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Policy Responses to Technological Change in the Workplace

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Abstract

The rise of new technologies has been a defining feature of advanced capitalist countries over the last decades, reigniting concerns about the future of work, rising inequality, and technological unemployment. While there is little doubt that rapid technological progress has far-reaching economic, social, and political consequences, little is known about viable and effective policies governments can implement to assist workers and communities in adjusting to a fast-changing economic landscape and rising labor market insecurity. This paper focuses on the ability of public policies to moderate technology-induced labor market vulnerability and its well-documented political downstream consequences. First, I suggest to theoretically classify policy responses according to their intended goal into a three-fold typology, distinguishing between investment, steering, and compensation policies. After that, I provide a detailed discussion on the current state of the empirical literature how such policy responses affect workers coping with technological change. In the last section, I discuss to what extent these findings can guide the adoption of policies to help workers adapt to technological change and point out potential avenues for future research.

Keywords: technological change; policy responses; social policy; regulation; automation; digitalization

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1 Introduction

The history of capitalism has been marked by constant technological advancement. There is ample evidence that the introduction of new technologies throughout history has profoundly transformed labor markets and caused extensive technological anxiety (Mokyr et al. 2015; Frey 2019). This process frequently led to sweeping predictions about widespread technological unemployment. Rifkin infamously anticipated that "more sophisticated software technologies are going to bring civilization ever closer to a near-workerless world" (1996: p. xv). However, the promise of a fully automated economy in the near future is predicated on the idea that machines and intelligent software can soon replace all human jobs and tasks in all economic sectors, which would force us to rethink the role of human beings in the social process. In contrast, there is scant empirical support for the idea that large-scale technological unemployment is imminent. Long-term technological unemployment has never happened on a massive scale. However, waves of technological change, from agricultural modernization to the more recent third and fourth industrial revolutions since the 1970s, have frequently led to large-scale displacements and frictional unemployment (Mokyr 2002; Acemoglu and Restrepo 2019).

From a theoretical perspective, introducing new technologies can have distinctive but interrelated effects on labor. Technological change can influence *long-term aggregate employment* through its impact on labor demand. As Acemoglu and Restrepo (2019) have shown, the balance between productivity effects and displacement effects determines the net effect on aggregate employment. Inevitably, new technologies will lead to a decline in the demand for some jobs and tasks, but they will also boost the productivity of firms and thus increase the demand for labor in non-automated tasks. Additionally, technological innovation creates reinstatement effects by generating new jobs and tasks where labor has a competitive edge. Projections frequently fail to consider that technological advancement leads to product innovation, which creates entirely new economic sectors (Mokyr et al. 2015). In fact, recent empirical research indicates that using robotics or artificial intelligence in the workplace does not necessarily result in a decline in aggregate employment levels and does not lead to widespread technological unemployment. Aggregate employment levels are either unaffected or even increase slightly with the introduction of new technologies (Arntz et al. 2018; Graetz and Michaels 2018; Dauth et al. 2021; Dottori 2021; Antón et al. 2022; Klenert et al. 2022).[1] A comparative OECD study supports the idea that technological advancement and aggregate employment levels go hand in hand (Georgieff and Milanez 2021). However, because research is inherently retrospective, we cannot predict whether novel technologies will have a different impact. In this regard, a recent study by Acemoglu and Restrepo (2019) issues a caution: while automation-induced displacement has recently increased, the creation of new tasks has decelerated. Thus, uncertainty exists regarding the extent to which aggregate employment levels will hold steady in the future as increasingly sophisticated robotics and artificial intelligence become more capable of performing tasks previously performed by humans. Nevertheless, presuming an end of work for everyone and that robots and computers have an absolute comparative advantage over humans in all tasks is evidently "nonsensical" (Mokyr et al. 2015: p. 45).

However, the distributive consequences of technological change are obscured by a simple focus on aggregate employment levels. To get a clearer picture, we also need to focus on how technological change affects the *level and distribution of wages*. While increasingly automated tasks and occupations will see diminishing income levels in relative (and probably absolute) terms, occupations for which technology is complementary are expected to benefit both in relative and absolute terms (Aghion et al. 2019). As there is little potential for career advancement and occupational upgrading due to the redundancy of automation-exposed workers, their wages may even decline, irrespective

[1] The United States (Acemoglu and Restrepo 2020a) and France (Aghion et al. 2019; Acemoglu et al. 2020) might be a partial exception in this regard.

of whether they can hold onto their current job (Acemoglu 2020). Observed displacement effects confirm the expectations of a routine-biased technological change (RBTC) and speak against a uniform shift in employment away from low-skilled toward high-skilled occupations as predicted by skill-biased technological change (SBTC). Yet, technology is not the sole driver of occupational change and patterns of occupational change vary across countries, and job polarization is less pronounced in many Continental European countries (Fernández-Macías 2012; Oesch 2013; Fernández-Macías and Hurley 2017; Oesch 2022). Even if to varying degrees, technological change primarily displaces routine workers in the middle of the income distribution and complements non-routine workers, leading to a rise in wage and employment polarization (Autor et al. 2003; Goos and Manning 2007; Goos et al. 2009). Thus, it is widely established in the economics literature that technological change has widespread and heterogeneous economic consequences on different workers (Autor et al. 2006; Acemoglu and Autor 2011; Autor and Dorn 2013). In particular, workers with lower levels of education and those in occupations that require performing routine tasks, which are simpler to automate than non-routine tasks (Autor et al. 2013), are at a higher risk of being displaced (i.e., the "losers" of technological change). In contrast, a large portion of workers can become more productive and benefit from the introduction of technology in their workplaces (Iversen and Soskice 2019).

Additionally, if the productivity of technology capital increases more quickly than that of labor, technological change can further reduce the *labor share in national incomes* (Acemoglu 2020). If more tasks are delegated to capital rather than labor, the labor share is anticipated to decline, while the labor share will rise as a result of additional tasks (Acemoglu and Restrepo 2019). While there is evidence that the labor share in the United States did not decline from the 1950s to the 1980s, technological improvements after the 1980s led to declining labor shares (Autor and Salomons 2018). A decreasing labor share does not only increase income inequality but also undermines the financial sustainability of the welfare state, which heavily relies on payroll taxes as a vital source of revenue.

Finally, workers who are impacted by technological change may experience severe short- to mid-term repercussions. While strong productivity effects might stabilize or even increase overall employment levels in the long run, *frictional unemployment and skill redundancy* will pose significant challenges. Existing evidence shows that a significant share of occupational restructuring from manufacturing towards services happens via lower job entries and partially early retirement (Kurer and Gallego 2019; Bessen et al. 2019; Dauth et al. 2021; Dottori 2021). Thus, technology-induced labor displacement often proceeds over a generation, with older workers leaving the workforce and fewer younger workers entering such jobs. Nevertheless, actual displacements are still very costly for the affected workers and translate into significant income losses (either due to unemployment or low-income work). The advent of artificial intelligence will likely aggravate such adjustment costs if automation takes over routine and non-routine service tasks (Acemoglu 2021) and affect younger workers where early retirement is not an option. Thus, frictional unemployment and skill redundancy are two of the major challenges facing society today.

In a nutshell, even if technological change benefits society, technology-induced labor market vulnerabilities are concentrated on some social groups and can cause significant economic and political disruption (Im et al. 2019; Boix 2019; Kurer 2020; Gallego and Kurer 2022). These consequences are significant and require answers in the form of adequate policy responses. Although there is little doubt that rapid technological progress has far-reaching economic, social, and political consequences, we know little about politically viable and effective policies governments can implement to help workers and communities adapt to a rapidly shifting economic landscape. Since there are already excellent reviews on the economic and political consequences of technological change (for example, see Özkiziltan and Hassel 2020; Özkiziltan and Hassel 2021; Gallego and Kurer 2022), the objective of this paper is not to examine the economic implications of technological change and its downstream political ramifications on political participation, policy preferences, and vote choice. This paper instead focuses on how public policies might mitigate some of the detrimental consequences of technological change on labor.

The paper continues by discussing three broader types of policy responses to technological change in the workplace. While there is a wide array of potential policy responses discussed in academia, politics, and the media, I propose to categorize policies according to their intended goal into a three-fold typology: (i) *compensation policies* aim to buffer the negative effects of technological change ex-post to cope with the danger of frictional unemployment, (ii) *investment policies* aim to prepare and upskill workers ex-ante to cope with structural changes at the workplace and to match the skill and task demands of new technologies, (iii) *steering policies* treat technological change not simply as an exogenous market force and aim to actively steer the pace and direction of technological change by shaping employment, investment, and innovation decisions of firms. While recent research has started exploring the link between technological change and social compensation and investment policies (for example, see Busemeyer et al. 2022 on digitalization and the welfare state), there is little research on active state steering of technological change. This is surprising given that most governments are everything but hesitant to actively promote and boost the speed of technological change. A prominent current example is the NextGenerationEU fund, where digitalization figures as a core pillar of the economic recovery plan.

After discussing the three types of policy responses and the corresponding policies theoretically, I review the current state of the empirical literature on how such policy responses affect workers coping with technological change. In doing so, I do not aim at a comprehensive historical review of policy responses to technological change since the First Industrial Revolution. There is no question that technological change has been more disruptive in the past when there were few, if any, public policies in place to help deal with labor market vulnerability. As a matter of fact, political conflicts surrounding earlier waves of technological change have substantially contributed to the gradual establishment of the welfare state, mechanisms of economic redistribution, and tighter labor laws on improved working conditions and decreasing working hours (Frey 2019; Esping-Andersen 1990). In this paper, I will focus on the more recent waves of technological change over the last roughly 50 years, which have been characterized by personal computers, information technology, robotics, and artificial intelligence. There is no doubt that the empirical research on policy responses to these more recent technologies is fragmented, contested, and piecemeal. Even though the literature is quickly evolving, drawing conclusions based on scant empirical evidence should be treated with caution. Findings can change when countries start embarking on more ambitious policy responses to technological change.

In the final section, I discuss to what extent the existing findings can help inform which policies can be adopted to help workers adapt to rapid technological change, how the problem pressure of technological change is different across countries, and how already existing institutions can help in coping with the pressures brought about from technological change.

2 Three Types of Policy Responses to Technological Change

How government should respond to technological change in the workplace is widely debated by policy experts, academics, and journalists alike. There is a wide range of potential policy responses, from unemployment benefits, education and retraining, and a universal basic income to industrial policy, taxation, and regulatory policies. In order to systematize this wide array of policy responses, I build on the welfare state and political economy literature (Beramendi et al. 2015; Rodrik and Stantcheva 2021b) and propose to classify policy responses into three distinct types according to their intended goal (see Table 1): *compensation policies* aim to financially provide for workers displaced by technology; *investment policies* aim to prepare or retrain new or displaced workers with the relevant skills needed in today's labor market; *steering policies* aim to affect the pace and direction of technological change.

Table 1: Types of Policy Responses to Technological Change in the Workplace

	Investment Policies	**Steering Policies**	**Compensation Policies**
Goal	Prepare and upskill workers ex-ante to cope with structural changes at the workplace and to match the demands of new technologies	Steer the pace and direction of technological change by shaping firms' employment, investment, and innovation decisions	Buffer the negative effects of technological change ex-post to cope with frictional unemployment
Idea	Social investment and predistribution	Economic interventionism	Social insurance and redistribution
Target	Individuals	Firms	Individuals
Policies	Education Training Active labor market policy Early childhood education and care	Capital tax deductions Robot and digital tax Research & development Employment protection Work time (reduction) Minimum wage Collective bargaining Work councils	Passive labor market policy Early retirement Wage insurance Job guarantee Negative income tax Universal basic income

2.1 Compensation Policies

To mitigate the adverse consequences of technological change and deal with frictional unemployment, governments can ex-post respond with compensation policies. *Passive labor market policies* (unemployment benefits) and early retirement schemes for workers displaced by technology are typical examples of such impact-cushioning policies to partially offset negative effects. Even though most countries have established generous unemployment benefit schemes, the extent to which workers are eligible to such programs varies greatly by welfare regime type (Esping-Andersen 1990). While Scandinavian countries grant almost universal access to basic social protection, eligibility in Anglo-Saxon, Continental, and Southern European welfare states heavily depends on your employment contract and employment biography (Emmenegger et al. 2012). As a result, access to basic social protection is not universal but largely fragmented along occupational lines in most countries. Because of this, many workers with precarious and unstable employment biographies fall through the cracks of the existing social security systems. This is further exacerbated by the rise of the platform and gig economy, where employment contracts are either inexistent (bogus self-employment) or highly precarious and fluid (De Stefano 2015). Thus, one policy option going forward is to universalize access to basic social protection by severing the link between the employment contract and access to social protection (Palier 2019).

Early retirement schemes aim to ease the transition from work into retirement. During the economic crises of the 1970s and 1980s, many European countries used early retirement schemes as a labor-shedding strategy. In light of population aging and limited fiscal resources, most countries have significantly scaled back early retirement options over the last three decades (Bürgisser 2019). Even during the Great Recession, early retirement schemes made up a very small portion of the labor market policy toolkit used (Clasen et al. 2012). Early retirement schemes are costly and thus only sensible in circumstances where a successful reintegration into the workforce is highly improbable. Moreover, generous early retirement schemes can discourage older workers from taking part in labor market training, which would help workers to stay in the labor market (Fouarge and Schils 2009).

More recently, the idea of *wage insurance* has received increasing attention. It would provide insurance to displaced workers who are forced to downgrade in the employment hierarchy by taking on a low-skilled job that pays less than their prior one. As part of the broader Trade Adjustment Assistance in the United States, there is a wage insurance scheme in place for workers aged 50 and over in particular industries that are severely impacted by import competition (Frey 2019). In his 2016 State of the Union Address, President Barack Obama made a case for a broader wage insurance: "Say a hard-working American loses his job — we shouldn't just make sure that he can get unemployment insurance; we should make sure that program encourages him to retrain for a business that's ready to hire him. If that new job doesn't pay as much, there should be a system of wage insurance in place so that he can still pay his bills." Thus, wage insurance could be an effective compensation policy protecting workers against the fundamental risk of earning loss following an involuntary displacement and reemployment process. Even though wage insurance schemes could expedite reemployment processes and decrease workers' anxiety about technological change, they are not a panacea. Most importantly, they come with the usual limitations of insurance mechanisms and eligibility rules, which make it unlikely that workers in precarious employment and with unstable employment biographies are covered by such a scheme.

The idea of a *job guarantee*, in which the government acts as an employer of last resort and guarantees employment to everyone who is ready, willing, and able to work for a living wage (Tscherneva 2018), is another potential policy response. The idea addresses the systemic nature of unemployment in capitalist market economies and tackles societal needs that are not satisfied by market forces. This is by no means a novel policy response. During Roosevelt's New Deal in the 1930s, the U.S. government directed and funded large-scale job projects across the country, involving up to 4.5 million workers at the peak (Tymoigne 2014). Due to the state's ability to generate a highly elastic demand for labor, a job guarantee can not only support full employment but also create a buffer stock for the private labor market and prevent the loss of human capital during extended periods of unemployment (Tscherneva 2018). Aside from the simple fact that (post-)Keynesian economics and expansive fiscal policy is not the current "instruction sheet" of the political and economic elite (Blyth 2013), there are also concerns regarding the practical design and implementation of a job guarantee to safeguard that it does not outcompete already existing public and private sector jobs.

Others argue that a *negative income tax* would be a better and more targeted compensation policy available to low-income workers (for example, see Frey 2019, p. 358). In order to receive a negative income tax subsidy, the only thing you need to do is to file your tax returns. The tax authorities can then determine right away if your income is below the established threshold and, thus, if you qualify for financial help. The experience of the Earned Income Tax Credit (EITC) in the United States suggests that it has significantly improved the precarious financial situation of many Americans, increased labor force participation, and improve the educational attainment of their children (Nichols and Rothstein 2015). Although the negative income tax is unquestionably an effective policy for assisting those at the very bottom of the income distribution, it is less obvious how such a tax should be tailored toward those who are adversely affected by technological change. As is known from the literature on routine-biased technological change, it is often not those at the very bottom of the income distribution who are displaced by the introduction of new technologies.

Finally, the perhaps most prominently discussed policy response to technological change would be the introduction of a *universal basic income* (UBI) and may be thought of as an extreme version of a non-targeted form of compensation. It is frequently proposed as a powerful policy response to a situation of widespread technological unemployment, which has not yet materialized. Nevertheless, a universal basic income could also help displaced workers who move to low-pay jobs or who fall through the cracks of the existing unemployment benefit system. According to existing studies, the introduction of a universal basic income would require substantial financial resources and could potentially undermine other social protection systems (Martinelli 2019). In the absence of widespread joblessness, a universal basic income likely overshoots the target. The goal would be more effectively served by more focused policy responses, such as partial job guarantees, sectoral or firm-specific wage insurance, or universalizing access to social protection.

Even though the paper focuses on vertical economic inequality, technological change can also generate horizontal inequalities because the benefits and costs of technological change are often unequally distributed in geographic terms. Beneficiaries of new technologies typically cluster in urban, high-density places, while more rural and sparsely populated areas tend to face declining economic opportunities (Moretti 2012; Autor et al. 2013; Rodríguez-Pose 2018; Iversen and Soskice 2019, Broz et al. 2021). Place-sensitive, compensatory policies to reduce horizontal inequality would include financial transfers to disadvantaged regions (e.g., fiscal equalization schemes within a country or structural funds within the European Union) and regionally specific compensation policies.

2.2 Investment Policies

From a policy perspective, displacement due to technological change is not problematic per se, but for the skill mismatches it can create. The skills of workers displaced by technology become obsolete, while the skills on demand can be costly to acquire (Restrepo 2015). Against this backdrop, governments can step in and aim to prepare individuals ex-ante to cope with structural changes at the workplace or address skills gaps by investing in retraining and lifelong learning to match the demands of new technologies. Over the last decades, welfare states have moved beyond simply providing compensation towards more capacitating, investment-oriented policies (Esping-Andersen 1999; Morel et al. 2011; Hemerijck 2012). By doing so, welfare states have incorporated a new set of functions and policy tools that aim to alleviate new social risks stemming from structural changes. Job market difficulties that arise from possessing low or obsolete skills can be countered by active labor market policies and specific educational policies that focus on lifelong learning.

Active labor market policies (ALMPs) are clearly on the rise in Europe. They consist of a variety of activation measures, from upskilling programs, employment assistance, job creation schemes to more workfare-oriented incentive reinforcements (Bonoli 2013). Upskilling, lifelong learning, and retraining measures with a heavy emphasis on human capital investment should be able to boost the skills and employability of redundant workers. In an ideal scenario, the effective execution of training measures also lowers the costs of social security and unemployment insurance schemes and limits wage inequality at the lower end of the income distribution. Scandinavian countries, who have a long track record of active labor market policies, are far better equipped compared to other advanced capitalist democracies (Morel et al. 2011). In contrast, while Continental European countries have begun to develop more extensive active labor market policies, Anglo-Saxon and Southern European countries still lag behind (Bürgisser 2022). Most concerning, however, is the fact that enabling policies with a strong emphasis on upskilling only make up a small portion of spending on active labor market policies in most countries. As a result, there is ample potential to refocus activity toward increased upskilling in order to meet the training requirements of the current and future workforce.

Education has historically been a major factor in how workers have adjusted to technological change (Goldin and Katz 2010; Frey 2019). Thus, increased spending on universal (tertiary) education can aid in preparing future labor market participants for cognitive non-routine jobs that are more difficult to automate. However, Baldwin (2019) and Susskind (2020), rightly caution against making general appeals for "more education". They contend that too little attention is paid to teaching uniquely human faculties and that individuals are frequently taught skills that machines have already mastered (or at least very soon will). Therefore, it is not just the quantity of education that matters, but also that the skills taught will remain out of reach to machines for longer. In this context, we need not only to embrace a new mindset, one that views lifelong learning and transitioning in and out of education as the new norm, but also gear training and education more towards digital skills and non-cognitive skills (e.g., communication, planning, and teamworking), which will be in greater demand (Gonzalez Vazquez et al. 2019).

Finally, even though *early childhood education and care* should not be seen as a direct policy response for displaced workers, it is nevertheless part and parcel of a bigger social investment strategy. In addition to greatly reducing intergenerational educational inequalities caused by social background

(Heckmann 2006), early childhood education and care also assist parents to reconcile work and family obligations and to have more time for potential retraining and lifelong learning opportunities.

2.3 Steering Policies

While designing effective policies to help workers adapt to technological change through investments in education and retraining and to cushion the most harmful consequences of displacement through compensation is undoubtedly important, governments can also aim to steer the pace and direction of technological change. Research from both environmental and labor economics indicates that technological change is not an uncontrollable, exogenous force but is strongly related to public policy and economic incentive structures (Mazzucato 2011; Aiginger and Rodrik 2020; Rodrik and Sabel 2019; Hémous and Olsen 2021; Rodrik and Stantcheva 2021a). One example of an environmental steering policy is the use of carbon taxes to penalize environmentally unfriendly innovation and behavior by increasing costs. Theoretically, steering policies may aim to either (i) accelerate or (ii) slow down the pace of technological change, or (iii) redirect the trajectory of technological change. Thus, governments have all the necessary means to play a crucial, correcting role in designing appropriate and effective policies to steer technological change in a direction that has more desirable distributive properties and reduces economic hardship.

Nascent research in labor economics argues that the market's ability to allocate resources in the most efficient way to develop technologies with high productivity gains is somewhat constrained. Instead, the current incentive structure for innovation is often tilted towards unnecessarily excessive labor-substituting technologies, leading to the development of so-called "so-so technologies" (Acemoglu and Restrepo 2019) and "the wrong kind of AI" (Acemoglu and Restrepo 2020b) that generate minor productivity improvements. These findings call for a broader reevaluation of the current incentive structure for technology development as well as a more active state steering towards more labor-augmenting technologies.

Taxation is one policy response to steer firms towards more labor-augmenting technology. Different tax rates on labor and capital alter the relative pricing and can reduce distortions. According to Acemoglu and Restrepo (2020b), a high tax rate on labor (payroll taxes) and an increasingly low tax rate on firm capital results in inefficient allocation and becomes particularly problematic if automation technologies are only marginally more productive than labor. As a result, excessive levels of automation are often the result of low capital tax rates and additional capital tax deductions. Against this backdrop, calls for the introduction of a specific robot tax have gained traction. While a robot tax may sound reasonable in theory, it is hard to define in practice what qualifies as a robot and how automation brought about by artificial intelligence would be managed in this context. Moreover, robots do not only substitute workers but also complement them, leading often to an overall positive net effect on employment and productivity. Taxing robots could therefore hinder technological innovation and reduce economic progress (Susskind 2020).

Steering policies can also focus on where technological innovation is created by improving and directing government funds into specific fields of *research and development*. According to Mazzucato (2011), the government must take on a proactive role if innovation-led growth should be a priority. By studying earlier technological innovations, she argues that the state has frequently played a key role in achieving ground-breaking discoveries that later enabled companies to develop. But lately, the U.S. government has adopted a more "laissez faire" approach and has not committed significant resources to innovation. Currently, a few big corporations have invested disproportionally large resources in research on artificial intelligence, which has led some to assert that innovation may lead to suboptimal technology choices (Korinek 2019; Acemoglu 2021). Thus, governments need to invest more in specialized research and development initiatives if they are to effectively influence and steer the development of new technologies.

Finally, firms operate within the broader constraints of the *labor market institutions* they are embedded in. These labor market institutions have a significant impact on how firms choose to innovate, invest, and hire. *Employment protection legislation* affects the hiring and firing costs of firms. *Minimum wage* hikes can affect the incentive structure of firms to pursue automation. Broader corporatist structures, such as *collective bargaining* and *work councils*, impact the broader relationship between workers, unions, and employers and can affect trust and coordination in the implementation of new technologies (Seidl 2022). I will go into more depth on the function of labor market institutions in the following section because there is relevant empirical evidence.

3 Existing Evidence of Policy Responses to Technological Change

This section discusses the existing empirical evidence on a variety of policy interventions that are directly or indirectly intended to tackle the impacts of technological change in the workplace. The goal of this section is to sketch out some preliminary conclusions on how these policy interventions affect the fate of those most a risk of automation. As I have already mentioned, I will concentrate on the more recent waves of technological change during the past roughly 50 years. The empirical research on some policy responses is very limited. Thus, some conclusions based on scant empirical evidence should be taken with a grain of salt.

3.1 Studies on Compensation Policies

There are a lot of impact evaluations and case studies of specific compensation policies without a direct reference to technological change, which help understand the relevance of compensation policies in reducing labor market risks. Overall, these studies show that public provision of social protection does significantly reduce job insecurity. As a result, the amount of income replacement provided by unemployment insurance and the length of unemployment benefits has an impact on perceived job insecurity (Anderson and Pontusson 2007; Dengler and Gundert 2021) and well-being (Voßemer et al. 2018).

On the other hand, empirical case studies that explicitly study technology-induced labor market risks and compensation policies are extremely rare. To my knowledge, there is only one study that explicitly draws this connection. Using an event study difference-in-differences design, Bessen et al. (2019) investigate the impact of automation on individual workers in the Netherlands and find that incumbent workers experience income losses due to automation in their firm. More importantly, they also study to what extent various welfare benefit systems can soften income losses and estimate that only about 15 percent of the negative wage income impact is absorbed by benefits (mainly due to unemployment benefits). Moreover, four years after the automation event, automation-affected workers have a 24 percent higher incidence of early retirement than non-automation-affected workers. Thus, even in the Netherlands, where unemployment benefit eligibility is very high among affected workers and where they are entitled to 38 weeks of unemployment benefits following job loss, automation-affected workers largely bear the cost themselves.

Even though multiple places are currently experimenting with various versions of a basic income, quantitative evidence on its effects is limited and, given the diversity of basic income schemes tested, impossible to generalize. For example, evidence from the Finish randomized control trial of a modest basic income (€560 per month) indicates that it had a slightly positive effect on employment and resulted in a large boost in life satisfaction (Allas et al. 2020). Apart from the constrained external validity, the interpretation of the Finish basic income is difficult as the unemployment benefit system was simultaneously reformed, making it difficult to tease out the net effect of the basic income.

3.2 Studies on Investment Policies

3.2.1 Training, ALMP, and Lifelong Learning

There is a growing strand of empirical literature investigating the link between automation risk, training (active labor market policies, lifelong learning, and on-the-job training), and employment outcomes. Taken together, the current evidence on automation risk and training points to three conclusions.

First, most of the research focuses on the impact of automation risk on access to formal or informal adult education and training across industrialized democracies. They find that workers at risk of automation are less likely to receive job training. This suggests a “Matthew effect” of adult education within the context of routine work and an “adult education penalty” of automation risk. Even though routine workers would be most in need of training, it is precisely the risk of automation that reduces their likelihood of receiving it (Nedelkoska and Quintini 2018; Ehlert 2020; Ioannidou and Parma 2021; Koster and Brunori 2021). Given that employers pay for most of the job-related adult education in OECD countries (Ehlert 2020), the prevailing interpretation is that companies refrain from investing in workers that may soon become obsolete. Moreover, routine workers might also not recognize their danger and thus underinvest in training.

More recent work explored cross-national differences in the impact of automation risk on access to training and the role of national institutions. Overall, the evidence is quite mixed. Neither the type of welfare regime (Ioannidou and Parma 2021) nor more proximate and specific labor market policies (Koster and Brunori 2021) appear to increase the access of routine workers to training, even though they both increase the overall attendance rate. More distant institutions such as the vocational education system or the stratified nature of school systems seem to close the gap in training attendance between routine and non-routine workers (Ehlert 2020).[2]

Second, routine workers who have already been laid off may benefit from state-sponsored active labor market policies. Schmidpeter and Winter-Ebner (2021) study an Austrian active labor market policy program that provides extensive training to unemployed workers. Using fine-grained register data from the public employment service, they find that a higher routine task intensity diminishes the likelihood of finding a job and that the effect of routine task intensity has increased over time. All unemployed workers, however, benefit significantly from education and training programs and has a favorable effect on employment. Notably, high routine task intensity amplifies this beneficial effect, i.e., individuals with higher routine task intensity profit substantially more from education and training programs. However, this positive interaction effect is significantly stronger among younger and better educated routine workers, pointing to a potential Matthew effect of education and training. Thus, older and less educated workers are more likely to experience the negative effects of routineness. Unlike in other programs, the Austrian active labor market policy program stands out because automation risk increases the likelihood of unemployed workers being assigned to and receiving training.

As a result, education and training seem to be powerful tools to cope with the labor market consequences of technological change among routine workers in Austria. However, active labor market policies can also result in a trade-off between job quality and job quantity because they may promote reemployment (job quantity) while failing to improve wages (job quality) of the unemployed. In a similar vein, evidence from Denmark suggests that generous retraining subsidies may reduce the adverse effects of automation on the income and employment of routine workers by enabling workers to transition out of routine work (Humlum 2020). Once more, this is a generous program of training subsidies that greatly boost training participation and job-finding probabilities among all unemployed workers. Finally, Haepp (2021) shows that training and upskilling programs in Germany could cushion the negative impact of automation exposure on job satisfaction and job-related identity loss.

Third, it is important to keep in mind that a significant portion of education and training takes place within firms, particularly in Continental Europe and Scandinavia. There is mounting evidence suggesting that sectoral active labor market policies and training programs with close links to

2 These papers investigate the whole population of routine workers. It is likely that strong labor rights and unions have an impact on adult training in classic manufacturing industries.

employers and unions (Schaberg 2017; Roder and Elliott 2019; Katz et al. 2020; Rodrik and Stantcheva 2021a) and in-firm training and upskilling (Cirillo et al. 2020; Ehlert 2020; Haipeter 2020) are more effective than more generic state-sponsored active labor market policies. One explanation is that training programs can be better tailored to the needs and demands of the local labor market by developing and designing training programs in close cooperation with employers and unions.

3.2.2 Education

Despite the fact that debates on technological change frequently center on a "race between education and technology" (Goldin and Katz 2010), regarding education and technology as exogenous, there are many reasons to think that they are both endogenous. Evidently, technological change promotes more education, while more education, in turn, encourages technological innovation (Prettner and Strulik 2020). While empirically disentangling the two is complex, there is increasing evidence that better educational systems – defined as having a greater share of secondary and tertiary graduates – are associated with less adverse consequences of technological change on labor force participation.

Based on macro- and micro-level data from 24 European economies since 1985, Grigoli et al. (2020) find that higher spending on active labor market programs and education reduces the likelihood of a negative impact of technological change on labor market participation, making the workforce more resilient to such developments. Similarly, Kattan et al. (2021) estimate structural equation models with data from 65 middle and high-income countries. Building on the widely criticized estimates of worst-case automation by Frey and Osborne (2017), they find that higher educational attainments, cognitive skills and general (vs. vocational) education are associated with employment in occupations that are less prone to automation, irrespective of country-specific level of economic development. In general, better education is predicted to significantly reduce the marginal effect of automation on wage inequality.

Overall, however, there is little research on how educational systems have adapted their curricula over the course of the most recent wave of technological changes and to what extent some countries have already effectively geared their education towards more digital skills and non-cognitive social skills.

3.3 Studies on Steering Policies

3.3.1 Taxation

Despite being widely discussed in recent years, very few empirical studies explicitly explore the impact of tax steering policies on the direction and pace of technological change in the context of automation and artificial intelligence. The impact of Italy’s tax depreciation allowances for digital technologies on technological investments and employment at the firm level is examined by Bratta et al. (2020). As part of its Industry 4.0 plan, Italy introduced a hyper-depreciation on smart tangible goods deemed necessary for the digital transformation of firms. The study makes use of a unique data set covering all Italian companies and relies on a difference-in-differences design with propensity score matching to identify the effect of digital investments on firm-level employment between 2017 and 2019. The findings show that depreciation allowances led to strong growth in investments in digital technologies and generated positive employment effects among investing firms. Even though the study is looking at a relatively short intervention period and has to be seen in the country-specific context of Italy, the findings are in line with the argument that labor displacement usually takes place at non-adopting firms (Koch et al. 2021; Fernández-Macías et al. 2021; Klenert et al. 2022). In a similar vein, Garrett et al. (2020) studied the impact of depreciation allowances for capital investment on local labor markets in the United States from 2002 to 2012. The results indicate that regions with a greater reduction in investment costs saw weak and temporary employment growth but robust and strong growth in capital investments. Thus, indicating that depreciation allowances have accelerated the replacement of labor with capital.

3.3.2 Labor Market Institutions

There is growing evidence supporting the importance of labor market institutions – such as minimum wages, collective bargaining, work councils, and employment protection legislation – in determining the pace and direction of technology adoption. Most of the research indicates that the pace of automation accelerates in the context of strong, labor-friendly labor market institutions. However, there are two distinct perspectives as to why this is the case.

The first perspective highlights the relative cost of labor versus capital. The literature on labor costs induced innovations assumes that technology adoption is a function of the relative prices of capital versus labor, with higher wages encouraging firms to automate and lower wages discouraging it (Acemoglu 2010; Alesina et al. 2018). Presidente (2019) argues that higher labor costs caused by labor-friendly institutions incentives firms to implement labor-substituting technologies and discourages investments in labor-complementing technologies. In a study on industrial robots' adoption in 35 OECD countries between 1993 and 2013, Presidente (2019) shows that labor-friendly institutions are strongly correlated with robots' adoption and can account for a big share of the cross-sectional variation in robot adoption. Likewise, Lordan and Neumark (2018) and Lordan (2019) argue that increasing minimum wages tilts incentives towards automation as labor becomes more expensive in relation to technology. Their research indicates that minimum wage hikes in the United Kingdom and the United States decreased employment among workers with a high compared to low routine task intensity.

This finding is further corroborated by Aaronson and Phelan (2020), who study the impact of minimum wage expansion on employment in low-wage occupations across U.S. states from 2010 to 2018. They find that minimum wage expansion had a significantly negative effect on routine low-wage employment across U.S. states but no effect on non-routine manual and cognitive employment. However, other findings show that minimum wage increases across the United States from 1980 to 2005 have slowed down the pace of automation if technology could not fully replace labor and still requires machine operators (Downey 2021).[3] In a more nuanced study, Alesina et al. (2018) argue that labor market regulation affects the wage premium between high- and low-skilled workers and influences incentives to adopt technologies. More stringent employment protection legislation leads to more low-skill biased technology adoption, while less stringent employment protection legislation leads to more high-skill biased technology adoption. As a result, labor market deregulation increases the share of low-skilled labor and lowers the share of high-skilled labor due to differences in technology adoption. This finding is consistent with a study by Dechezleprêtre et al. (2020) on the effect of the Hartz reforms in Germany, where the lower effective cost of labor reduced automation innovation.

The second perspective focuses on how corporatism – through strong unions, work councils, and collective bargaining – fosters trust, coordination, and a collectively shared sense of ownership, which can accelerate the diffusion of advanced technologies in national economies. From a varieties of capitalism perspective, we would expect that liberal market economies excel at radical innovation in high-technology sectors, whereas coordinated market economies would be better in incremental

3 It is likely that future automation technologies – especially in combination with artificial intelligence – will decrease the demand for low-skilled machine operators and increase the need for more high-skilled IT personnel. Thus, the effect of minimum wage hikes on technological adoption and routine employment might be weaker, which could explain the contradictory results reported by Aaronson and Phelan (2020), Lordan and Neumark (2018), and Lordan (2019).

innovation of quality-oriented production (Hall and Soskice 2001). Thus, liberal market economies should be "ahead in path-breaking technological innovation" (Dølvik and Steen 2018: p. 41).[4]

However, Lloyd and Payne (2019) report the exact opposite in a case study of robotics and artificial intelligence adoption in Norway and the United Kingdom. Despite United Kingdom's substantial strength in technological innovation, Norway has much more advanced workplace automation. Even though the United Kingdom invests heavily in research and development, its initiatives for robot adoption have largely failed because of the absence of a long-term funding policy. The government-funded initiatives in Norway, on the other hand, are numerous, long-term oriented, and successfully promote automation at the level of SMEs and the public sector. More importantly, Norway's institutionalized social partnership model and collaborative style of policymaking provide the necessary stability to undertake consistent and long-term investments in technology diffusion. Such institutions can create a shared sense of ownership around the idea that artificial intelligence and robotics are essential to the sustainability and competitiveness of Norway's high-wage, high-welfare model (see also, Ilsøe 2017; Dølvik and Steen 2018; Neufeind et al. 2018). In these circumstances, unions and worker representatives are not opposed to automation because they can negotiate the broader terms of technological implementation as part of the already existing social pact. This is further corroborated by a study of 32 OECD countries from 1995 to 2017, which finds that corporatism has a significant positive impact on investment in digitalization, public education, and active labor market policy (Seidl 2022).

Moreover, it appears that the fate of routine workers is significantly improved by strong unions. Quantitative evidence at the local labor market level and the worker level in Germany (Dauth et al. 2021) and Italy (Dottori 2021) – notably the two European countries with the highest levels of robot stocks – demonstrates that displacement effects of robots are lower in regions with higher union density. However, it remains unclear if this is due to higher dismissal costs or more pressure for on-the-job retraining. Micro-level evidence from the United States also suggests that union membership increases job tenure and decreases routine workers' likelihood of becoming unemployed (Parolin 2020). Yet, organized labor also leads to two opposing trends for workers at risk of automation. While higher union density significantly inhibits the decline of wages among routine workers, union density also accelerates the decline in the overall employment share of routine work (Parolin 2021). Qualitative case studies provide further evidence that organized labor and strong social partnership (corporatism) play an important role in the in-house upskilling of routine workers and give labor a say in when and how technology is being adopted.[5]

4 Conclusion

The following conclusions can be drawn from reviewing the available empirical evidence. First, income losses brought on by technological displacement cannot be fully compensated by existing compensation schemes, even if displaced workers have access to social protection. Moreover, workers in many countries either receive just partial access to these benefits or fall fully through the cracks of the existing safety nets. In light of this, universalizing access to social rights, benefits, and protection independent of the employment contract is of utmost importance (Palier 2019), particularly considering the rise of precarious employment relationships (Emmenegger et al. 2012;

[4] It is important to note that the original measure for radical versus incremental innovation by Hall and Soskice (2001) has been widely criticized for misrepresenting innovation patterns in liberal and coordinated market economies (Taylor 2004).

[5] On the role of unions in technology adoption, there are excellent case studies on the implementation of "Industrie 4.0" in German manufacturing plants (Haipeter 2020), car factories in Italy (Cirillo et al. 2020), food-processing industries in the UK and Norway (Lloyd and Payne 2021b), and the public health sector in Scotland and Norway (Lloyd and Payne 2021a).

Bürgisser and Kurer 2021), which are further accelerated by the gig economy (De Stefano 2015; Berg 2015; Behrendt et al. 2019; Thelen 2018; Rahman and Thelen 2019). While this issue is less pressing in Scandinavian countries with more universal access to social protection, it is especially problematic in Continental and Southern European but also in Algo-Saxon countries, where many workers fail to receive benefits under the current social security system.

Second, boosting educational opportunities in the formative years of life could be a potent and cost-effective tool against the future risk of technological change. However, simply focusing on educational expansion is not an option to improve the chances of the current working-age population. Even though adult education and active labor market policies can be costly and evidence of its effectiveness is more mixed (Kattan et al. 2021; Caliendo and Schmidl 2016), well-designed and targeted retraining and active labor market policies can help to equip displaced workers with the necessary skills. The existing evidence on ALMP and training programs suggests that (i) routine workers seem to have a lower likelihood of benefiting from training opportunities, (ii) active labor market policies can help unemployed routine workers, and (iii) in-firm training or programs developed in collaboration with local employers and unions are likely more effective. However, many countries currently lack widespread lifelong learning programs, training, and active labor market policies, which aim to significantly upskill their workforce.

Third, the review of steering policies highlights the ability of political actors to shape the pace and direction of technological change. The incentives to innovate and adopt technologies are not only shaped by national innovation systems (Edquist et al. 1997; Hall and Soskice 2001), industry and occupational structures and wage structures (Arntz et al. 2016; Frey and Osborne 2017) but also by tax incentives, broader labor market institutions, and corporatism. Particularly, small and open corporatist states (Katzenstein 1985) seem well prepared to quickly adapt to disruptive technological change due to an institutionally facilitated shared sense of challenges and high levels of trust. Arguably, some of the discussed policies in this context reflect historically grown political-economic institutions, particularly those relating to corporatist structures, and cannot easily be implemented by governments. Nevertheless, they can help understand how distributive effects of technology adoption are moderated differently across countries.

There are also some caveats when interpreting these scattered pieces of empirical evidence. First, we know little about several policies covered in the theoretical conceptualization. This is either due to the fact that they have not yet been implemented (wage insurance, negative income tax, universal basic income, robot tax, digital tax) or because no empirical research has been done on their impact in the context of technological change (lifelong learning, ECEC, research and development).

Second, empirical research evaluates past patterns of technological change and cannot easily be generalized to the future. For example, a lot of research focuses on the role of industrial robots. Such robots have not only been around for a while, but they also cluster strongly in (car) manufacturing industries in some countries (most notably in Germany and Italy). Thus, industrial robots should not be confused with more sophisticated technologies, such as robots enhanced by artificial intelligence or ICT investments, which are likely to have distinct and more disruptive distributive properties along the skill and routine task gradient.

Finally, there are no universally applicable policy responses to address technological change. Some of the discussed policy responses are not as urgent in some countries as they are in others. The urgency of a particular policy response in a country is the result of at least three pertinent factors: (i) current and projected future *problem pressure* stemming from the adoption of new technologies at the workplace, (ii) existing *institutional legacies* to cope with such pressures, and (iii) potential *trade-offs between introducing new policies and the existing institutional framework* that may adversely impact historically evolved institutional complementarities.

Unfortunately, it is beyond the scope of this paper to provide an in-depth examination of the magnitude of problem pressure experienced by individual countries, their institutional capacity to deal with such pressure, and any potential policy trade-offs that may arise. This could be an exciting avenue for future research. In order to assess the country-specific level of problem pressure, one could study the extent of industrial robot adoption per manufacturing worker in Europe. This varies significantly and is highest in Germany, Sweden, Denmark, Belgium, and Italy (Atkinson 2018). Going beyond industrial robot adoption, the diffusion of information and communications technology (ICT) through the economy could be gauged by OECD and the European Union KLEMS data. They provide several interesting measures that indicate that ICT diffusion is particularly advanced in the Netherlands, Sweden, Denmark, and the United Kingdom. Even though extremely important to understand the future of technological change, the adoption of artificial intelligence has not yet occurred on a large scale and is still difficult to assess empirically in a comparative manner (for an excellent overview, see Özkiziltan and Hassel 2021).

While we know less about how the problem pressure stemming from new technologies varies across countries and sectors, we are more informed about the ability of the existing institutional legacies to moderate such pressure. As previously mentioned, Scandinavian countries with the combination of universal safety nets, well-established training and education programs, and a long tradition of corporatism are better prepared to cope with such problem pressure of technological change and the knowledge economy than Anglo-Saxon, Continental, and Southern European countries. Thus, universal access to social protection and generous education and training programs should be a particular high policy priority in these countries.

More generally, there is a tendency to study policy responses in isolation. Thus, we still know relatively little about potential policy trade-offs of introducing new policies that could conflict with the existing institutional framework and the interplay between country-specific problem pressures and institutional legacies. Moreover, while we have a reasonably good understanding that workers at high risk of automation do not have a stronger preference for education and training and tend to prefer rather compensation and redistribution (Thewissen and Rueda 2019; Busemeyer and Sahm 2021; Kurer and Hausermann 2022), there is little research on the political feasibility of the discussed policy responses and the political coalitions that might support them.

Finally, research needs to pay more attention to the broader implications of steering policies and their distributive properties. In addition to increasing compensation and investment policies in response to rising labor market risks, multiple governments policies already steer the pace and direction of technological change. The return of state activism since the Great Recession and the re-appearance of industrial policies (Bulfone 2022) indicates that steering policies are likely to gain in importance in the coming years and deserve more scholarly attention.

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