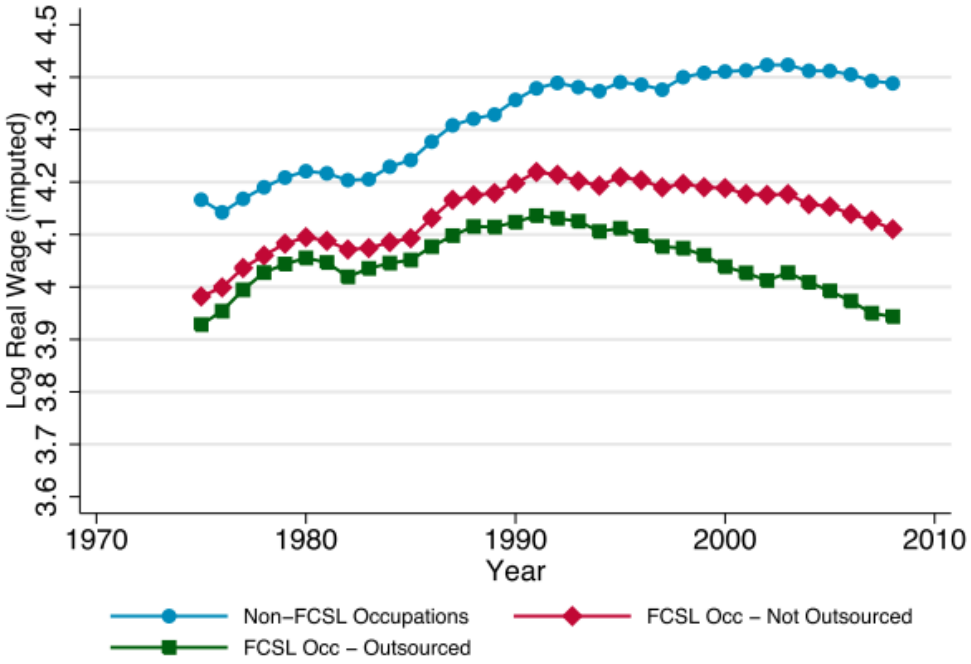
The fact that the minimum wage has not reduced employment levels for low-wage workers suggests that the labor markets for such workers are not competitive and that firms operating in monopsonistic or oligopolistic market conditions have power to set wages for such workers. Under these conditions, both minimum wage policies and centralized union power can provide a counterweight to uncompetitive employer power, fostering higher wages, more employment, less wage inequality, and greater efficiency.

Finally, it is important to note that the reallocation of low-wage labor to more productive firms triggered by the minimum wage between 2015 and 2020 occurred under strong macroeconomic conditions and increasing labor demand both overall and at larger higher-paying firms. In recessionary conditions, increases in the minimum wage could result in job losses for low-wage workers because of inadequate aggregate demand. Potential post COVID19 changes in consumer behavior that reduce the demand for in-person services, while increasing the demand for digital services, may also mean that future minimum wage increases result in larger job losses for low-wage workers.

h. Wage Inequality and Outsourcing

Non-standard employment jumped in the period after the Hartz reforms continuing a long-term trend of increased domestic outsourcing. A study of West German establishments following food, cleaning security, and logistics (FCSL) occupations and industries from the mid-1970s to 2010, found that domestic outsourcing of these occupations picked up in the late 1980s and early 1990s (Goldschmidt and Schmieder,

2017). Across major industries such as retail and manufacturing, the share of establishments with at least one worker in FCSL occupations declined significantly from 1975 to 2010. Simultaneously, the share of workers in FCSL occupations employed in business service or temp agencies increased markedly. The rise of domestic outsourcing is linked to broader changes in the German wage structure during this period: wages in outsourced jobs fell by around 10-15% compared to similar non-outsourced jobs, and outsourcing of FCSL services alone accounted for an estimated 9% of increased wage dispersion. As the figure below shows, outsourced and non-outsourced wages move in tandem with general wage trends until around 1990, at which point FCSL wages diverge, but more so for outsourced jobs.



Source: Goldschmidt and Schmieder, 2017, Figure VIII.

i. Wage Inequality from Firm and Sorting Effects

Firms play an important role in wage inequality. On average across OECD countries, between firm changes in the dispersion of average wages explain about half of the changes in overall wage inequality from the early 1990s to around 2013-18 (OECD, 2020). In Germany, from 1996 to 2016, as much as 65% of overall wage inequality was wage inequality between firms (OECD, 2020, pg. 15-16). A recent study of West Germany from 1996 to 2014 confirms that the continuous increase in wage dispersion among full-time male workers was driven by between-plant wage dispersion (as opposed to within-plant wage dispersion) (Baumgarten et al., 2020). In particular, industry effects and the decline in collective bargaining coverage were the most important factors contributing to the increase in between-plant wage dispersion and affected the lower-tail of wage inequality rather than the upper-tail. The study also confirms that at the individual-level, education has been a key factor in wage inequality as the wage gap

between highly educated and less educated workers has grown (Baumgarten et al., 2020).

Between firm wage inequality is a product of both composition effects and firm-wage premia. In general, there are two ways to conceptualize how firm-level profitability affects firm-level wage premia—through productivity passthrough and through rent-sharing. Productivity passthrough measures the extent to which firms pass through productivity gains to workers in the form of higher wages. Forthcoming OECD research finds that firm-level differences in productivity passthrough are positively correlated with pay differences among nearly identical workers at different firms. For Germany, the research indicates that as passthrough increases, wage premia dispersion increases as well. The study finds that passthrough is higher in highly concentrated labor markets and labor markets with limited job mobility, competitive product markets, for male and highly-skilled workers, and in countries with decentralized collective bargaining.

An OECD study of six European countries from 2004 to 2013 finds that industrial robots disproportionately raise productivity and profits in superstar firms that are more productive to begin with, and that robotization contributes to the declining labor share. In other words, superstar firms earn superstar rents, which materialize as higher wages for their workforce and are increasingly retained as profit (Stiebale, Suedekum, Woessner, 2020).

Another study finds that investment by German companies in digital technologies between 2011 and 2016 was associated with wage increases for the firms' workers. This finding indicates that such investment increases worker productivity and results in higher wages. The study also finds that workers primarily engaged in routine and non-complex tasks enjoy the largest wage benefits when they are working for firms making such investment. However, most workers doing such tasks are likely to remain employed in companies that are not investing in digital technology and hence they earn lower wages for the same occupations (Arntz et al., 2019).

Firms also differ in “rent-sharing,” defined as the extent to which they share profits with their workers. Firms may decide to share profits with their workers for efficiency incentive reasons—offering wages above market rates may encourage more effort and greater worker productivity. From this perspective, higher wages lead to higher labor productivity in contrast to standard labor market analysis according to which higher productivity leads to higher wages. Rent-sharing may also be the result of worker bargaining power through unions, works councils and other institutions that give workers a “voice” or influence as stakeholders in wage decisions (Stansbury and Summers, 2020).

Research on the drivers of wage inequality in Germany is consistent with the "rent sharing" explanation of inter-firm wage inequality (Card, 2013). The article evaluates the role of firms in rising wage inequality among full-time male workers in West Germany between 1985 and 2009. It finds that differences in firm-level wage premium, combined with differences in the personal characteristics of workers including age and education, explain a large share of the increase in wage inequality during this period. A related study concludes that the rising probability that skilled workers were employed by firms that offered them a significant wage premium was a major factor behind growing wage

inequality in Germany over the same period (Card, Heining, Kline, 2013). The study also finds that among male workers who changed jobs, workers who moved to a firm with higher paid co-workers received a wage increase, whereas those who moved to firms with lower-paid co-workers receive a pay cut.

III. Predictions about the Effects of Automation on the Future of the German Labor Market through 2030

A. Pre-COVID estimates

This section presents a range of estimates of the possible effects of automation on the German labor market under different scenarios through 2030 based on models by the McKinsey Global Institute (MGI). The estimates are based on assumptions about the pace and extent of automation and about the sources and growth of labor demand across occupations, sectors and regions pre the onset of the COVID pandemic in 2020.

MGI broadly defines automation, as also defined in this report, as robots, software, digital platforms, and intelligent machines and systems that can carry out tasks otherwise done by humans. Considering the extent to which these currently demonstrated technologies could be adopted, future economic growth, and growth in demand for tasks that can and cannot be automated, MGI forecasts potential employment changes for more than 800 occupations across 46 countries, representing nearly 90% of global GDP. MGI examines two scenarios, one based on current mid-point economic trends and the second based on a step-up scenario that assumes additional investment in areas such as infrastructure and energy transitions. MGI identifies seven catalysts of future job demand, including rising incomes, health care for the aging, technology spending, investment in real estate and construction, investment in infrastructure, and energy transitions and efficiency. Rather than forecasting the future, MGI projections serve as guides to the range of possibilities for the future of the labor market. Which scenario unfolds will ultimately depend on business strategies, investments in education and training, and other government policies.

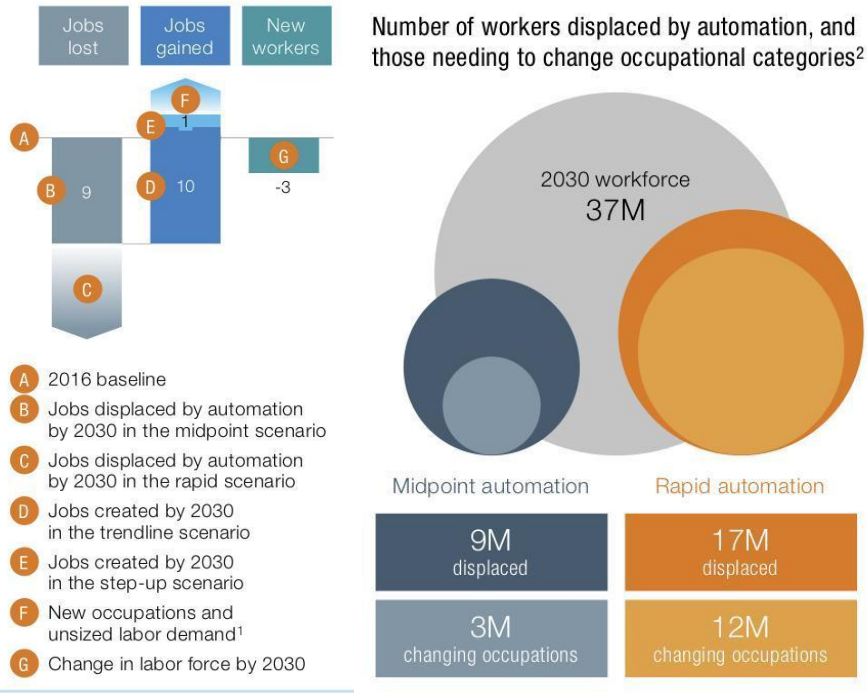
In January 2017, based on this methodology, MGI published a study that found that while less than 5% of occupations could be fully automated with currently demonstrated technologies, 60% of occupations have 30% or more of their constituent activities that could be automated (MGI, 2017). MGI published another study in December 2017 that found that under a likely mid-point scenario for the pace of automation about 15% of the global workforce—or 400 million workers—could be displaced between 2016 and 2030, requiring between 75 and 375 million workers, or 3% to 14% of the global workforce, to change occupational categories (MGI, 2017). In developed economies, where high labor costs are likely to accelerate the adoption of labor-saving technologies, the share of the workforce that might have to change occupational categories and the skills associated with them is even higher. In these countries, routine jobs in major occupational categories such as production and office support, and jobs requiring a high school education or less--both categories that accounted for significant shares of pre-COVID19 employment--are likely to decline while jobs in occupational categories such as healthcare and care providers, educators, builders, managers, and jobs requiring a college or advanced degree are projected to grow.

Automation risks are greatest for routine cognitive tasks such as data-collection and data-processing, and routine manual and physical tasks in structured, predictable environments, like production-line jobs in manufacturing. In advanced economies, including Germany, the US and most European countries, large shares of middle-skill, middle-wage employment consist of such routine jobs.

A recent update of MGI's research estimates that as automation adoption continues in the decade ahead, almost all of today's 235 million European workers will face at least some degree of change as their occupations evolve (MGI, 2020). In Germany, up to 24% of current work activity hours may be automated by 2030 under the midpoint automation scenario, while rapid automation could result in displacement of up to 47%. Up to 32% of the projected 2030 workforce may have to change occupational groups in the midpoint scenario (MGI, 2017).[13] As noted earlier, however, significant displacement effects are likely to be offset by replacement effects--productivity induced increases in income and in the demand for goods and services—and in reinstatement effects as new tasks and occupations result from automation. Consistent with the productivity and replacement effects, the MGI model finds that rising incomes, followed by rising technology spending and rising spending on healthcare, are likely to be the largest catalysts of labor demand through 2030.[14] In the trendline growth scenario around 10 million jobs will be created in Germany, enough to offset both the displacement effects of automation and the projected decline in the working-age population of nearly 8% (4 million people) by 2030, double the projected decline (4%, or 13.5 million people) in the EU over the same period (MGI, 2020).

Additionally, as Arntz et al. (2019) point out, distinct features of the German social market system, such as labor protection legislation that makes it costly for firms to lay off workers and raises firms' incentive to retrain workers, and a strong vocational education system for skilled workers may further reduce or offset the effects of labor-displacing automation on the demand for human workers.

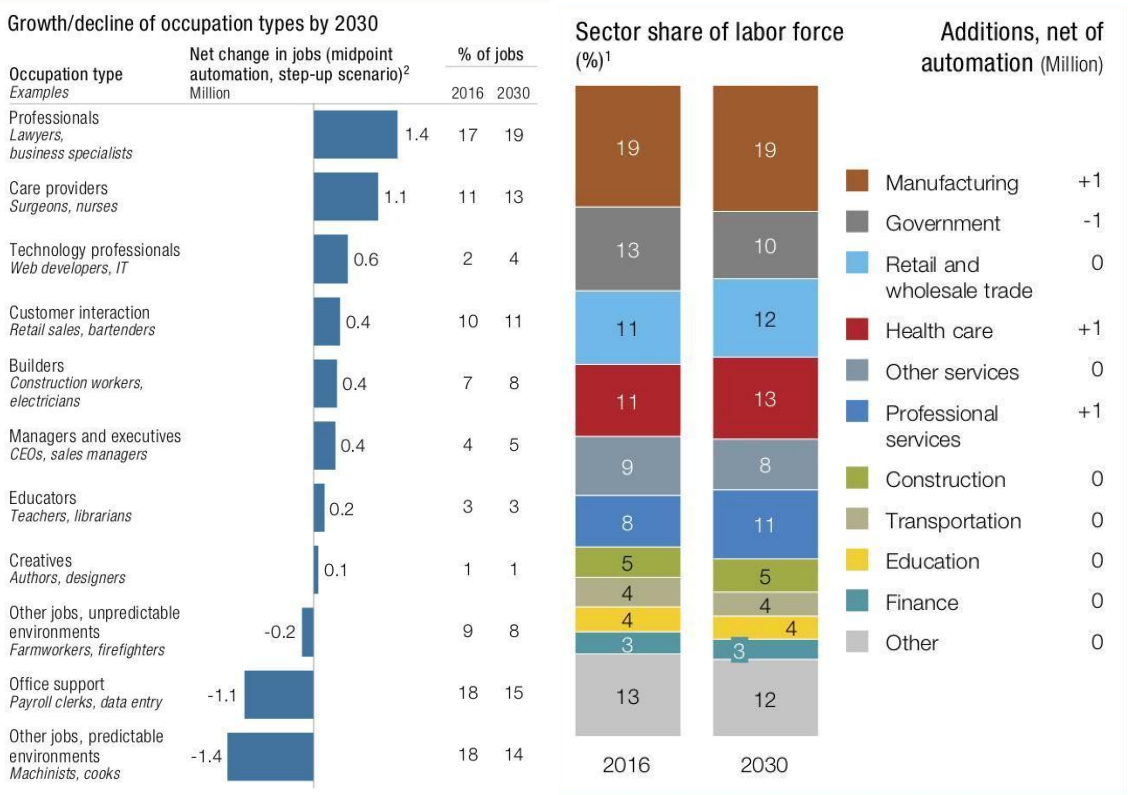
[13] We updated the MGI calculations on Germany using 2017 as a base year. There is little change from the estimates presented in this report. Unless otherwise mentioned, the statistics mentioned here are from the MGI report.
[14] This used 2017 as a base year.



Source: MGI, 2017, pgs. 94-95.

While few occupations in Germany are fully automatable, nearly 60% of all occupations have at least 30% technically automatable activities. Consistent with RBTC, activity types that are most susceptible to automation are routine-physical or routine-cognitive activities in predictable environments, including processing data, collecting data, and predictable physical activities. Combined, these three activity types account for 51% of total working hours currently spent in all German occupations, and according to MGI around two-thirds or more of the time spent in these activities can be automated by adapting currently demonstrated technologies.[15] Activity types that largely complement technological change tend to be non-routine cognitive activities in unpredictable environments. These activity types, such as managing people (7% of total current working hours), applying expertise (15% of total working hours), and interfacing with stakeholders (15% of total working hours), have a much lower likelihood of automation. Similarly, the occupations most likely to be displaced due to automation are those in predictable environments (-1.4 million), office support (-1.1 million), and other jobs in unpredictable environments (-0.2 million), while the occupations most likely to increase are professionals (+1.4 million), care providers (+1.1 million), technology professionals (+0.6 million), customer interaction (+0.4 million), builders (+0.4 million), managers (+0.4 million), educators (+0.2 million), and creatives (+0.1 million). The sectors that are projected to account for the majority of the labor force in Germany by 2030 include manufacturing (19%), health care (13%), retail and wholesale trade (12%), and professional services (11%).

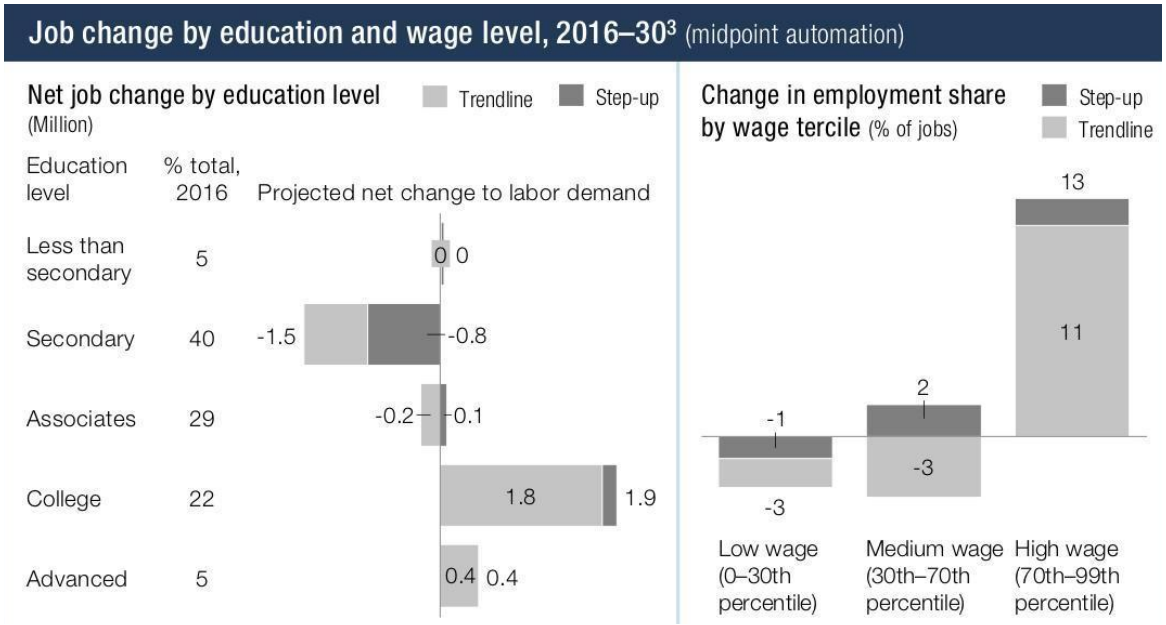
[15] These estimates use 2017 as a base year.



Source: MGI, 2017, pgs. 94-95.

In Germany, like all advanced economies, occupations requiring higher levels of education have lower automation potential. For example, MGI finds that occupations requiring high school education or less or only some post-secondary education (e.g. logging equipment operators, stock clerks, travel agents) are twice as likely to be automatable as occupations requiring a college or university degree (e.g. nursing assistant, electricians, lawyers, teachers, etc.). Virtually all trendline job growth in Germany during the 2016 to 2030 period is predicted to occur in relatively high-wage (70th percentile or higher) jobs that require a college education or higher. A recent IAB study also finds that jobs with higher levels of educational requirements are less likely to be substituted/automated with available technologies, and that the negative association between educational attainment and substitutability became stronger between 2013 and 2016 (Dengler and Matthes, 2018). Another study of the German labor market from 2016 to 2021 similarly concludes that occupations with high average daily wages will increase most from technology investments, whereas low- and particularly medium-paid occupations and industries will face stagnating or even declining employment, thereby increasing wage inequality (Arntz et al., 2019).

In summary, both existing and ongoing research indicate that routine-biased automation and the polarization of employment, along with rising returns to tertiary education, will continue in Germany, resulting in more job opportunities for those at the top of the education and wage distribution and the hollowing-out of the middle and lower-ends of the distribution.



Source: MGI, 2017, pgs. 94-95.

Within Germany and other advanced economies, the job displacement and job creation effects of automation are not evenly distributed across regions and geographies. A recent MGI report on automation's effects on local economies in the EU estimates that more than one-third of job growth since 2007 has been generated by only 48 cities (MGI, 2020). In the future, uneven job growth is likely to continue and exacerbate geographic concentration. From 2003 to 2017, mobility across borders in Europe increased by more than 50% (from 0.4% to 0.6% of the total population). Germans, however, are five times more likely to move from one part of Germany to another than to move to another country. In Germany, this suggests increased clustering into dynamic cities like Munich and Berlin or stable local economies, such as high-tech manufacturing hubs like Stuttgart. Germany is home to 72% of Europe's high-tech manufacturing hubs. As individuals relocate to different cities for new job opportunities, frictional unemployment will increase. However, if remote work continues to increase in the post-COVID19 economy, the location patterns of digital work and job opportunities may change stemming or even reversing recent trends of regional and urban concentration.

Average values per clusters (2013-18)

Less economically favorable — More economically favorable

		Regions	Population	Economic indicator				Industry mix	Labor market	
		# (Share of EU total, %)	Millions (share of EU total, %)	GDP per capita, thousands, EUR	Real GDP CARG, 2013-18	Unemployment rate, %	Net migration rate	Share of employment in high-growth industries, %	Share of population with tertiary education, %	Old-age dependency ratio
Dynamic growth hubs	Megacities	2 (<1%)	26 (5%)	47.4	2.1	6.2	-0.7	9.4	48.4	21.4
	Superstar hubs	46 (4%)	76 (15%)	41.4	1.5	5.5	7.0	4.7	40.6	27.2
Stable economies	Diversified metros	64 (6%)	49 (9%)	30.4	0.6	7.4	3.9	1.2	30.1	31.2
	Diversified non-metros	267 (24%)	63 (12%)	28.1	1.4	5.4	5.4	1.2	27.7	32.1
	High tech manufacturing centers	78 (7%)	25 (5%)	35.6	0.2	3.8	6.2	0.8	24.7	30.9
	Service-based economies	102 (9%)	89 (17%)	29.4	0.6	4.8	4.9	1.9	34.9	30.3
	Tourism havens	98 (9%)	33 (6%)	25.2	-0.4	10.2	4.1	0.9	28.2	32.3
Shrinking regions	Aging population regions	107 (10%)	25 (5%)	23.1	0.7	6.5	2.0	0.6	29.8	41.6
	Agriculture-based regions	58 (5%)	17 (3%)	10.9	0.7	7.8	-3.5	0.2	19.2	32.2
	Educated and emigrating areas	85 (8%)	34 (7%)	15.1	0.3	7.5	-4.8	0.5	24.1	26.9
	Industrial bases	72 (7%)	27 (5%)	18.7	-0.0	3.9	-1.1	0.4	20.4	27.9
	Public sector-led regions	81 (7%)	27 (5%)	19.0	1.1	15.3	-0.2	0.6	22.1	34.3
	Trailing opportunity regions	35 (3%)	26 (5%)	20.1	-0.3	17.3	-1.1	0.7	25.0	31.0

Source: MGI, 2020. Calculations for Germany in progress. Dynamic cities include 1) Megacities with highly educated workforces and high-growth industries and 2) Superstar hubs, which are among the fastest growing regions in Europe. Stable economies include service-based economies, high-tech manufacturing centers, diversified metros, diversified non-metros, and tourism havens. Shrinking regions are declining due to outmigration, aging, or both. Shrinking regions are particularly concentrated in Eastern and Southern Europe.

B. Post-COVID Estimates

In 2021, MGI published a new study that updated its estimates on the effects of automation on the future of work based on changes in business, work and consumer practices triggered by the pandemic (MGI, 2021). Overall, the results of the new MGI study confirm the results of the earlier one. The new study concludes that compared with MGI's earlier estimates of the effects of automation on work, the pandemic is likely to cause a significant increase by 24% in the number of jobs displaced and a significant increase by 21% in the number of workers needing to transition occupations in Germany by 2030. And most of the job growth during this period in Germany is projected to occur in high-wage occupations in health care and STEM-related fields while low and middle-wage jobs decline as a share of total employment.

IV. Automation and a Policy Agenda for Good Jobs and Inclusive Growth

How should Germany's distinctive social market system be adjusted to address the challenges and exploit the opportunities of the continuing automation of work in a post COVID19 future? Overall, even with accelerating labor-displacing automation, given its declining population

Germany's long-term labor problem is likely to be too few workers rather than too few jobs (Varian, 2020). The policy challenge will not be enough jobs but "enough good jobs"--jobs that provide middle-class earnings, safe working conditions, legal protections, and social protections and benefits--to maintain high levels of employment. In the long run, access to good jobs is essential to making technology-enabled growth inclusive growth (OECD, 2016, Tyson 2021).

A good jobs agenda for Germany has several components.

First, all working age individuals, both citizens and legal immigrants, should have equitable access to good jobs.[16] This means empowering them to acquire the skills necessary for good jobs through access to quality education at all stages in life and in all forms--primary/secondary; vocational and college; adult training and reskilling.

Almost all net labor demand growth over the next decade is likely to be in high-wage occupations in Germany as RBTC continues to automate and reduce both low and middle skill/wage tasks. AI will exacerbate these trends by driving RBTC automation into higher level cognitive demand tasks, and workers will need to "reskill and upskill" to keep pace with the different and higher skill requirements of job opportunities. Occupational transitions, sometimes accompanied by geographic transitions, will require more personalized training and other forms of support for workers forced to make them.

In its annual report (2020/2021), the German Council of Economic Experts emphasizes the importance of strengthening lifelong learning opportunities in several ways including: improving the skills of teachers in digital areas and investing in digital technologies in primary and secondary schools; expanding vocational training positions and curriculum; and increasing lifelong professional development opportunities, with a focus on low-skilled workers.

Second, active labor market policies (ALMPs) including training programs, job search assistance and income support programs, wage subsidies and public works programs, and start-up programs to support micro entrepreneurs and independent workers should cover all workers, should be expanded and should be better integrated with businesses to help workers make the necessary transitions across occupations and across regions/locations. Unemployment insurance and other forms of income support are necessary for unemployed workers while they train and search for jobs.

Third, temporary emergency measures that provided unemployment insurance and other forms of social insurance to on-demand and independent workers during the COVID pandemic should be made permanent as the share of such workers in total employment continues to grow. Many social and legal protections covered in standard employment contracts should be extended to such workers. So-called portable benefits systems that tie benefits to workers rather than to

[16] Given its declining population, Germany is likely to need additional immigration. All of the components of the good jobs agenda described here should apply to both citizens and legal immigrants.

their employers and are funded on a prorated basis by multiple employers are a promising way to provide and fund benefits for workers with multiple, often temporary task-based employment relationships.

Fourth, unions, works councils and other ways to increase worker voice and negotiating power in both standard and on-demand work arrangements should be strengthened. During the last three decades, the significant erosion of such power has contributed to wage stagnation, wage inequality and the decoupling of wage and productivity growth in Germany and the other advanced economies. In many industries and firms, especially those at the automation frontier, market concentration/power has increased, and individual companies are able to dictate the wages and terms of employment for both their standard and on-demand workers, often using sophisticated AI tools to manage and monitor them. Unions and other organizations to represent worker interest are important counterweights to employer power, fostering higher wages, better working conditions, and more employment.

Fifth, the federal government can take multiple direct fiscal actions to support the creation of good jobs. This starts with macroeconomic policies to sustain strong aggregate demand and high-pressure labor markets. Tax policy is also critical. Labor is currently taxed at higher rates than physical and knowledge capital in Germany and other advanced economies, and this has been a powerful incentive for businesses to replace costly labor with less costly capital. Increases in taxes on corporate income, including a global minimum corporate tax rate currently under discussion in the OECD, would moderate this bias as would a reduction in payroll and other employment-related taxes. . Targeted tax credits for R&D and innovations that enable rather than substitute for human skills in sectors with growing demand like health care and education are also a powerful tool for encouraging the creation of good jobs as are direct government investments in these areas.

Government investment in widely and publicly available broadband and related digital tools is also an essential component of a good jobs agenda both to enable individual workers to get training for and access to them and to support small businesses and entrepreneurial startups. Germany has underinvested in its digital infrastructure—mobile and fixed broadband connections are hampered by inadequate fiber connections and slow performance in rural/small communities. In its most recent report, the German Council of Economic Experts called for more public funding for broadband infrastructure

Finally, a combination of policies including minimum wages, tax credits related to work, like the earned income tax credit in the US, and social protections including health and pension coverage are essential components of a good jobs agenda for workers who will remain in low-wage, low skill jobs. As documented earlier in this report, the introduction of a federal minimum wage in Germany boosted income growth for low-wage workers and reduced wage inequality without reducing employment, and the newly elected coalition government in Germany has identified a significant increase in the minimum wage as a priority.

APPENDIX

A Good Jobs Agenda

Good jobs are the best way to share automation's benefits with workers.

Good jobs are those that provide:

- Earnings consistent with a middle-class living standard.
- Legal protections: against harsh and dangerous working conditions; against discrimination; against excessive market power of employers.
- A quality work environment: time pressure and health risks.
- Access to education and training, social insurance (policies to protect people against the financial implications of social risk, such as ill health, old age, and job loss) and health care and other social protections.
- Worker voice: unions, collective bargaining rights, and works councils to represent workers as stakeholders in the companies/businesses that employ them.

This list has considerable overlap with the OECD definition of good jobs. See: OECD (2016) "How Good is Your Job? Measuring and Assessing Job Quality"

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I. Policies for a Good Jobs Agenda

- **Macroeconomic policies:** adequate aggregate demand and commitment to full employment.
- **Competition policies:** to maintain competitive conditions in product and labor markets.
- **Tax policies:** taxes on labor vs. taxes on capital.
- **Education and VET policies:** new labor market entrants and lifetime learning.
- **Social insurance and social protections:** lifetime income security not security of a particular job in a particular place.
  - Minimum Wage
  - Protections for workers in non-standard employment
- **Active Labor Market Policies**
  - Unemployment Compensation
  - Job Search Assistance and Monitoring (e.g., job centers)
  - Training
  - Employment subsidies
  - Public sector work program

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II. Policies to Promote Creation of Good Jobs

- **Overlapping national goals:** a high-productivity competitiveness agenda and a good jobs agenda
- In a social market economy, the creation of good jobs depends on innovation, investment and employment decisions of businesses.
- **Policies to promote good job creation by businesses:** high productivity firms create good jobs.
  - Apprenticeship system
  - Kurzarbeit system and hours flexibility in employment contracts
  - Industrial and regional development policies (coordination of employment/training and industrial/regional policies)
  - Policies to promote dissemination and use of new technologies by SMEs (customized business services)
  - R&D policies: tax incentives; direct public funding; national mission moonshots
    - Direction of technological change depends on incentives, relative power (capital vs. labor), norms, and challenges to be addressed (health, climate change, security)

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Institutions to Promote Good Jobs

- **Institutions for labor voice**
  - Labor unions/collective bargaining
  - Works Councils
- **Employer associations**
- **Dialogues among social partners**

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BMAS Policy Initiatives pre COVID, December 2019

Reforms for lifelong learning for skills upgrade

- Creation of individual learning accounts; 500 euros per year up to 5,000 euros.
- Creation of online platform listing federal and state continuing education and training (CET) opportunities to make it easier for workers and companies to navigate them; prototype is complete.
- Investment in retraining from social partners; e.g. IG Metall and employers; Siemens Fund for the Future initiative to finance qualification projects.

Reforms to the portfolio of Federal Employment Agencies

- Introduction of "Lifelong Career Counselling" (LBB) project launched nationally in 2019, which consists of counselling before entering working life, during working life, and a career counselling self-discovery tool. The focus is on the needs of organizations and in close consultation with the social partners and regional business self-governance structures.
- Emphasis on intervention by Federal Employment Agency pre-unemployment
- "MYSKILLS - Identifying Professional Competencies" for targeted skills development and placement in employment. It is a testing process that uses videos and images to identify practical vocational knowledge; it aims to enhance the counselling and placement services of employment agencies, joint institutions and licensed local authority agencies.

Reforms for work organization

- BMAS is supporting companies in setting up in-house "Innovation Spaces," to test the potential of new ideas; these spaces are agreed upon by works councils and management and evaluated scientifically. For example, a company may experiment with new digital technologies. Emphasis is on SMEs.

Minimum wage: introduced in 2015; adjusted based on independent commission assessment of collectively agreed wages.
Pension reform: basic pension supplement to the pension entitlements of low-income earners who have worked more than 35 years, including child care and caring for relatives.

German Policy COVID19 and post COVID19

Overall assessment: The German Social Market Economy has performed well and has demonstrated its strengths during the pandemic.

- Rapid passage of two large fiscal stimulus packages (about 8% of GDP)
- **Emergency housing measures:** eviction ban due to missed payments; deferment of rent payments; mortgage forbearance; deferment of utility payments and/or assured continuity of service even if payment missed.
- **Health care system:** public health system and treatment capacity; rapid rollout of widespread testing; automatic mechanism to reduce employer costs for sick leave; access to paid sick leave for self-employed; existing Infection Protection Act that predates the pandemic that requires paid sick leave for workers with mild symptoms that cannot work from home; self-employed also have right to income replacement if infected.
- **Kurzarbeit system:** both policy and flexible work-time practices including employer-initiated reductions in working time, reduced overtime and pay reductions. Kurzarbeit and resilience to shocks.
    - More flexibility, coverage and benefits extended to workers on Kurzarbeit in stimulus packages and temporary easing of regulations. Simplified access, extended access to agency workers, reduced employer cost to zero, increased the statutory replacement rates for lost earnings, lifted restrictions on taking another job; increased staff 14x to process claims. Claimed by 30% of employees.

Source: OECD Employment Outlook, 2020

German Policy COVID19 and post COVID19

- **VET system:** young adults have good employment prospects and ability to enter high-skill occupations. Germany has a low unemployment rate for youth. VET encouraged during pandemic by policy measures.
  - In Germany and in other countries with strong VET systems and cooperative social dialogue, there has been significant rise in propensity of middle-educated workers to be employed in high-skill occupations.
- **Support for small businesses, including self-employed**: cash support of up to 15,000 euros for small firms with up to ten employees; liquidity measures; support for SMEs; self-employed receive compensation for loss of earnings.
  - A significant fraction of non-standard employment in Germany is “voluntary” and disproportionately women and mothers.

Likely Permanent Effects of COVID19 on Trends in Automation and the Future of Work

Trends likely to be accelerated or strengthened:

- Automation and digitization; Shift to remote work; Growth of independent work, especially gig work. Growing concentration of market power in product and labor markets. Wage inequality.

Trends likely to be weakened or reversed:

- Urbanization, densification.

New trends:

- Changes in patterns of consumption and consumer behavior.
- Changes in patterns of investment.
- Changes in patterns of regional growth.

Appendix Table 1: Skill Definitions			
Source	**Low**	**Middle**	**High**
Autor (2019, pg. 5)	Manual and service occupations	Production, office, and sales occupations	Professional, technical, and managerial occupations
Brekelmans and Petropoulos (2020, pg. 6)	Food prep, building and grounds, cleaning, personal care and personal services, agriculture, sales occupations	Office and admin, mechanics and repairers and construction workers, transportation and material moving occupations, precision production and machine operators occupations	Managers, professionals, technicians occupations
Eurofound (Ifsa_egais series)	Elementary occupations and skilled agriculture, service and sales workers, forestry and fishery occupations	Clerical support workers, plant and machine operators and assemblers, craft and related trade workers occupations	Managers, professionals, and technicians and associate professionals occupations
OECD (2019, pg. 83)	Low-skill workers are those with jobs in sales and services and elementary occupations (ISCO 5 & 9)	Middle-skill workers hold jobs as clerks, craft workers, plant and machine operators and assemblers occupations (ISCO 4, 7 & 8)	High-skill workers are those who have jobs in managerial, professional, technical and associated professional occupations (ISCO 1, 2 & 3)
MGI (2020, pg. 139)	Service workers and shop and market sales workers and elementary occupations (ISCO-88 major groups 5 & 9) in Europe; for the US, annual/annualized median wages less than $30k in 2018	Clerks, craft and related trades workers, plant and machine operators and assemblers (ISCO-88 major groups 4, 7 & 8) in Europe; for the US, annual/annualized median wages between $30k-60k in 2018	Legislators, senior officials and managers, professionals, technicians and associate professionals (ISCO-88 major groups 1, 2 & 3) in Europe; for the US, annual/annualized median wages greater than $60k in 2018