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Skills at work in Liberal and Coordinated Market Economies.
A tasks-level assessment of job discretion and satisfaction

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Abstract

This study investigates (1) the relationship between computer use at work and both job tasks and task discretion as well as (2) the mediating role that job tasks and task discretion play in the relationship between computer use and job satisfaction. By comparing these relationships in Germany and the UK, we contribute to the long-standing debate on the upskilling/deskilling nature of the use of technology and the repercussions of this use on the overall quality of work. We use data from the UK Skills Surveys and the BIBB/BAuA Employment Surveys and apply structural equation modelling (SEM). In line with the literature on routine-biased technological change (RBTC), our results suggest that computers are complementary to the performance of less routine and more abstract cognitive tasks and that this relationship is conducive to a higher level of task discretion and job satisfaction in both countries. Moreover, after accounting for differences in job tasks performed, we find a negative direct effect of computer use on both task discretion and job satisfaction in the UK but not in Germany. Our results indicate that the ultimate effect of the use of technology on both jobs and job satisfaction depends on the institutional contexts in which this technology is introduced. These contextual differences are related to the institutional arrangements and managerial practices typical of different production and skill regimes.

1. Introduction

Since their early appearance in the workplace, computers have spurred a vivid debate on their consequences for work organisational, and social processes. At the core of this debate lies the question of whether adopting technology leads to an upgrading of skills or a downgrading of work (Attewell 1987; Bailey and Leonardi 2015; Bloomfield and Coombs 1992; Gallie 1991). With the digital transformation of work, this question has recently regained importance, partly because the skill requirements of jobs are strongly associated with job quality and ultimately with workers' job satisfaction (Gallie 2007) as well as with labour market inequalities (e.g., in terms of earnings) (Kristal and Edler 2019).

Despite its relevance, answers to the question of the upskilling or deskilling nature of technology – and the related consequences of this technology for job quality – remain controversial. Scholars from a largely Marxist tradition argue that technology is an instrument used to increasingly standardise labour processes by reorganising work into a series of low-skilled tasks and that technology has therefore resulted in lower-skilled jobs with little intellectual content and autonomy (Braverman 1974; Jenkins and Sherman,1979). Various qualitative case studies support this perspective empirically (e.g. Haakestad and Friberg 2017). In contrast, scholars who support the upskilling thesis suggest that a technology-driven decentralisation of information (Acemoglu et al. 2007) and the complementarity of technology to non-routine cognitive tasks have increased the demand for skills and led to large human-capital endowments (Autor et al., 2003; Goldin and Katz, 1998). This upskilling perspective is supported by a series of quantitative studies that document a steady growth in abstract tasks and skilled occupations, with corresponding benefits for wages (e.g., Breemersch et al. 2017; Fonseca et al. 2018; Keister and Lewandowski 2017).

These conflicting perspectives and findings might result from conceptual differences in the definition of skills: While upskilling proponents typically focus on the type and range of tasks performed, deskilling proponents refer to the degree of autonomy and to workers' control over the work process. Several authors therefore suggest considering both *distinct yet related* dimensions of occupational skills to derive a better understanding of the relationship (a) between technology and both upskilling and deskilling and (b) between technology and the quality of work (De Witte and Steijn 2000; Martinaitis et al. 2020; Noon et al. 2013; Rolfe 1986, 1990; Spenner 1983, 1990; Vallas and Beck 1996; Felstead et al. 2007). This conceptional differentiation is also supported by the fact that trends in job tasks and task discretion do not necessarily evolve in the same direction (Gallie 2012). Moreover, whether technology and the quality of work are positively or negatively related might depend on the type of job tasks and on workers' task discretion (e.g. Hardin 1960; Parayitam et al. 2010; Shepard 1977).

Our study therefore addresses two research questions: First, we examine the link between computer use (i.e. the use of any computerised equipment at work) and both job tasks and task discretions and thereby reveal whether upskilling and deskilling are indeed mutually exclusive. Second, we investigate the mediating role of both job tasks and task discretion in the relationship between computer use and job satisfaction. We take computer use as an indicator of the use of technology because computers are the most widespread form of technology used among the labour force (Autor et al. 2003; Elsayed et al. 2017; Green 2012; Menon et al. 2019; Spitz-Oener 2006).

Moreover, we compare these relationships between production regimes in both Germany and the UK. This comparison challenges the deterministic notion of the upskilling and the deskilling thesis because both argue that technology impacts all institutional and organisational contexts (e.g. Bailey and Leonardi 2015). We maintain that while computers are generally complementary to a specific set of tasks and substitutive to the performance of others, their impact on organisational practices – and thus the extent to which they replace certain tasks and impact the degree of workers' task discretion – is contingent on the specific institutional arrangements in which they are used (Autor et al. 2002). Germany and the UK are characterised by clearly different institutional arrangements regarding their market coordination (Estevez-Abe et al. 2001; Hall and Soskice 2001), skill formation (Thelen 2004), and corporate governance (Waddington 2004). The mixture of industrial and managerial practices and cultures in these two countries might therefore influence how computers are adapted to production processes and thereby shape workers' task discretion and job tasks as well as their overall job satisfaction (Gallie 2007, 2011; Green and McIntosh 2001).

Contributing to the existing literature, our study theoretically and empirically highlights how job tasks and task discretion are related yet distinct aspects of occupational skills and investigates their role as mediators in the relationship between technological innovation and workers' job satisfaction (i.e. workers' assessments of the quality of work). Moreover, our study demonstrates the importance of national institutional contexts in moderating the impact of technology on work organisation and job satisfaction.

2. A brief synopsis of the upskilling/deskilling debate

Referring to our first research question, we begin with a brief summary of the debate. In the European debate, Friedmann (1946) is one of the most influential authors to point to how technology leads to a deteriorating quality of work by negating workers' *craftsman-like* skills/tasks and removing workers' capacity to control the productive process. As Gallie (2012) notes, Friedmann identifies technology as the main factor behind *Taylorising* work tasks and thereby behind eliminating the opportunity for workers to exercise discretion, autonomy, and control over their jobs. In the US debate, Leavitt and Whisler (1958) were among the first to claim that computer and information technology (ICT) leads to a centralisation of decision-making, authority, and power in the hands of a "tight little oligarchy" of high-ranking managers and employers. Similarly, Braverman (1974) argues that the automation of the labour process is a means of transferring control, discretion, and autonomy from the shop floor to management because this automation supports the application of scientific management and thus also this management's ability to ensure that labour power is successfully converted into labour.

The underlying idea of the deskilling thesis is that information is a source of power and that workers and middle management would therefore lose power if information gathered in computerised systems became accessible to top management. Supporting empirical evidence has been provided by a large body of organisational studies (e.g. Blauner 1964;; Gallie et al. 2003; Menon et al. 2019). The *equation between required skills and task discretion* is crucial to the deskilling perspective, with discretion understood as workers' ability to choose between alternative courses of action and to exercise control over the way, order, and turnaround times in which tasks are performed. Reducing skills thus entails closer supervisory control and a loss of workers' autonomy and discretion in the workplace (Blauner 1964; Fox 1974; Gallie et al. 2003; Jaques 1956, 1967; Spenner 1983, 1990).

In contrast, proponents of the upskilling thesis argue against any inherently centralising tendency of computer technology (Lindbeck and Snower 2000; Radner 1993; Wyner and Malone 1996). They stress that such a tendency could lead to substantial costs for management and that computers may instead promote the organisational decentralisation of power and control due to shared information or the number of management levels. Moreover, an upskilling scenario is echoed in the literature on *skill-biased technological change* (SBTC), which suggests that computer technology, education, and skills are strongly complementary and that technology thus favours returns for skilled workers and increases the demand for skills (Goldin and Katz 1998). This position is strengthened by a large number of empirical studies that document strong relationships between ICT use, high-skilled tasks, the demand for tertiary-educated workers, and rising college wage premiums (e.g. Bresnahan et al. 2002; Goldin and Katz 2008).

Due to the theoretical and observed evidence of polarising trends in both earnings and occupational structures (Acemoglu 1999), the SBTC thesis was developed into the thesis of *routine-biased technological change* (RBTC) (Acemoglu and Autor 2011; Autor et al. 2003; Goos et al. 2009), whose key argument is that computer technology modifies the job tasks required and performed in the workplace, which are classified along two distinct dimensions: *routine* vs *non-routine* and (analytical and interpersonal) *cognitive* vs *manual* tasks.

While SBTC relates the introduction of computers to changes in earnings structures mainly through the complementarity of computers to skill levels and through returns to more highly educated workers, it makes no direct claim regarding the relationship between technology and the content of work in terms of job tasks or task discretion. In contrast, RBTC connects technology and the evolution of earnings and occupational structures through its relationship to the types of tasks performed by workers in different occupations and thus also makes an argument for the relationship between computers and job tasks. According to RBTC, technology serves as a substitute for explicit and codifiable routine-task operations – at both the low and middle level of the occupational hierarchy – and as a complement to higher-level cognitive and manual tasks, resulting in a steady growth of skilled jobs. In line with the idea of the growing complexity of tasks, a large body of empirical studies has also revealed that computerised workplaces are associated with a more-educated workforce (e.g. Berman et al. 1998; Esposito and Stehrer 2008). However, the RBTC literature also signals a parallel increase in non-automatable manual tasks, thereby causing a U-shaped occupational polarisation of the occupational structure between high-skilled positions and low-skilled jobs (Autor et al. 2003; Goos et al. 2009; Acemoglu & Autor 2011).[1]

The deskilling and upskilling perspectives clearly refer to two different dimensions of occupational skills: The upskilling perspective points to the complexity and variability of job *tasks*, while the deskilling argument refers to task *discretion*. The argument that task discretion and the complexity of tasks are two fundamental yet distinct dimensions of skills follows from the work of Fox (1974), Friedmann (1961), and Spenner (1983, 1990). For example, Spenner (1990, p. 402, 403) differentiates between *substantive complexity* ("the level, scope and integration of mental, manipulative and interpersonal tasks in a job") and *autonomy control* ("discretion or leeway available in a job to control the content, manner, and speed with which tasks are done"). Similarly, Rolfe (1986, 1990) distinguishes between *technical complexity* and *discretion* based on the same idea that while tasks are carried out as organisational requirements,

[1] The economic literature usually identifies a rise in low-skilled jobs in Europe and the US and a growth in low-skilled janitorial services, which echoes the sociological thesis of the so-called *service proletariat* (Esping-Andersen, 1993). Bernardi and Garrido (2008) have shown evidence of a U-shaped trend of polarisation for Spain; however, Fagan et al. (2005) report notable skill differences in the occupational structure of manual services between Germany and the UK, with a higher level of manual-workforce qualification in the German service sector. It follows that "non-automatable, non-routine manual/physical tasks" may differ between the two countries. Unfortunately, our data do not allow for properly distinguishing between these differences.

the nature of such requirements does not dictate how tasks should be completed, but how they should be determined by the hierarchy of power within an organisation (see also Myles 1990; Martinaitis et al. 2020; Autor et al. 2002). The interplay between the type and complexity of job tasks and the degree of task discretion thus varies across organisations.

Following this line of reasoning, the clear distinction between these two dimensions might allow recent evidence on the evolution of skills and tasks to be reconciled without necessarily implying a unidimensional upskilling view of technological change. This view has received empirical support (e.g. Iacono and Kling 1991; Vallas 1993; Vallas and Beck 1996): For example, Zuboff (1988) identified a general upskilling of production work for more abstract job tasks but a minimal expansion of autonomy.

This brief synopsis of the upskilling/deskilling debate highlights the relevance of disentangling different dimensions of occupational skill requirements in order to understand the skill-biased nature of technological innovation and its ultimate impact on job satisfaction. However, while studies have shown that job tasks and task discretion may be affected differently by technology, how the interplay between these two dimensions determines the overall effect of technology on job satisfaction remains poorly understood. Moreover, researchers in this area – using mostly single-country cases – are quick to generalise their findings and might thereby underestimate the role of the institutional context of the implementation of technology. With our comparative study, we contribute to a more-comprehensive understanding of the relationship between the implementation of technology (i.e. the association between computer use in the workplace, job tasks, and task discretion) and job satisfaction.

3. Embeddedness in institutional contexts

Both the upskilling and deskilling perspectives are based on a deterministic understanding of technological change and therefore assume that technology similarly impacts job tasks and task discretion across countries (with similar levels of economic development). However, cross-country studies reveal that workers in similar occupations can be exposed to different job tasks (Green 2012; Green et al. 2003) and to very different styles of managerial supervision and control (Gallie 2007, 2011; Lincoln and Kalleberg 1990; Maurice et al. 1986).

Such country differences could result from the fact that capitalist economies follow different production strategies, which also results in favouring different types of employment relationships, skill-formation regimes, and skills equilibria (tasks and discretion) (Estevez-Abe et al. 2001; Gallie 2007, 2011; Hall and Soskice 2001) not to mention labour market configurations and efficiency (Barbieri 2009; Barbieri, Scherer 2009; Barbieri et al. 2016; Barbieri, Cutuli 2016; Barbieri, Cutuli 2018).

In this line of reasoning, both the *Varieties of Capitalism* (VoC) approach (Hall and Soskice 2001) and approaches related to *production regime* theory (Gallie 2007) are prominent. In this paper, we take the VoC approach, which distinguishes between two broad types of political economies based on the degree and institutional arrangement of market coordination. *Coordinated Market Economies* (CMEs) – which are exemplified by the ideal-typical German case – are characterised by a set of institutions (e.g. centralised and coordinated wage bargaining, the presence of work councils, and strong vocational education and training systems) that incentivise firms to adopt employment strategies that rely on highly skilled labour endowed with extensive work autonomy, responsibilities, and the encouragement to share information (Estevez-Abe et al. 2001; Herrigel and Sabel 1999). In contrast, firms in *Liberal Market Economies* (LMEs) – which are exemplified by Anglo-Saxon countries, such as the UK – rely heavily on competitive market relationships and hierarchies to organise relationships between workers and other actors. Top managers typically have strong, unilateral control over both the firm and production processes, including substantial freedom to hire and fire in order to adapt to fast-changing employment conditions and product markets. Due to highly fluid labour markets, firms adopt employment strategies based on a workforce that is mainly endowed with general skills and low(er) company attachment. The underlying idea is that these different national institutional contexts are associated with different managerial strategies and practices of organising work at the firm level because firms have a comparative advantage if they behave according to the respective institutional rationale (Hall and Soskice 2001; Holm et al. 2010; Lopes et al. 2014, 2017).

The implementation of new technologies and the consequences of these technologies for job tasks and task discretion are hence likely to differ in these two institutional arrangements. In CMEs, in which workers' occupation- and industry-specific skills more strongly contribute to the organisation of product lines and production processes, firms should (1) use technology more often to relieve their (comparatively well-paid and well-trained) workers from simple routine tasks and (2) increase the use of workers' analytical, problem-solving, and non-routine manual potential, which enhances labour productivity.[2] However, due to the prevalence of diversified quality production in Germany (Sorge and Streeck 2016) and the more-consensus-based approach to decision-making in CMEs (Edlund and Grönlund 2008), technology-implementation processes are influenced by strong trade unions and high levels of employment protection, especially in manual-intensive industries (see also Baccaro et al. 2018). Routine tasks might thus be more integrated than substituted when implementing computerised work tools. Here, routine tasks also more often include tasks that require manual dexterity and occupation-specific skills than in LMEs, which are more often associated with simple tasks. In LMEs, in which firms have less access to a highly trained workforce and face higher labour turnovers, technology can be used as an instrument to more effectively increase control over work processes, to increasingly standardise tasks, and to reduce skill requirements (Dobbin and Boychuk 1999).

Comparative case studies show very high variability in the degree of discretion that workers exert on their job – regardless of similar technological work settings – according to extremely diverse forms of managerial control and skill regimes (Gallie 2007; Lincoln and Kalleberg 1990). For example, Dobbin and Boychuk (1999) report strong differences in workers' task discretion between Scandinavian (social-democratic) countries and LMEs and conclude that production regimes and managerial systems may favour skill- versus rule-governed modes of production, with contrasting consequences for job autonomy. Hence, to gain a better understanding of how production and work are restructured in response to technological innovations, the institutional context in which firms operate must be considered.

We compare Germany and the UK as the two ideal-typical cases of CME and LME, respectively. Due to the different types of institutional embeddedness of managerial strategies in the two countries, it might be as misleading to assume a common trend towards deskilling in terms of a generalised loss of workers' autonomy and control as it would be to expect a common upskilling trend towards an increase in non-routine or cognitive tasks.

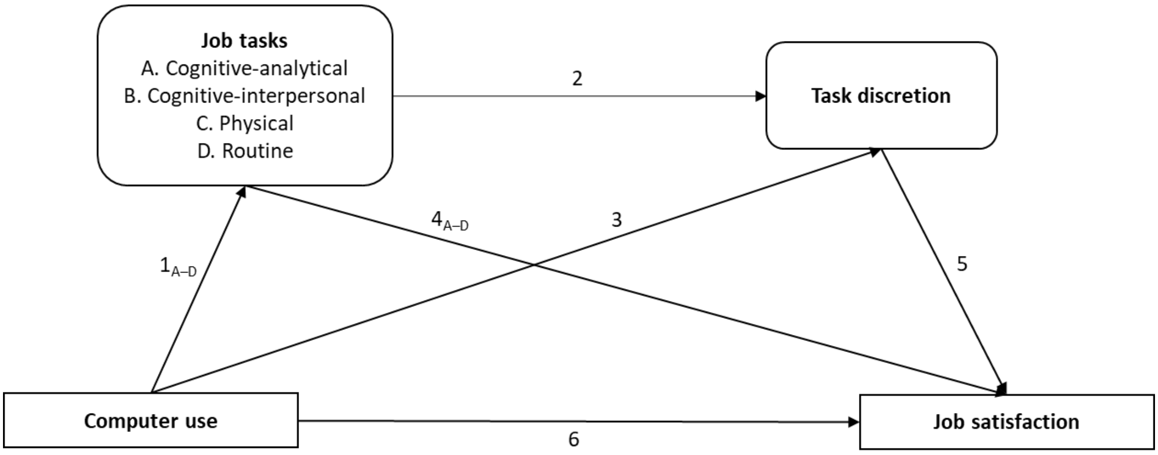
Before presenting our comparative expectations, we next discuss our theoretical model of the mediating role that job tasks and task discretion play in the relationship between computer use and job satisfaction.

[2] OECD data reveal that labour productivity (GDP per hour worked) is higher in Germany than in the UK (https://data.oecd.org/lprdty/gdp-per-hour-worked.htm#indicator-chart).

4. Theoretical model and expectations

Figure 1 presents our stylised theoretical model. The relationship between computer use and both job tasks and task discretion as two distinct yet related dimensions of skills (our first research question) is indicated by Paths 1 and 3, respectively. The mediating role of the two skills dimensions for the relationship between computer use and job satisfaction (our second research question) is indicated by the joint Paths 1–4 and 3–5, respectively. Path 6 indicates the remaining direct influence of computer use at work on job satisfaction, independent of (i.e. after controlling for) jobs tasks and task discretion. Here, research has revealed that the use of computerised equipment in the workplace can also have a direct *alienating* effect, for example, due to technostress or computer anxiety (e.g. Ayyagari et al. 2011; Brod 1984; Ragu-Nathan 2008).
We begin with the two mediations and derive expectations about country differences. We then present some considerations on variations across groups of workers while focusing on occupational class position and participation in job-related training.

Figure 1: Stylised theoretical model of the role of tasks and task discretion on the relationship between computer use and job satisfaction



Research has consistently shown that the diversity and complexity of job tasks (Path 4) as well as the possibility of controlling the pace, timing, and methods of work (Path 5) are associated with higher levels of job satisfaction. Concerning the proposed mediation via job tasks (Paths 1–4), RBTC research argues that computers complement (analytical and interpersonal) cognitive tasks yet substitute (manual and non-manual) routine tasks. Thus, we expect that the extent of computer use should result in variations in the extent to which non-routine (cognitive and manual) job tasks are reinforced and that routine tasks should be reduced (Path 1), which should thus influence workers' job satisfaction (Path 4) (see also Taber and Alliger, 1995).
Through their complementarity to more non-routine (especially cognitive-analytical) tasks, computer technologies may eventually be conducive to higher levels of task discretion (Paths 1–2) because non-routine (especially cognitive) tasks are more difficult for employers and management to monitor, which may thus also yield higher job satisfaction (Nassab, 2008). Gallie et al. (2003, pg. 419) interpret the rise in task complexity as being "accompanied by rising task

discretion”, whereas Green (2012) proposes that discretion impacts job tasks. While the lack of appropriate longitudinal data on work practices impedes the ability to empirically study the opposite directions of this relationship, in order to properly model the direct effect of computer use on task discretion (i.e. net of differences in tasks between computer users and non-users), we follow Gallie et al. (2003) and Green et al. (2021) and impose a direct relationship between job tasks and task discretion, as indicated by Path 2.

Moreover, while the use of computerised equipment is complementary to more abstract and less monitorable tasks, this use may simultaneously (according to the deskilling perspective) increase the possibility for management to monitor and control work by centralising information, independent of the type of job tasks: According to Bloom et al. (2014), while information technologies are associated with more workers’ empowerment and autonomy, cheaper communication technologies act as a centralising force, thereby allowing a broader span of managerial control and reducing workers’ discretion. We expect this process to lead to a negative direct effect of computers on workers’ task discretion, as indicated by Path 3. By influencing the extent of workers’ task discretion (Path 3), the extent of computer use could generate differences in job satisfaction (Path 5). Indeed, for Scotland, Sutherland (2016) has shown that job autonomy is positively related to job satisfaction.

Based on our discussion about the differences between skill and production regimes, we expect that both mediations – via job tasks and via task discretion – should be stronger in the UK than Germany: In the UK, differences in the composition of job tasks and levels of task discretion might be more-strongly influenced by the use of computerised technologies than in Germany. As a competing expectation, it would be possible to assume that even if associations between computer use and job task or autonomy are smaller in Germany (e.g. because new technologies might be associated with widespread occupational upskilling, greater task discretion, and opportunities for participation), differences in task compositions and levels of task discretion could be more influential for job satisfaction in Germany than in the UK. This competing expectation stems from the idea that skills and production regimes might moderate workers’ expectations and assessments of their job tasks and their level of autonomy, with German workers having higher expectations than British workers, for example, due to differences in the asset specificity of skills and collective agreements (Busemeyer 2009).

The mediating role of job tasks and task discretion in the interplay between technology and job satisfaction might differ not only across institutional contexts but also across groups of workers (within countries). We consider two workers’ characteristics to be closely related to this interplay: *occupational class position* and *further training*. Both social stratification and labour market research highlight the importance of the monitoring problem for justifying the favourable position of upper-service-class positions (Erikson and Goldthorpe 1992). Hence, employees in service-class positions (i.e. the salariat) might experience computer use differently than other workers because computers are considered to be largely *complementary* to the non-routine cognitive tasks typical of higher-level occupations and to simultaneously constitute a powerful instrument for controlling and monitoring the discretionary efforts of highly educated workers, whose activities are intrinsically difficult to monitor. For other workers, computer use might be less influential for task discretion because their work is characterised by a higher degree of routine (cognitive or manual) tasks, which are generally easier to monitor. Occupational class could thus be a moderator for the two mediations. We therefore expect that job-task mediation should more positively influence job satisfaction among the salariat than among other classes and that mediation via task discretion should be more negatively affected for the salariat because they risk losing more autonomy.

Participation in job-related adult training might be another relevant moderator related not only to the direct impact of computer use on job satisfaction (Path 6) but also to the mediating role of job tasks (Paths 1–4). Adult training might increase workers' proficiency in ICT skills, which could thereby contribute to mitigating the stress-enhancing and alienating effects associated with computer use (Path 6) or to increasing requirements in problem-solving or other cognitive job tasks (Path 4) (Cedefop 2015; Desjardins and Rubenson 2013). Accordingly, we expect to find a (stronger) direct negative effect of computer use on job satisfaction for non-trained workers and a more-positive mediating effect of jobs tasks for trained workers.

Due to the difficulty of deriving concrete expectations about country differences for these two potential moderators, we include the two moderation analyses as an explorative analytical step in our study. We also include educational attainment as a control variable in the analyses (not shown in Figure 1) and allow education to covary with all variables since it arguably influences computer use and all other investigated jobs aspects.

5. Research design

5.1. Data and variables

We use individual-level data from the BIBB/BAuA Employment Survey (2006, 2012, 2018) for Germany and the Skills Survey (2006, 2012, 2017) for the UK. Both surveys provide comparable and high-quality information on our variables of interest (see below). We restrict our sample to employees aged 20 to 65. After dropping cases with missing information on at least one variable of interest, our final sample consists of 49,446 cases for Germany that range from 16,040–16,778 cases per survey year. For the UK, sample sizes are considerably smaller, with 11,283 cases in total and 2,742–5,853 cases per survey year.

Data were collected using the *job requirements approach*, which is essentially an adaptation of occupational psychologists' methods in the context of socioeconomic surveys. This approach provides information on several job-related characteristics, such as the use of technology, job tasks, task discretion, and job satisfaction. Table 1 reports information on each selected item and its latent construct of reference.

Table 1: List of selected items on latent constructs of interest

The UK	Germany
Job satisfaction	
Satisfaction with the opportunity to use your abilities[1]	Satisfaction with opportunities for applying skills[2]
Satisfaction with able to use your own initiative[1]	Satisfaction with type and content of work[2]
Satisfaction with this aspect of own job – the work itself[1]	Satisfaction with work on the whole[2]
Job tasks	
Cognitive-analytical	
Importance of spotting problems or faults[3]	Confronted with new tasks[4]
Importance of working out causes of problems/ faults[3]	Recognise and close your own gaps in knowledge[5]
Importance of thinking of solutions to problems[3]	Improve existing procedures or try something new[4]
	React to problems and solve them[5]
Cognitive-interpersonal	
Importance of counselling, advising or caring for customers or clients[3]	Purchasing, procuring, selling[5]
Importance of dealing with people[3]	Advertising, Marketing, Public Relations, PR[5]
importance of selling a product or service[3]	
Physical	
Importance of physical stamina[3]	Work standing up[4]
Importance of physical strength[3]	Lift and carry heavy load[4]
Routine	
How much variety in job[8]	One and the same operation is repeated in every detail[4]
How often work involves short repetitive tasks[6]	Execution of work is prescribed in every detail[4]
Task discretion	
Influence personally have on: how hard work[7]	Influence the amount of work assigned to you[4]
Influence personally have on: how to do the task[7]	Plan and schedule your own work yourself[4]
Influence personally have on: what tasks to do[7]	
How much choice over the way in which job is done[7]	Decide for yourself when to take a break[4]

Original scales: [1] 1 (*completely satisfied*) to 7 (*completely dissatisfied*); [2] 1 (*not satisfied*) to 4 (*very satisfied*); [3] 1 (*essential*) to 5 (*not at all*); [4] 1 (*never*) to 4 (*frequently*); [5] 1 (*never*) to 3 (*frequently*); [6] 1 (*never*) to 5 (*always*); [7] 1 (*A great deal*) to 4 (*none at all*); [8] 1 (*a great deal*) 5 (*none at all*). Some variables are reverse coded to facilitate interpretation.

Our variable *computer use* measures the use of any computerised equipment at work. This broad indicator is also useful in accounting for workers for whom computer use may not be a central component of the job but is relevant in shaping workplace dynamics. In the UK, computer users include workers who reported that computer use is *essential*, *very important*, or *fairly important* in their job, whereas non-users are those who reported *not very important* or *not important at all*. In Germany, computer users are defined as workers who reported that they work with computers *frequently*, whereas non-users are those who do so only *sometimes* or *never*. Different specifications of the variable yield similar results.

We operationalise workers' *job satisfaction* with an indicator consisting of three (reverse-coded) items about workers' satisfaction with both the skills content of their job (in terms of job tasks and task discretion) and their job altogether. Although the wording of these items differs slightly across the two country datasets, we consider them to clearly belong to the same latent construct of interest. Cronbach's alphas of 0.76 for Germany and 0.84 for the UK indicate reasonable levels of reliability. Table 2 shows average levels of normalised items of job satisfaction for computer users and non-users: In Germany and the UK, computer users are more likely than non-users to be satisfied with each of the three satisfaction dimensions.

To measure *job tasks* and *task discretion*, we identified a set of items from each dataset that is comparable and clearly belongs to only one of the latent constructs of interest. Conceptually, we follow Autor et al. (2003) and empirically integrate adaptions by Green (2012) and Spitz-Oener (2006). Using a factor analysis (FA), we obtained four factors that capture different task domains – cognitive-analytical, cognitive-interpersonal, physical, and (manual and non-manual) routine – and one indicator that captures task discretion, thereby confirming the theoretical definition of the latent-skills dimensions for both countries. Detailed factor solutions are reported in Table A1 in the Appendix. To confirm the robustness of our latent constructs, we also performed a FA that included additional items that are not directly comparable across datasets but that are nevertheless related to our underlying concepts. The results support our classification based on the comparable items only (see Online Supplement, Table S1). Distributions of each item for computer users and non-users are reported in Table 2. As the range of scales differs across items as well as countries (see Table 1), each item is normalised on a scale from 0–1 to increase comparability.

To operationalise occupational class position, we use one-digit codes from the 2008 International Standard Classification of Occupation (ISCO-08). For the main analysis, we use the differentiation between the salariat group (as defined in Goldthorpe, 1992) and all other classes as the second category.[3] Different operationalisations yield similar results.

Adult training participation is measured as attendance at any job-related training within the two years prior to the interview for Germany. For the UK, the item is measured based on whether a worker "received instructions or training from someone that took them away from their normal job" or completed "some other work-related training" in the previous twelve months.

As mentioned above, we further include workers' educational attainment as a control variable. Educational attainment is measured using the 1997 revision of the International Standard Classification of Education (ISCED). We distinguish between less-educated (ISCED 0–2), intermediately educated (ISCED 3–4), and highly educated workers (ISCED 5+). We also consider a set of control variables in our robustness checks: industry captured by nine categories of the one-digit SIC92 classification for the UK and by ten categories of the NACE rev 1 classification for Germany, gender as a dummy variable, age captured by three 15-year groups (with ethnic background as a dummy variable, indicating non-white workers for the UK and migration background for Germany), and survey year (three categories). Correlation matrices for all included variables are presented in Tables S2a and S2b (Online Supplement).

[3] Armed-forces occupations are excluded.

Table 2: Mean and standard deviation of items of interests for computer users and non-users in Germany and the UK

The UK	User Mean	SD	Non-user Mean	SD	**Germany**	User Mean	SD	Non-user Mean	SD
Job satisfaction									
Satisfaction with	0.76	0.19	0.70	0.22	Satisfaction with	0.75	0.20	0.70	0.20
being able to use your own initiative	0.77	0.18	0.73	0.21	opportunities for applying skills	0.72	0.22	0.68	0.23
this aspect of own job – the work itself	0.74	0.18	0.73	0.19	work on the whole	0.74	0.20	0.71	0.21
Cognitive-analytical									
Importance of:	0.79	0.24	0.66	0.30	React to problems and solve them	0.85	0.25	0.70	0.32
working out causes of problems/ faults	0.74	0.26	0.58	0.32	Recognise and close your own gaps in knowledge	0.66	0.28	0.52	0.31
thinking of solutions to problems	0.78	0.24	0.57	0.32	Confronted with new tasks	0.77	0.25	0.62	0.31
					Improve existing procedures or try something new	0.68	0.27	0.56	0.31
Cognitive-interpersonal									
Importance of:	0.68	0.35	0.49	0.40	Purchasing, procuring, selling	0.33	0.40	0.27	0.38
dealing with people	0.91	0.18	0.78	0.28	Advertising, Marketing, Public Relations, PR	0.27	0.35	0.13	0.27
selling a product or service	0.46	0.39	0.30	0.38					
Importance of:	0.41	0.35	0.65	0.29	Work standing up	0.60	0.38	0.89	0.25
physical strength	0.34	0.34	0.64	0.30	Lift and carry heavy load	0.30	0.36	0.61	0.38
How much variety in job	0.28	0.26	0.46	0.32	Execution of work is prescribed in every detail	0.51	0.35	0.56	0.37
How often work involves short repetitive tasks	0.57	0.28	0.67	0.28	One and the same operation is repeated […]	0.66	0.36	0.76	0.33
Influence personally have on:	0.80	0.23	0.75	0.27	Plan and schedule your own work yourself	0.87	0.27	0.70	0.36
how to do the task	0.66	0.29	0.53	0.34	Influence the amount of work assigned to you	0.57	0.38	0.50	0.39
what tasks to do	0.75	0.26	0.64	0.32	Decide for yourself when to take a break	0.76	0.37	0.59	0.43
How much choice over the way in which job	0.71	0.26	0.63	0.31					
N	8,596		2,687			36,023		13,423	

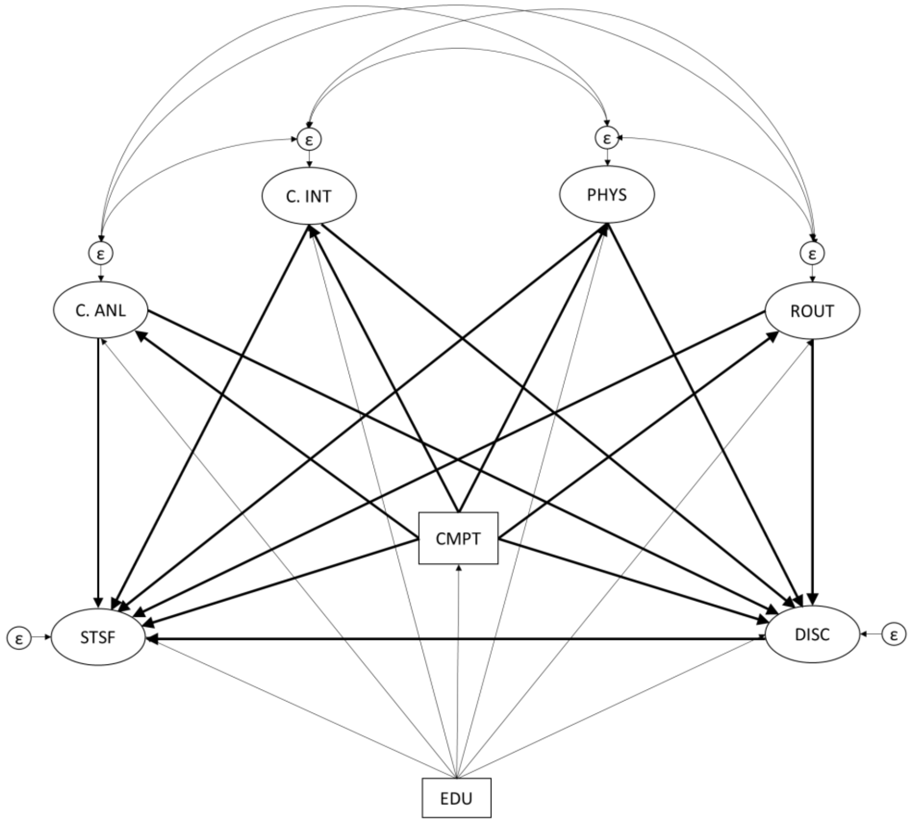
Notes: All variables are normalised on a scale from 0–1, with higher values indicating higher levels of the latent construct of interest. Weighted. Original scales reported in Table 1.

Sources: UK Skills Survey (2006, 2012, 2017) for the UK; BIBB/BAuA Employment Survey (2006, 2012, 2018) for Germany; authors' calculations.

5.2. Methods

We test our theoretical model using structural equation modelling (SEM), as presented in Figure 2. Circled variables represent latent constructs. The underlying observed variables for each dataset are reported in Table 1. Squared variables are observed. The thick lines represent relationships that directly test our hypotheses and the theoretical model reported in Figure 1. Models are tested for each country separately on the yearly pooled sample as no major changes in the relationships of interest are expected across analysed years.[4]

Figure 2: Empirical structural equation model



Notes: STSF = job satisfaction; C.ANL = cognitive-analytical tasks; C.INT = cognitive-interpersonal tasks; PHYS = physical tasks; ROUT = routine tasks; DISC = task discretion; CMPT = computer use at work; EDU = level of education.

Our SEM includes a correlation between the errors of the different job-task dimensions (which is theoretically supported by the fact that the different tasks required in an occupation are related), and the overall definition of a job is given by the *simultaneous* observation of all dimensions. We thus refrain from interpreting the mediating role of each single task index on task discretion and job satisfaction separately since the complementarity between computers and job requirements is given by the overall task profile. To check for theoretically possible moderations by occupational class position and adult training participation, we estimate multi-group SEM models for these subgroups of workers.

[4] We also tested the multiple-group SEM for each year. The Wald test could not reject the null hypothesis of equality in the parameters of interest. Furthermore, we estimated OLS regressions for each path of interest, including the survey wave as a control variable (see Online Supplement, Tables S3a and S3b).

SEM has several advantages: First, it allows both measurements and structural components to be included, which is critical because job satisfaction and skill requirements at work are not directly observed but obtained through latent constructs. Second, SEM tests our theoretical model by including both structural paths and latent constructs on different data and contexts, and it compares the performances under different conditions. This advantage also relaxes the issue of different item wordings across datasets. Third, SEM enables path models of complex direct and indirect effects to be developed, thereby helping us accurately test the complex mediating processes of interest (Chin 1998). As highlighted by Bollen and Pearl (2013), the core of the SEM analysis involves specifying a theoretical model and subsequently testing whether this model is plausible given the observed data. SEM is a confirmatory approach that relies on translating theory into a statistical model. If the theoretical model is problematic and/or if empirical instruments are not accurate, the model will not be able to reproduce the data, and estimated parameters will not be interpretable, thereby casting doubt on the strong causal assumptions of zero coefficients or zero covariances. In other words, researchers do not obtain any causal relationship from SEM, and SEM instead reflects and depends on researchers' theoretical assumptions about *possible and plausible* causal connections (Bollen and Pearl 2013). In the present work, our main assumption indicates the exogeneous nature of the technological change (Path 1 in Figure 1).[5]

Defining the theoretical foundations of a SEM model is even more relevant when disposable data on technological innovation take the form of cross-sectional surveys, as in our case, which leaves room for possible objections of endogeneity. It is, of course, possible and legitimate to argue that the changing nature of work towards more abstract and analytical cognitive content and procedures requires and/or favours the introduction of new technologies and computers in the workplace (thereby reversing Path 1 in our theoretical model). While we cannot statistically exclude any endogeneity issue, we stress that *distinguishing the relevant from the incidental* is always advisable. Indeed, a firm theory of the effects of technological innovation on production, occupational structures, social life, and organisations has been established in social sciences for decades. Our study is in line with this body of research. However, a crucial limitation of SEM is its difficulty in including numerous control variables to account for potential confounding factors, which are usually considered in the analysis of the effects of computer use on skills and tasks at work (Green 2012; Green et al. 2003; Menon et al. 2019). We thus estimated separate OLS regressions for all paths highlighted in the SEM model, including the aforementioned controls. This robustness check confirms the results estimated via SEM (see Appendix, Tables A2a and A2b).

6. Results

We begin with some descriptive findings and examine the average levels of task performance among computer users and non-users in the UK and Germany, as presented in Table 2 (see Methods). While the performance of cognitive-analytical tasks is most pronounced (especially for computer users) in both countries, important differences exist regarding the use of the other three task subsets both within and between countries: In Germany, routine and physical tasks are relatively more frequent than cognitive-interpersonal tasks (among both computer users and non-users), which is exemplary of the technology-implementation processes in diversified quality production in German manufacturing, as discussed above. In the UK, cognitive-interpersonal tasks are more frequent than routine or physical tasks for

[5] For a recent discussion on technology as the exogenous driver behind new forms of work and on the effects of new technologies on the future of work and skills, see: "The changing nature of work and skills in the digital age" (European Union 2019).

computer users, whereas for non-users, the extent of physical tasks is greatest among these three subsets. Differences in task use between computer users and non-users are thus generally more pronounced in the UK than in Germany.

We now turn to our multivariate analysis. Table 3 presents the results of SEM for both the UK and Germany, decomposed into direct and total effects and the percentage of total effects accounted for by mediation. Goodness-of-fit (GoF) statistics are included at the bottom of Table 3 to provide information on how well our model fits the data. The comparative fit index (CFI) indicates that our model improves the fit of a baseline model that assumes no covariances between items among latent variables by 95.4 per cent in the UK and 92.8 per cent in Germany. These improvements are considerable and exceed the recommended minimum value of 0.90 for a satisfactory model fit. Moreover, regarding the root mean square error of approximation (RMSEA), which adjusts for errors for each degree of freedom used, results are indicative of a good model fit, with values equal to the recommended upper bound of 0.05. Finally, we present the index of the standardised root mean square residual (SRMR) as a measure of how close our model comes on average to reproducing each correlation. In both countries, values are below the recommended cut-off of 0.05, which again confirms that our model fits the data well in both Germany and the UK (for details on GoF, see Acock 2013; Kyndt and Onghena 2014). We therefore next discuss the presented results. Note that all variables except dichotomous ones are z-standardised to increase comparability.

We begin with our first research question – that is, the relationship between computer use and both job tasks and task discretion. The upper part of Table 3 presents estimates for Path 1 in our theoretical model and the association between computer use and our four factors/dimensions of job tasks (A–D). In Germany and the UK, computer use is clearly associated with higher levels of (analytical and interpersonal) cognitive tasks and lower levels of routine and physical tasks. These effects are highly significant. One country difference emerges: The negative association between computer use and routine tasks appears larger in the UK than in Germany. Further analyses suggest that the small(er) effect size for Germany might originate from the measurement of routine tasks performed in both surveys; however, this is the common form of measurement (results available upon request). Fernandez-Macias and Hurley (2016) criticise the concept of routine tasks proposed by the economic literature for its imprecise definition and introduce a further distinction between *routine tasks* (in terms of the level of cognitive or manual simplicity/sophistication) and *repetitive tasks* (in a temporal sense). In this respect, Frey and Osborne (2017) identify finger- and manual dexterity characterised by the repetitive performance of hand- and finger accuracy as a potential bottleneck for automation. These tasks are thus *repetitive* but *not routine*. Our data do not allow for operationalising this distinction; thus, our measure of routine tasks is likely conservative. Similarly, the somewhat larger association with physical tasks in Germany is likely driven by substitutions of routine- rather than non-routine physical tasks.

Table 3: Direct and total effects of computer use on job tasks, task discretion, and job satisfaction in the UK and Germany

	the UK			Germany		
	Direct effect	Total effect	% of total effect via mediation	Direct effect	Total effect	% of total effect via mediation
Path 1: Relationship between computer use and job tasks						
DV: Cognitive-analytical (A)						
Computer use	0.452*** (0.020)	n.i.p.	0	0.352*** (0.007)	n.i.p.	0
DV: Cognitive-interpersonal (B)						
Computer use	0.479*** (0.020)	n.i.p.	0	0.113*** (0.006)	n.i.p.	0
DV: Physical (C)						
Computer use	-0.541*** (0.020)	n.i.p.	0	-0.696*** (0.010)	n.i.p.	0
DV: Routine (D)						
Computer use	-0.216*** (0.013)	n.i.p.	0	-0.057*** (0.008)	n.i.p.	0
Paths 2 and 3: Relationship between computer use and task discretion (incl. mediation via tasks)						
DV: Task discretion						
Computer use	-0.034* (0.015)	0.190*** (0.015)	118	0.085*** (0.012)	0.427*** (0.009)	80
Cognitive-analytical	0.087*** (0.008)	n.i.p.	0	0.418*** (0.013)	n.i.p.	0
Cognitive-interpersonal	0.067*** (0.011)	n.i.p.	0	0.258*** (0.018)	n.i.p.	0
Physical	-0.022** (0.008)	n.i.p.	0	-0.215*** (0.009)	n.i.p.	0
Routine	-0.653*** (0.030)	n.i.p.	0	-0.276*** (0.012)	n.i.p.	0
Paths 4, 5, 6: Relationship between computer use and job satisfaction (incl. mediation via tasks and discretion)						
DV: Job satisfaction						
Computer use	-0.117*** (0.022)	0.184*** (0.022)	164	-0.021 (0.013)	0.190*** (0.009)	111
Cognitive-analytical	0.052*** (0.011)	0.094*** (0.012)	45	0.185*** (0.013)	0.290*** (0.012)	36
Cognitive-interpersonal	0.026 (0.016)	0.058** (0.017)	55	0.011 (0.017)	0.076*** (0.017)	86
Physical	0.011 (0.012)	0.000 (0.013)	-110	-0.032** (0.010)	-0.086*** (0.010)	63
Routine	-0.829*** (0.046)	-1.145*** (0.047)	28	-0.259*** (0.013)	-0.328*** (0.013)	21
Task discretion	0.483*** (0.025)	n.i.p.	0	0.251*** (0.012)	n.i.p.	0
Goodness-of-fit statistics						
CFI	0.954			0.928		
RMSEA	0.051			0.047		
SRMR	0.038			0.035		

Notes: DV = dependent variable; n.i.p. = no indirect path included. All continuous variables are z-standardised (mean = 0, standard deviation = 1). Controlled for educational attainment. Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Sources: UK Skills Survey (2006, 2012, 2017) for the UK and BIBB/BAuA Employment Survey (2006, 2012, 2018) for Germany; authors' calculations.

The middle of Table 3 reports estimates for the association between computer use and task discretion and integrates mediation via job tasks. Beginning with the direct effect of computer use on task discretion (i.e. net of computer-task complementarities and while capturing Path 3 in our theoretical scheme), important country differences can be observed: Computer use is associated with lower levels of task discretion in the UK (-.034) but with higher levels in Germany (.085). The same results emerge after including detailed controls for workforce composition (see Appendix, Tables A2a and A2b). Both effects are relatively small yet statistically significant. The total effect of computer use on task discretion (including both Paths 2 and 3) is positive and statistically significant in both countries, but larger in Germany. In the UK, 118 per cent of the total effect is explained by mediation via job tasks (Path 2), which links the observed differences in task discretion between computer users and non-users to different tasks performed. In Germany, this mediation accounts for 80 per cent of the total effect, and estimates for the different task dimensions reveal that cognitive tasks are associated with higher levels of discretion, whereas routine and physical tasks are associated with lower levels. Effects are significant in both countries but considerably larger in Germany, except – again – for routine tasks (see discussion above). As mentioned above, we refrain from interpreting the indirect effects of computer use via each of the task indicators separately. In sum, the differences between the direct and total effects of computer use on task discretion reveal the importance of tasks as composite indicators of types of occupations and jobs that explain most variation between workers. The country differences found are indicative of the dissimilar production strategies that underlie these associations.

We now turn to our second research question – that is, the mediating role of job tasks and task discretion in the relationship between computer use and job satisfaction. Results are presented towards the bottom of Table 3. The direct effect of computer use on job satisfaction – that is, independent of job tasks and task discretion (referring to Path 6 in Figure 1) – is negative in both countries (-0.117 in the UK and -0.021 in Germany) and could be generated by technostress or anxiety. These direct effects are larger and statistically significant only in the UK. Once the role of job tasks and task discretion has been accounted for (via Paths 1–4, 3–5, and 1–2–5, respectively), the total effect of computer use on job satisfaction becomes positive and statistically significant in both the UK and Germany (0.184 and 0.190, respectively). Mediation via the indirect paths of job tasks and task discretion accounts for 164 per cent of the total effect in the UK and 111 per cent in Germany. These results reveal the explanatory relevance that the associations between computer use, job tasks, and task discretion have for job satisfaction.[6]

Overall, the results confirm our theoretical expectation that complex job profiles and the possibility of controlling work processes should be positively associated with job satisfaction in both countries (see direct and total effects of job tasks and task discretion), thereby linking differences in task composition and task discretion between computer users and non-users to workers' job satisfaction. Country differences between Germany and the UK reflect the different skill- and production regimes, as discussed in the theoretical section above. In the UK, mediation via job tasks – and particularly via routine tasks[7] – is much more pronounced than in Germany, which accounts for a substantial part of the total effects of computer use on both task discretion and job satisfaction. Differences in the levels of task discretion and job satisfaction by computer use that remain net of the indirect paths via job tasks are strongly indicative of prevalent managerial practices of implementing and using computer technologies as a means of centralising decision-making and increasing control over work processes. In

[6] As a robustness check, we also estimated OLS regressions that accounted for demographic, occupational, and industrial differences between computer users and non-users. The total effect of computer use on the degree of job satisfaction was found to decrease in the UK and to no longer be significant, while the negative direct effect remained significant (see Appendix, Table A2a). In Germany, the already small negative direct effect approximated zero and became non-significant (see Appendix, Table A2b).

[7] Routine tasks in the UK have by far the largest direct and total effect on job satisfaction; however, the negative direct effect of computer use is robust after excluding the routine-task indicator from the SEM model.

Germany, on the other hand, total effects of computer use on job satisfaction are more-strongly determined by decentralising modes of production that encourage the discretionary effort of workers both directly via computer use and indirectly via job tasks. Since differences in the effects of job tasks by computer use are less pronounced in Germany than in the UK, we would tend to interpret this result as an effect of structural differences between the two countries regarding the impact of tasks.

As discussed in the theoretical section, we are also interested in differences across groups of workers. We begin with multi-group comparisons of SEM between salariat workers and members of other occupational classes. Detailed results are presented in Table A3 (Appendix). In the UK, the observed *direct* effects of computer use on both task discretion and job satisfaction remain negative across all occupational classes but statistically significant only for non-salariat workers. Nevertheless, the positive *total* effects of computer use on both task discretion and job satisfaction are more pronounced for non-salariat- than for salariat workers. As expected, these positive associations are determined by mediation via job tasks, with computer-task complementarities being most relevant to non-salariat worker groups.

For Germany, the alienating effect of computer use on job satisfaction is more pronounced among salariat- than non-salariat workers, which also results in a smaller total effect that is still positive and statistically significant. In contrast, the positive *direct* effect of computer use on task discretion is larger among salariat workers. However, the positive *total* effect of computer use on task discretion is larger for other occupational classes – most likely due to a stronger mediation via job tasks – and further reflects the large positive total effect on job satisfaction.

Second, we expected participation in adult training to intervene in the interplay between job tasks, task discretion, and job satisfaction. Results for this group-comparison SEM model are presented in Table A4 (Appendix). In both countries, the main group difference is observable for the direct negative effect of computer use on job satisfaction. In accordance with our theoretical considerations, an alienating effect of computer use is larger and statistically more relevant among non-trained than trained workers in both countries. Differences are somewhat more pronounced in Germany; however, we do not find empirical support for our expectation that the mediating effect of job tasks should be more positive for trained workers.

These results should be considered explorative because tests for group invariances of the parameters could not reject the null hypothesis of equality between occupational classes and between training groups. Moreover, as we only observed level differences but not differences in the direction of effects, these findings imply that our theoretical model of the relationship between technology and job satisfaction applies to different groups of workers, though to differing extents.

7. Conclusions

By comparatively analysing Germany and the UK, two ideal types of production regimes, and management practices, our study contributes both theoretically and empirically to the ongoing upskilling/deskilling debate by examining how computer use is associated with tasks performed and task discretion as two distinct dimensions of occupational skills. Moreover, we contribute to a better understanding of whether job tasks and task discretion mediate the relationship between technological innovation and job satisfaction.

Our results stress that in both countries, *computers are complementary to less routine and more abstract tasks while reducing physical and repetitive tasks and that this relationship is conducive to higher average levels of task discretion and workers' job satisfaction*. This finding is in line with the RBTC thesis that technology complements highly skilled jobs and substitutes more routine ones. However, *national institutions and labour market configurations do make a difference*: After accounting for the association between computer use and the types of tasks performed, the direct effect of computer use on task discretion and workers' job satisfaction proved to be exemplary of the two different institutional regimes: Our results imply that technology in the UK (a liberal market economy in which firms have strong incentives to pursue production and employment strategies based on a flexible labour force with little attachment to the firm) serves as an instrument for further centralising decision-making and increasing control over the labour process. This is not the case in Germany.

More generally, our results indicate that technology is not an entirely exogeneous variable that affects the outcomes of implementation – in terms of job tasks, job discretion, and workers' satisfaction with their working conditions – in a deterministic and unilateral way. Our study thereby contributes to the upskilling/deskilling debate by demonstrating the different yet related issues of the complexity of the tasks performed and the degrees of work discretion. Moreover, our results stress that the relationship between computer-task complementarities and firms' organisational structures and practices – and perhaps also job discretion and satisfaction – is contingent on the wider institutional and labour context in which technology is introduced.

Clearly distinguishing between different skill dimensions is relevant to better understanding the link between technology and the overall quality of work – as demonstrated in our study – not only theoretically, but also policy-wise. Policy interventions that aim to increase job satisfaction – which, in the long run, impacts labour productivity – should focus on strategies that encourage the use of computerised equipment by means of decentralising information and decision-making at the shop-floor level, thereby empowering workers and lower-level managers not only in collaborative work environments and production systems, as in Germany, but also in shareholder-oriented production models, as in the UK. One important instrument in this regard might be *targeted* training measures for increasing workers' proficiency in ICT use and complex task domains. Such training could equip the labour force with relevant skills and strengthen workers' capacity to exercise control over their work process and conditions while enabling executives' to maximise labour productivity and the competitiveness of firms.

Although our theoretical expectations are corroborated by empirical evidence, our study is not without limitations, which are mainly related to the nature of the available data. Despite the vivid debate on technological change and the task content of jobs in the last decade, we still lack micro-level longitudinal and cross-country comparable data. It is therefore difficult to advance strong causal claims via an empirical analysis of cross-sectional data. Our '*causal'* paths are hence mainly driven by theoretical considerations, however solidly embedded in decades of literature. Consequently, one of the main issues that future research will have to tackle (using appropriate data) is that the relationship between computers and any potential outcome (e.g. wages, discretion, or satisfaction) could be the result of occupational (or institutional) characteristics that simultaneously determine the use of technology and the content of the work. Existing research has dealt with this issue by building an occupational-level pseudo panel (Green 2012). While this approach is certainly informative, it only accounts for within-occupational differences between computer users and non-users and/or for variation in time within aggregate constructs. The advantage of our approach is that including continuous measures of job tasks performed enables us to account for differences in job tasks and task discretion between computer users and non-users, even *between* occupational categories.

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Appendix

Table A1: Factor analysis of comparable skills items for the UK and Germany

	C.ANL	DISCRET	PHYS	C.INT	ROUT	Uniq.
The UK						
Importance of						
… working out causes of problems	0.925					0.132
… spotting problems	0.892					0.198
… thinking of solutions to problems	0.847					0.219
Influence personally have on						
… what task to do		0.806				0.302
… how to do the tasks		0.793				0.333
… how hard to work		0.714				0.462
How much choice have over way in which job is done		0.675				0.438
Importance of						
… physical stamina			0.941			0.108
… physical strength			0.935			0.114
… counselling, and advising				0.812		0.311
… dealing with people				0.742		0.390
… selling a product of service				0.683		0.479
How often work involves short and repetitive tasks					0.819	0.297
How much variety in job					0.681	0.354
Eigenvalues	*3.690*	*2.095*	*1.583*	*1.469*	*1.028*	
Germany	C.ANL	PHYS	DISCRET	ROUT	C.INT	Uniq.
Confronted with new tasks	0.740					0.430
Recognize and close your own gaps in knowledge	0.688					0.508
React to problems and solve them	0.682					0.506
Improve existing procedures or try something new	0.645					0.498
Work standing up		0.858				0.254
Lift and carry heavy load		0.827				0.300
Influence the amount of work assigned to you			0.745			0.409
Plan and schedule your own work yourself			0.689			0.425
Decide for yourself when to take a break			0.644			0.481
Execution of work is prescribed in every detail				0.812		0.282
One and the same operation is repeated in every detail				0.799		0.296
Purchasing, procuring, selling					0.822	0.292
Advertising, Marketing, Public Relations, PR					0.748	0.360
Eigenvalues	*2.934*	*1.622*	*1.253*	*1.113*	*1.038*	

Notes: Factor loadings estimated using the principal-component-factor method. Orthogonal rotation applied. Weighted. Blanks represent abs(loadings) < 0.35.
Sources: UK Skills Survey (2006, 2012, 2017) for the UK and BIBB/BAuA Employment Survey (2006, 2012, 2018) for Germany; authors' calculations.

Table A2a: The UK – OLS regressions of total and direct effects of computer use on discretion and satisfaction

	Total effect on discretion	**Direct effect on discretion**	**Total effect on satisfaction**	**Direct effect on satisfaction**
Computer Use	0.092**	-0.068*	0.050	-0.079*
	(0.035)	(0.033)	(0.037)	(0.036)
Task indicators				
Cognitive-analytical		0.157***		0.091***
		(0.013)		(0.012)
Cognitive-interpersonal		0.097***		0.031*
		(0.013)		(0.014)
Physical		-0.006		0.022
		(0.014)		(0.014)
Routine		-0.242***		-0.240***
		(0.013)		(0.014)
Discretion				0.313***
				(0.013)
Educational attainment (reference: less-educated (ISCED 0–2))				
Intermediately educated (ISCED 3–4)	0.196***	0.160**	-0.156***	-0.234***
	(0.052)	(0.049)	(0.044)	(0.041)
Highly educated (ISCED 5+)	0.194***	0.107*	-0.292***	-0.418***
	(0.056)	(0.053)	(0.051)	(0.047)
Occupation (reference: managers)				
Professionals	-0.378***	-0.314***	-0.055	0.097**
	(0.035)	(0.035)	(0.041)	(0.038)
Technicians and associate professionals	-0.457***	-0.361***	-0.162***	0.051
	(0.038)	(0.037)	(0.041)	(0.038)
Clerical-support workers	-0.655***	-0.410***	-0.421***	-0.020
	(0.044)	(0.043)	(0.049)	(0.043)
Service- and sales workers	-0.694***	-0.487***	-0.372***	-0.006
	(0.040)	(0.040)	(0.046)	(0.044)
Skilled agriculture-, forestry-, and fishery workers	-0.407**	-0.260	-0.133	0.077
	(0.152)	(0.142)	(0.240)	(0.230)
Craft- and related-trades workers	-0.608***	-0.497***	-0.182***	0.047
	(0.049)	(0.050)	(0.051)	(0.049)
Plant- and machine operators and assemblers	-1.101***	-0.773***	-0.595***	-0.031
	(0.064)	(0.062)	(0.063)	(0.059)
Elementary occupations	-0.943***	-0.565***	-0.695***	-0.154*
	(0.054)	(0.058)	(0.060)	(0.064)
Further-training participation	0.073**	-0.010	0.052*	-0.029
	(0.023)	(0.022)	(0.026)	(0.024)
Constant	0.440**	0.484***	0.401	0.267
	(0.144)	(0.131)	(0.207)	(0.173)
Observations	11,283	11,283	11,283	11,283
R-squared	0.139	0.226	0.074	0.258

Notes: All continuous index variables are predicted scores from a separate factor analysis for each latent construct (see Table A1). Controlled for industry, age, gender, ethnic background, and survey year. Weighted. Robust standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Sources: UK Skills Survey (2006, 2012, 2017); authors' calculations.

Table A2b: Germany – OLS regressions of total and direct effects of computer use on discretion and satisfaction

	Total effect on discretion	**Direct effect on discretion**	**Total effect on satisfaction**	**Direct effect on satisfaction**
Computer use	0.225***	0.121***	0.093***	0.006
	(0.017)	(0.017)	(0.016)	(0.016)
Task indicators				
Cognitive-analytical		0.194***		0.088***
		(0.007)		(0.008)
Cognitive-interpersonal		0.113***		0.020**
		(0.006)		(0.006)
Physical		-0.090***		-0.067***
		(0.007)		(0.007)
Routine		-0.140***		-0.117***
		(0.006)		(0.006)
Discretion				0.160***
				(0.007)
Educational attainment (reference: less-educated (ISCED 0–2))				
Intermediately educated (ISCED 3–4)	0.177***	0.132***	-0.136***	-0.181***
	(0.033)	(0.032)	(0.031)	(0.031)
Highly educated (ISCED 5+)	0.302***	0.142***	-0.208***	-0.345***
	(0.035)	(0.033)	(0.034)	(0.034)
Occupation (reference: managers)	0.177***	0.132***		
Professionals	-0.249***	-0.203***	-0.060*	-0.022
	(0.020)	(0.020)	(0.030)	(0.029)
Technicians and associate professionals	-0.316***	-0.134***	-0.216***	-0.083**
	(0.020)	(0.020)	(0.030)	(0.030)
Clerical-support workers	-0.456***	-0.207***	-0.373***	-0.181***
	(0.024)	(0.024)	(0.034)	(0.033)
Service- and sales workers	-0.497***	-0.263***	-0.291***	-0.078*
	(0.027)	(0.027)	(0.036)	(0.035)
Skilled agriculture-, forestry-, and fishery workers	-0.462***	-0.142*	-0.124	0.127
	(0.071)	(0.068)	(0.076)	(0.078)
Craft- and related-trades workers	-0.705***	-0.381***	-0.289***	-0.013
	(0.027)	(0.028)	(0.035)	(0.035)
Plant- and machine operators and assemblers	-0.919***	-0.504***	-0.496***	-0.149***
	(0.034)	(0.035)	(0.040)	(0.040)
Elementary occupations	-0.891***	-0.402***	-0.612***	-0.232***
	(0.040)	(0.040)	(0.044)	(0.045)
Further-training participation	0.172***	0.089***	0.170***	0.108***
	(0.013)	(0.012)	(0.013)	(0.013)
Constant	0.227***	0.159**	0.240***	0.163**
	(0.052)	(0.051)	(0.058)	(0.057)
Observations	49,446	49,446	49,446	49,446
R-squared	0.153	0.220	0.046	0.101

Notes: All continuous index variables are predicted scores from a separate factor analysis for each latent construct (see Table A1). Controlled for industry, age, gender, ethnic background, and survey year. Weighted. Robust standard errors in parentheses.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Sources: BIBB/BAuA Employment Survey (2006, 2012, 2018); authors' calculations.

Table A3: SEM of direct and total effects of computer use on job tasks, task discretion, and job satisfaction, separated by occupational class position, including tests for the parameter invariance of direct effects

	The UK				Germany			
	Lower ESeC		**Higher ESeC**		**Lower ESeC**		**Higher ESeC**	
	Direct effect	**Total effect**	**Direct effect**	**Total effect**	**Direct effect**	**Total effect**	**Direct effect**	**Total effect**
DV: Cognitive-analytical tasks								
Computer use	0.408*** (0.023)	*No Ind. Path*	0.341*** (0.059)	*No Ind. Path*	0.126*** (0.010)	*No Ind. Path*	0.352*** (0.010)	*No Ind. Path*
DV: Cognitive-interpersonal tasks								
Computer use	0.428*** (0.024)	*No Ind. Path*	0.075 (0.063)	*No Ind. Path*	0.035* (0.014)	*No Ind. Path*	0.201*** (0.010)	*No Ind. Path*
DV: Physical tasks								
Computer use	-0.487*** (0.023)	*No Ind. Path*	-0.521*** (0.071)	*No Ind. Path*	-0.659*** (0.020)	*No Ind. Path*	-0.737*** (0.011)	*No Ind. Path*
DV: Routine tasks								
Computer use	-0.114*** (0.011)	*No Ind. Path*	-0.099** (0.034)	*No Ind. Path*	0.025 (0.016)	*No Ind. Path*	0.006 (0.012)	*No Ind. Path*
DV: Task discretion								
Computer use	-0.048** (0.017)	0.115*** (0.017)	-0.058 (0.045)	0.067 (0.046)	0.060*** (0.013)	0.246*** (0.011)	0.042* (0.018)	0.394*** (0.013)
Cognitive-analytical	0.110*** (0.011)	*No Ind. Path*	0.065*** (0.013)	*No Ind. Path*	0.145*** (0.017)	*No Ind. Path*	0.488*** (0.017)	*No Ind. Path*
Cognitive-interpersonal	0.068*** (0.013)	*No Ind. Path*	0.079*** (0.022)	*No Ind. Path*	0.264*** (0.015)	*No Ind. Path*	0.236*** (0.023)	*No Ind. Path*
Physical	-0.011 (0.010)	*No Ind. Path*	-0.062*** (0.014)	*No Ind. Path*	-0.244*** (0.010)	*No Ind. Path*	-0.183*** (0.014)	*No Ind. Path*
Routine	-0.737*** (0.046)	*No Ind. Path*	-0.646*** (0.054)	*No Ind. Path*	-0.100*** (0.011)	*No Ind. Path*	-0.363*** (0.017)	*No Ind. Path*
DV: Job satisfaction								
Computer use	-0.104*** (0.025)	0.119*** (0.025)	-0.108 (0.061)	-0.010 (0.065)	-0.038 (0.022)	0.059** (0.019)	-0.025 (0.016)	0.182*** (0.011)
Cognitive-analytical	0.070*** (0.015)	0.130*** (0.016)	0.043* (0.017)	0.071*** (0.018)	0.174*** (0.030)	0.262*** (0.029)	0.232*** (0.016)	0.322*** (0.014)
Cognitive-interpersonal	0.052** (0.018)	0.090*** (0.020)	-0.010 (0.027)	0.025 (0.030)	-0.070* (0.029)	0.091*** (0.024)	0.006 (0.020)	0.050* (0.020)
Physical	-0.023 (0.014)	-0.029 (0.015)	0.061** (0.018)	0.033 (0.021)	0.101*** (0.020)	-0.047** (0.015)	-0.071*** (0.012)	-0.105*** (0.012)
Routine	-0.862*** (0.066)	-1.266*** (0.072)	-0.874*** (0.079)	-1.155*** (0.083)	-0.249*** (0.018)	-0.310*** (0.018)	-0.180*** (0.015)	-0.247*** (0.015)
Task discretion	0.548 (0.030)	*No Ind. Path*	0.436*** (0.040)	*No Ind. Path*	0.610*** (0.048)	*No Ind. Path*	0.185*** (0.014)	*No Ind. Path*
Goodness-of-fit statistics								
CFI	0.954				0.921			
RMSEA	0.048				0.047			
SRMR	0.039				0.038			

Notes: DV dependent variable. Underlined coefficient estimates indicate rejection of the null hypothesis of equality between groups. All continuous variables are z-standardised to have a mean of 0 and a standard deviation of 1. Controlled for educational attainment. Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Sources: UK Skills Survey (2006, 2012, 2017) for the UK and BIBB/BAuA Employment Survey (2006, 2012, 2018) for Germany; authors' calculations.

Table A4: SEM of direct and total effects of computer use on job tasks, task discretion, and job satisfaction, separated by training participation, including tests for the parameter invariance of direct effects

	The UK				**Germany**			
	Trained		**Non-trained**		**Trained**		**Non-trained**	
	Direct effect	**Total effect**	**Direct effect**	**Total effect**	**Direct effect**	**Total effect**	**Direct effect**	**Total effect**
DV: Cognitive-analytical tasks								
Computer use	0.222*** (0.033)	*No Ind. Path*	0.504*** (0.025)	*No Ind. Path*	0.175*** (0.008)	*No Ind. Path*	0.430*** (0.013)	*No Ind. Path*
DV: Cognitive-interpersonal tasks								
Computer use	0.212*** (0.033)	*No Ind. Path*	0.523*** (0.027)	*No Ind. Path*	0.067*** (0.007)	*No Ind. Path*	0.152*** (0.010)	*No Ind. Path*
DV: Physical tasks								
Computer use	-0.638*** (0.037)	*No Ind. Path*	-0.513*** (0.025)	*No Ind. Path*	-0.652*** (0.013)	*No Ind. Path*	-0.798*** (0.015)	*No Ind. Path*
DV: Routine tasks								
Computer use	-0.202*** (0.024)	*No Ind. Path*	-0.185*** (0.016)	*No Ind. Path*	-0.000 (0.008)	*No Ind. Path*	-0.097*** (0.012)	*No Ind. Path*
DV: Task discretion								
Computer use	-0.032 (0.025)	0.122*** (0.024)	-0.038 (0.020)	0.201***(0.019)	0.096*** (0.014)	0.302*** (0.011)	0.067** (0.023)	0.487*** (0.016)
Cognitive-analytical	0.070*** (0.012)	*No Ind. Path*	0.101*** (0.012)	*No Ind. Path*	0.377*** (0.019)	*No Ind. Path*	0.424*** (0.019)	*No Ind. Path*
Cognitive-interpersonal	0.042* (0.018)	*No Ind. Path*	0.084*** (0.014)	*No Ind. Path*	0.233*** (0.021)	*No Ind. Path*	0.264*** (0.032)	*No Ind. Path*
Physical	-0.013 (0.012)	*No Ind. Path*	-0.030** (0.012)	*No Ind. Path*	-0.190*** (0.011)	*No Ind. Path*	-0.199*** (0.017)	*No Ind. Path*
Routine	-0.596*** (0.041)	*No Ind. Path*	-0.700*** (0.043)	*No Ind. Path*	0.067*** (0.023)	*No Ind. Path*	-0.400*** (0.025)	*No Ind. Path*
DV: Job satisfaction								
Computer use	-0.079* (0.036)	0.130*** (0.037)	-0.130*** (0.029)	0.176*** (0.028)	-0.012 (0.015)	0.106*** (0.012)	-0.049* (0.021)	0.214*** (0.015)
Cognitive-analytical	0.055*** (0.017)	0.085*** (0.018)	0.056*** (0.016)	0.107*** (0.017)	0.179*** (0.021)	0.283*** (0.020)	0.174*** (0.019)	0.266*** (0.018)
Cognitive-interpersonal	0.011 (0.026)	0.029 (0.028)	0.039* (0.020)	0.081*** (0.022)	0.005 (0.021)	0.069** (0.021)	-0.009 (0.029)	0.049 (0.029)
Physical	0.048** (0.017)	0.042* (0.019)	-0.012 (0.016)	-0.026 (0.017)	-0.004 (0.012)	-0.056*** (0.011)	-0.066*** (0.017)	-0.109*** (0.016)
Routine	-0.850*** (0.067)	-1.108*** (0.065)	-0.816*** (0.064)	-1.165*** (0.066)	-0.222*** (0.014)	-0.287*** (0.014)	-0.313*** (0.024)	-0.400*** (0.023)
Task discretion	0.432*** (0.039)	*No Ind. Path*	0.499	*No Ind. Path*	0.276*** (0.017)	*No Ind. Path*	0.217*** (0.018)	*No Ind. Path*
Goodness-of-fit statistics								
CFI	0.954				0.921			
RMSEA	0.05				0.047			
SRMR	0.04				0.036			

Notes: DV dependent variable. Underlined coefficient estimates indicate rejection of the null hypothesis of equality between groups. All continuous variables are z-standardised to have a mean of 0 and a standard deviation of 1. Controlled for educational attainment. Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Sources: UK Skills Survey (2006, 2012, 2017) for the UK and BIBB/BAuA Employment Survey (2006, 2012, 2018) for Germany; authors' calculations.

Online Supplement

Table S1: Factor analysis of all relevant skill items – the UK and Germany

The UK	**Factor 1**	**Factor 2**	**Factor 3**	**Factor 4**	**Factor 5**	**Uniq.**
Importance of						
… working out causes of problems	0.901					0.169
… spotting problems or faults	0.854					0.253
… thinking of solutions to problems	0.839					0.224
… analysing complex problems in depth	0.662					0.368
Influence personally have on						
… how to do the tasks		0.795				0.312
… what tasks to do		0.747				0.388
… quality standards to work to		0.710				0.480
… how hard to work		0.682				0.510
How much choice have over way in which		0.645				0.483
Importance of						
… physical strength			0.864			0.238
… physical stamina			0.859			0.254
… skill or accuracy using hands			0.798			0.322
… knowledge of use of operational tools			0.718			0.405
… counselling, and advising others				0.769		0.384
… dealing with people				0.699		0.462
… selling a product or service				0.650		0.484
… persuading or influencing others				0.577		0.422
… teaching people				0.552		0.495
How much variety in job					-0.673	0.414
How often work involves short and repetitive					-0.615	0.556
My job requires that I keep learning new					0.584	0.505
Importance of planning own activities		0.392			0.434	0.487
Importance of organising own time		0.353			0.392	0.536
Eigenvalues	6.000	3.056	1.952	1.684	1.159	
Germany	**Factor 1**	**Factor 2**	**Factor 3**	**Factor 4**	**Factor 5**	**Uniq.**
Confronted with new tasks	0.698					0.477
React to problems and solve them	0.650					0.536
Recognize and close your own gaps in	0.615					0.606
Work under strong deadline or performance	0.597					0.552
Improve existing procedures or try something	0.577					0.539
Organizing, planning and preparing work proc	0.424			0.356		0.601
Work standing up		0.708				0.383
Measuring, testing, quality control		0.658				0.487
Lift and carry heavy load		0.639				0.493
Monitoring, control of machines, plants,		0.636				0.483
Manufacturing, producing goods and		0.616				0.544
Influence the amount of work assigned to you			0.696			0.467
Decide for yourself when to take a break			0.674			0.490
Plan and schedule your own work yourself			0.648			0.473
Purchasing, procuring, selling				0.746		0.413
Advertising, Marketing, Public Relations, PR				0.613		0.543
Providing advice and information	0.434			0.559		0.456
Execution of work is prescribed in every					0.789	0.320
One and the same operation is repeated in					0.784	0.319
Eigenvalues	3.610	2.473	1.354	1.278	1.105	

Notes: Factor loadings estimated using the principal-component factor method. Orthogonal rotation applied. Weighted. Blanks represent abs(loadings) < 0.30.

Sources: UK Skills Survey (2006, 2012, 2017) for the UK and BIBB/BAuA Employment Survey (2006, 2012, 2018) for Germany; authors' calculations

Table S2a: Correlation matrix of individual-level predictors – the UK

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1. Computer use	1																		
Importance of																			
2. … spotting problems or mistakes	0.201	1																	
3. … working out causes of problems/mistakes	0.223	0.759	1																
4. … thinking of solutions to problems	0.303	0.631	0.754	1															
5. … counselling […]	0.217	0.164	0.171	0.238	1														
6. … dealing with people	0.256	0.142	0.143	0.223	0.505	1													
7. … selling a product or service	0.170	0.095	0.133	0.157	0.345	0.264	1												
8. … physical stamina	-0.293	0.086	0.076	0.011	0.032	-0.046	0.012	1											
9. … physical strength	-0.350	0.059	0.050	-0.038	-0.043	-0.098	-0.004	0.770	1										
10. How much variety exists in the job	-0.143	-0.011	-0.043	-0.130	-0.065	-0.097	-0.020	0.188	0.213	1									
11. How often work involves short repetitive tasks	-0.260	-0.192	-0.217	-0.318	-0.251	-0.284	-0.085	0.083	0.144	0.329	1								
Personal influence on																			
12. … how hard to work	0.099	0.152	0.158	0.197	0.129	0.145	0.107	-0.023	-0.028	-0.062	-0.230	1							
13. … how to do the task	0.150	0.157	0.194	0.266	0.157	0.183	0.117	-0.068	-0.081	-0.172	-0.341	0.444	1						
14. … what tasks to do	0.170	0.139	0.178	0.245	0.177	0.200	0.171	-0.078	-0.094	-0.146	-0.311	0.426	0.617	1					
15. Amount of choice over how to do the job	0.132	0.132	0.168	0.238	0.104	0.138	0.094	-0.108	-0.113	-0.187	-0.374	0.343	0.520	0.458	1				
Satisfaction with																			
16. … the opportunity to use abilities	0.098	0.131	0.171	0.217	0.157	0.170	0.057	-0.006	-0.041	-0.166	-0.362	0.226	0.285	0.274	0.301	1			
17. … the ability to use own initiative	0.081	0.152	0.182	0.242	0.148	0.160	0.068	-0.022	-0.048	-0.171	-0.352	0.294	0.386	0.357	0.407	0.746	1		
18. … the work itself	0.011	0.075	0.106	0.135	0.116	0.119	0.027	0.009	-0.017	-0.147	-0.310	0.199	0.212	0.209	0.256	0.593	0.555	1	
19. Education	0.394	0.107	0.124	0.240	0.175	0.217	0.038	-0.232	-0.310	-0.211	-0.269	0.081	0.157	0.144	0.147	0.043	0.042	-0.009	1

Sources: UK Skills Survey (2006, 2012, 2017); authors' calculations.

Table S2b: Correlation matrix of individual-level predictors – Germany

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1. Computer use	1																	
2. Purchasing, procuring, selling	0.037	1																
3. Advertising, marketing, public relations, PR	0.176	0.261	1															
4. Reacting to problems and solving them	0.232	0.095	0.179	1														
5. Recognising and closing own gaps in knowledge	0.207	0.060	0.156	0.357	1													
6. Execution of work is prescribed in every detail	-0.068	-0.074	-0.114	-0.070	-0.043	1												
7. The exact same operation is repeated in every detail	-0.135	-0.011	-0.138	-0.181	-0.155	0.381	1											
8. Being confronted with new tasks	0.256	0.036	0.162	0.330	0.321	-0.057	-0.224	1										
9. Improving existing procedures or trying something new	0.178	0.097	0.190	0.302	0.272	-0.125	-0.200	0.420	1									
10. Working while standing	-0.371	0.096	-0.072	-0.028	-0.052	0.108	0.100	-0.105	-0.009	1								
11. Lifting and carrying heavy loads	-0.370	0.086	-0.080	-0.029	-0.047	0.154	0.153	-0.084	-0.042	0.518	1							
12. Planning and scheduling own work oneself	0.253	0.103	0.163	0.210	0.162	-0.241	-0.170	0.219	0.262	-0.163	-0.165	1						
13. Influencing the amount of work assigned	0.083	0.122	0.153	0.123	0.111	-0.160	-0.123	0.138	0.214	-0.026	-0.053	0.330	1					
14. Deciding for oneself when to take a break	0.211	0.057	0.106	0.092	0.086	-0.147	-0.091	0.116	0.093	-0.274	-0.180	0.302	0.221	1				
15. Satisfaction with the type and content of work	0.105	0.052	0.097	0.106	0.087	-0.156	-0.143	0.135	0.158	-0.050	-0.082	0.160	0.141	0.103	1			
16. Satisfaction with opportunities for applying skills	0.096	0.046	0.082	0.123	0.098	-0.145	-0.135	0.157	0.174	-0.038	-0.069	0.169	0.156	0.111	0.576	1		
17. Satisfaction with work on the whole	0.059	0.034	0.059	0.031	0.033	-0.148	-0.082	0.070	0.106	-0.062	-0.105	0.144	0.160	0.122	0.509	0.471	1	
18. Education	0.312	0.004	0.204	0.252	0.197	-0.199	-0.310	0.259	0.231	-0.192	-0.283	0.234	0.129	0.123	0.081	0.064	0.025	1

Sources: BIBB/BAuA Employment Survey (2006, 2012, 2018); authors' calculations.

Table S3a: Detailed OLS regression results of total and direct effects of computer use on task discretion and job satisfaction – the UK

	Total effect on discretion	**Direct effect on discretion**	**Total effect on satisfaction**	**Direct effect on satisfaction**
Computer Use	0.092**	-0.068*	0.050	-0.079*
	(0.035)	(0.033)	(0.037)	(0.036)
Task indicators				
Cognitive-analytical		0.157***		0.091***
		(0.013)		(0.012)
Cognitive-interpersonal		0.097***		0.031*
		(0.013)		(0.014)
Physical		-0.006		0.022
		(0.014)		(0.014)
Routine		-0.242***		-0.240***
		(0.013)		(0.014)
Discretion				0.313***
				(0.013)
Educational attainment (reference: less-educated (ISCED 0–2))				
Intermediately educated (ISCED 3–4)	0.196***	0.160**	-0.156***	-0.234***
	(0.052)	(0.049)	(0.044)	(0.041)
Highly educated (ISCED 5+)	0.194***	0.107*	-0.292***	-0.418***
	(0.056)	(0.053)	(0.051)	(0.047)
Occupation (reference: managers)				
Professionals	-0.378***	-0.314***	-0.055	0.097**
	(0.035)	(0.035)	(0.041)	(0.038)
Technicians and associate professionals	-0.457***	-0.361***	-0.162***	0.051
	(0.038)	(0.037)	(0.041)	(0.038)
Clerical-support workers	-0.655***	-0.410***	-0.421***	-0.020
	(0.044)	(0.043)	(0.049)	(0.043)
Service- and sales workers	-0.694***	-0.487***	-0.372***	-0.006
	(0.040)	(0.040)	(0.046)	(0.044)
Skilled agriculture-, forestry-, and fishery workers	-0.407**	-0.260	-0.133	0.077
	(0.152)	(0.142)	(0.240)	(0.230)
Craft- and related-trades workers	-0.608***	-0.497***	-0.182***	0.047
	(0.049)	(0.050)	(0.051)	(0.049)
Plant- and machine operators and assemblers	-1.101***	-0.773***	-0.595***	-0.031
	(0.064)	(0.062)	(0.063)	(0.059)
Elementary occupations	-0.943***	-0.565***	-0.695***	-0.154*
	(0.054)	(0.058)	(0.060)	(0.064)
Industry (reference: agriculture and fishery)				
Energy and water	-0.095	-0.129	-0.118	-0.115
	(0.146)	(0.132)	(0.220)	(0.182)
Manufacturing	-0.223	-0.182	-0.195	-0.081
	(0.133)	(0.120)	(0.206)	(0.168)
Construction	-0.095	-0.139	0.049	0.051
	(0.139)	(0.126)	(0.208)	(0.171)
Distribution, hotels, & restaurants	-0.273*	-0.226	-0.197	-0.038
	(0.131)	(0.119)	(0.204)	(0.167)
Transport & communication	-0.402**	-0.382**	-0.088	0.075
	(0.138)	(0.126)	(0.208)	(0.170)
Banking, finance, & insurance, etc.	-0.282*	-0.259*	-0.136	-0.010
	(0.132)	(0.119)	(0.204)	(0.166)
Public admin, education, & health	-0.252	-0.258*	-0.034	0.046
	(0.132)	(0.119)	(0.204)	(0.166)
Other services	-0.128	-0.133	0.069	0.124
	(0.137)	(0.125)	(0.208)	(0.172)

	Total effect on discretion	Direct effect on discretion	Total effect on satisfaction	Direct effect on satisfaction
Further-training participation	0.073**	-0.010	0.052*	-0.029
	(0.023)	(0.022)	(0.026)	(0.024)
Age (reference: 20–35)				
35–49	0.151***	0.091***	0.119***	0.018
	(0.026)	(0.025)	(0.029)	(0.026)
> 49	0.183***	0.129***	0.164***	0.057*
	(0.029)	(0.028)	(0.031)	(0.028)
Female	0.002	0.035	0.124***	0.156***
	(0.025)	(0.024)	(0.028)	(0.026)
Non-white workers	-0.166***	-0.095*	-0.172***	-0.063
	(0.042)	(0.039)	(0.044)	(0.042)
Survey year (reference: 2006)				
2012	-0.031	-0.005	-0.115***	-0.081**
	(0.027)	(0.026)	(0.029)	(0.026)
2017	-0.069**	-0.039	0.025	0.068**
	(0.025)	(0.024)	(0.026)	(0.024)
Constant	0.440**	0.484***	0.401	0.267
	(0.144)	(0.131)	(0.207)	(0.173)
Observations	11,283	11,283	11,283	11,283
R-squared	0.139	0.226	0.074	0.258

Notes: All continuous index variables are predicted scores from factor analyses. Sampling weights included. Robust standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Sources: UK Skills Survey (2006, 2012, 2017); authors' calculations.

Table S3b: Detailed OLS regression results of total and direct effects of computer use on task discretion and job satisfaction – Germany

	Total effect on Discretion	Direct effect on Discretion	Total effect on Satisfaction	Direct effect on Satisfaction
Computer use	0.225***	0.121***	0.093***	0.006
	(0.017)	(0.017)	(0.016)	(0.016)
Task indicators				
Cognitive-analytical		0.194***		0.088***
		(0.007)		(0.008)
Cognitive-interpersonal		0.113***		0.020**
		(0.006)		(0.006)
Physical		-0.090***		-0.067***
		(0.007)		(0.007)
Routine		-0.140***		-0.117***
		(0.006)		(0.006)
Discretion				0.160***
				(0.007)
Educational attainment (reference: less-educated (ISCED 0–2))				
Intermediately educated (ISCED 3–4)	0.177***	0.132***	-0.136***	-0.181***
	(0.033)	(0.032)	(0.031)	(0.031)
Highly educated (ISCED 5+)	0.302***	0.142***	-0.208***	-0.345***
	(0.035)	(0.033)	(0.034)	(0.034)
Occupation (reference: managers)				
Professionals	-0.249***	-0.203***	-0.060*	-0.022
	(0.020)	(0.020)	(0.030)	(0.029)
Technicians and associate professionals	-0.316***	-0.134***	-0.216***	-0.083**
	(0.020)	(0.020)	(0.030)	(0.030)
Clerical-support workers	-0.456***	-0.207***	-0.373***	-0.181***
	(0.024)	(0.024)	(0.034)	(0.033)
Service- and sales workers	-0.497***	-0.263***	-0.291***	-0.078*
	(0.027)	(0.027)	(0.036)	(0.035)
Skilled agriculture-, forestry-, and fishery workers	-0.462***	-0.142*	-0.124	0.127
	(0.071)	(0.068)	(0.076)	(0.078)
Craft- and related-trades workers	-0.705***	-0.381***	-0.289***	-0.013
	(0.027)	(0.028)	(0.035)	(0.035)
Plant- and machine operators and assemblers	-0.919***	-0.504***	-0.496***	-0.149***
	(0.034)	(0.035)	(0.040)	(0.040)
Elementary occupations	-0.891***	-0.402***	-0.612***	-0.232***
	(0.040)	(0.040)	(0.044)	(0.045)
Industry (reference: agriculture/mining/electricity/gas & water supply)				
Other manufacturing	-0.137***	-0.110**	-0.017	0.028
	(0.037)	(0.035)	(0.038)	(0.037)
Manufacturing of basic metals and fabricated metal products and electrical equipment	-0.279***	-0.264***	-0.009	0.040
	(0.035)	(0.034)	(0.037)	(0.036)
Construction	0.038	0.018	0.094*	0.089*
	(0.041)	(0.040)	(0.042)	(0.041)
Trade	-0.235***	-0.227***	-0.108**	-0.041
	(0.039)	(0.037)	(0.040)	(0.039)
Personal-service activities	-0.185***	-0.178***	-0.043	-0.002
	(0.038)	(0.036)	(0.039)	(0.038)
Financial intermediation	0.004	-0.014	-0.029	-0.048
	(0.038)	(0.037)	(0.043)	(0.042)
Business activities	-0.004	-0.029	-0.092*	-0.114**
	(0.037)	(0.036)	(0.042)	(0.041)
Public administration/education	-0.242***	-0.215***	-0.015	0.038
	(0.034)	(0.033)	(0.036)	(0.035)

	Total effect on Discretion	Direct effect on Discretion	Total effect on Satisfaction	Direct effect on Satisfaction
Health- and social work	-0.335***	-0.257***	-0.009	0.100**
	(0.037)	(0.036)	(0.038)	(0.037)
Further-training participation	0.172***	0.089***	0.170***	0.108***
	(0.013)	(0.012)	(0.013)	(0.013)
Age (reference: 20–35)				
36–50	0.042**	0.070***	0.012	0.019
	(0.014)	(0.014)	(0.015)	(0.015)
51–65	0.088***	0.135***	0.034*	0.038*
	(0.016)	(0.015)	(0.016)	(0.016)
Female	-0.125***	-0.102***	0.028*	0.063***
	(0.013)	(0.012)	(0.014)	(0.013)
Migration background	0.025	0.051**	-0.147***	-0.134***
	(0.020)	(0.019)	(0.021)	(0.020)
Survey year (reference: 2006)				
2012	0.034*	0.013	0.021	0.008
	(0.013)	(0.013)	(0.013)	(0.013)
2018	-0.060***	-0.088***	0.062***	0.057***
	(0.014)	(0.014)	(0.015)	(0.015)
Constant	0.227***	0.159**	0.240***	0.163**
	(0.052)	(0.051)	(0.058)	(0.057)
Observations	49,446	49,446	49,446	49,446
R-squared	0.153	0.220	0.046	0.101

Notes: All continuous index variables are predicted scores from factor analyses. Sampling weights included. Robust standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Sources: BIBB/BAuA Employment Survey (2006, 2012, 2018); authors' calculations.

Table S4a: The UK – Descriptive statistics of the individual-level variables used

	Mean	SD	Min	Max
Job satisfaction (fac)	0	1.000	-4.520	1.513
Satisfaction with the opportunity to use own abilities	0.748	0.199	0	1.000
Satisfaction with being able to use own initiative	0.763	0.188	0	1.000
Satisfaction with the work itself	0.737	0.183	0	1.000
Task discretion (fac)	0	1.000	-3.355	1.351
Personal influence on how hard to work	0.793	0.239	0	1.000
Personal influence on what tasks to do	0.629	0.308	0	1.000
Personal influence on how to do the tasks	0.726	0.277	0	1.000
Amount of choice over how the job is done	0.696	0.276	0	1.000
Cognitive-analytical tasks (fac)	0	1.000	-3.032	1.075
Importance of spotting problems or mistakes	0.765	0.256	0	1.000
Importance of working out causes of problems	0.709	0.284	0	1.000
Importance of thinking of solutions to problems	0.739	0.272	0	1.000
Cognitive-interpersonal tasks (fac)	0	1.000	-3.075	1.274
Importance of counselling, advising, or caring for customers and clients	0.641	0.369	0	1.000
Importance of dealing with people	0.878	0.214	0	1.000
Importance of selling a product or service	0.425	0.397	0	1.000
Physical tasks (fac)	0	1.000	-1.299	1.714
Importance of physical stamina	0.459	0.353	0	1.000
Importance of physical strength	0.403	0.351	0	1.000
Routine tasks (fac)	0	1.000	-1.957	2.364
How much variety exists in the job	0.316	0.283	0	1.000
How often the work involves short and repetitive tasks	0.589	0.281	0	1.000
Working with computers	0.789	0.408	0	1.000
Education				
less-educated (ISCED 0–2)	0.071	0.256	0	1.000
intermediately educated (ISCED 3–4)	0.507	0.500	0	1.000
highly educated (ISCED 5+)	0.422	0.494	0	1.000
Occupation (ISCO-08)				
Managers	0.164	0.370	0	1.000
Professionals	0.165	0.371	0	1.000
Technicians and associate professionals	0.124	0.330	0	1.000
Clerical-support workers	0.129	0.335	0	1.000
Service- and sales workers	0.184	0.388	0	1.000
Skilled agricultural-, forestry-, and fishery workers	0.005	0.068	0	1.000
Craft- and related-trades workers	0.074	0.262	0	1.000
Plant- and machine operators and assemblers	0.063	0.243	0	1.000
Elementary occupations	0.092	0.289	0	1.000
Industry (SIC92)				
Agriculture & fishing	0.009	0.092	0	1.000
Energy & water supply	0.012	0.107	0	1.000
Manufacturing	0.132	0.338	0	1.000
Construction	0.045	0.207	0	1.000
Distribution, hotels, & restaurants	0.183	0.387	0	1.000
Transport & communication	0.061	0.239	0	1.000
Banking, finance, & insurance	0.177	0.382	0	1.000
Public admin, education, & health	0.341	0.474	0	1.000
Other services	0.041	0.198	0	1.000
Attendance of job-related training in the previous year	0.454	0.498	0	1.000
Age				
20–34	0.347	0.476	0	1.000
35–49	0.383	0.486	0	1.000
> 49	0.270	0.444	0	1.000
Gender	0.491	0.500	0	1.000
Non-white	0.100	0.300	0	1.000
Survey year				
2006	0.331	0.471	0	1.000
2012	0.322	0.467	0	1.000
2017	0.348	0.476	0	1.000

Sources: U.K. Skill Survey (2006, 2012, 2017); authors' calculations. Weighted.

Table S4b: Germany – Descriptive statistics of the individual-level variables used

	Mean	SD	Min	Max
Job satisfaction (fac)	0	1	-4.234	1.620
Satisfaction with type and content of work	0.733	0.199	0	1
Satisfaction with opportunities for applying skills	0.707	0.224	0	1
Satisfaction with work on the whole	0.729	0.203	0	1
Task discretion (fac)	0	1	-2.663	1.144
Planning and scheduling own work oneself	0.812	0.312	0	1
Influence on the amount of work assigned	0.546	0.387	0	1
Deciding for oneself when to take a break	0.703	0.397	0	1
Cognitive-analytical tasks (fac)	0	1	-3.391	1.485
Reacting to problems and solving them	0.799	0.283	0	1
Recognising and closing own gaps in knowledge	0.613	0.297	0	1
Being confronted with new tasks	0.717	0.280	0	1
Improving existing procedures or trying something new	0.643	0.293	0	1
Cognitive-interpersonal tasks (fac)	0	1	-0.909	2.572
Purchasing, procuring, selling	0.308	0.395	0	1
Advertising, marketing, public relations, PR	0.222	0.330	0	1
Physical tasks (fac)	0	1	-1.676	1.327
Working while standing	0.703	0.372	0	1
Lifting and carrying heavy loads	0.405	0.394	0	1
Routine tasks (fac)	0	1	-2.094	1.325
Execution of work is prescribed in every detail	0.529	0.356	0	1
The exact same operation is repeated in every detail	0.695	0.353	0	1
Working with computers	0.660	0.474	0	1
Education				
less-educated (ISCED 0–2)	0.063	0.243	0	1
intermediately educated (ISCED 3–4)	0.630	0.483	0	1
highly educated (ISCED 5+)	0.307	0.461	0	1
Occupation (ISCO-08)				
Managers	0.045	0.206	0	1
Professionals	0.182	0.386	0	1
Technicians and associate professionals	0.234	0.424	0	1
Clerical-support workers	0.114	0.318	0	1
Service- and sales workers	0.122	0.327	0	1
Skilled agricultural-, forestry-, and fishery workers	0.010	0.100	0	1
Craft- and related-trades workers	0.158	0.364	0	1
Plant- and machine operators and assemblers	0.077	0.267	0	1
Elementary occupations	0.059	0.236	0	1
Industry (NACE)				
Agriculture/mining/electricity/gas & water supply	0.029	0.167	0	1
Other manufacturing	0.117	0.321	0	1
Manufacturing basic metals and fabricated metal products and	0.184	0.388	0	1
Construction	0.061	0.239	0	1
Trade	0.099	0.298	0	1
Personal-service activities	0.114	0.318	0	1
Financial intermediation	0.035	0.183	0	1
Business activities	0.070	0.256	0	1
Public administration/education	0.167	0.373	0	1
Health- and social work	0.125	0.331	0	1
Attendance of job-related training in the previous 2 years	0.598	0.490	0	1
Age				
20–35	0.301	0.459	0	1
36–50	0.427	0.495	0	1
51–65	0.272	0.445	0	1
Gender (male)	0.546	0.498	0	1
Migration background	0.157	0.364	0	1
Survey year				
2006	0.343	0.475	0	1
2012	0.321	0.467	0	1
2018	0.336	0.472	0	1
Observations	49,446			

Sources: BIBB/BAuA Employment Survey (2006, 2012, 2018); authors' calculations. Weighted.