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# How computerisation is transforming jobs

## Evidence from Eurofound's European Working Conditions Survey

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# How computerisation is transforming jobs: Evidence from Eurofound's *European Working Conditions Survey*

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## Abstract

This paper investigates changes in the task content, methods and tools of European jobs from 1995 to 2015. Drawing on the taxonomy of tasks proposed by Bisello and Fernández-Macías (2016), this work tries to better understand whether changes in the average intensity of tasks performance are the result of changes in the shares of employment across jobs, or changes in the task content within-jobs, or both. The main findings from a combined analysis of the European Working Conditions Survey (EWCS) and European Jobs monitor data (EJM) suggest that jobs with more social task content expanded relative to the rest, but this is in contrast with a decline in the amount of social tasks people actually do in those (and other) jobs over the same period. A similar contradictory trend can be observed in terms of routine tasks, with compositional and intrinsic changes going in opposite directions: an actual increase in the total levels of routine at work is recorded, notwithstanding marginal compositional declines. The implications of these findings in the context of the current debate on the impact of technological change on employment are discussed.

**Keywords**: Tasks, Technical Change, Structural Change, Labour Markets, Europe, Occupations.

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## Contents

## Introduction

The effects of the digital revolution sparked by the introduction of microchips in the 1970s are still felt today. The continuous increase in performance and decrease in cost of microprocessors facilitated a fast adoption of different digital technologies such as the personal computer, the internet and mobile phones, among many others. The use of microchips in computers and other digital devices enables fast and cheap processing of information which, combined with other technologies, is transforming the economy. Today, the use of computer in our economy is pervasive. According to the Digital Economy and Society data[1] (DESA 2018), in 2018 98% of enterprises[2] in the European Union used computers and 97% had internet access. Around 60% of all individuals active in the labour market used computers, laptops, smartphones, tablets or other portable devices at work.

The process of computerisation that took place in the last decades, together with the most recent diffusion of automation (both software and robots), lead to the substitution of human input to perform specific types of tasks within production and distribution process (a process defined as automation of labour). Theoretical and empirical studies suggest that jobs with high routine task content are much more likely to be automated because they are easier to codify and therefore can be accomplished by machines (Information and Communication Technologies, ICT) following explicit programmed rules (Autor et al., 2003). On the contrary, jobs primarily characterised by tasks requiring a high degree of intellectual skills, such as finding solutions to complex problems and creativity, exhibit complementarity between these tasks and IT tools. Similarly, jobs requiring direct physical proximity, flexible interpersonal communication and more in general social skills - which are typical of services – also tend to face lower risks of substitution.

However, predicting what jobs may be more at risk of automation on the basis of their current task composition and intensity only gives a partial assessment of the potential effect of digital technologies on work and employment. Indeed, technological transformations not only determine changes in the employment shares across jobs based on their task content but can also contribute to changes in the task content itself over time. In most cases, machines replace specific tasks but not others, changing the contents of jobs and occupations. For instance, the introduction of ATMs replaced a large part of the tasks previously performed by bank clerks, but rather than the occupation of bank clerk disappearing as such, it changed its task content (increasing its customer service orientation, for instance). In Europe, for 21% of individuals who, at work, use any type of computers, portable devices or computerised equipment or machinery, the main job tasks changed as a result of the introduction of new software or computerised equipment (DESA 2018).

Against this background, this working paper aims at analysing empirically the task-structure dynamics of European jobs. The investigation focuses on the evolution of the task content, methods and tools in Europe in the last 20 years. In particular, by expanding previous work conducted in the context of the European Jobs Monitor (see Eurofound, 2016), it tries to better understand whether changes in the average intensity of tasks are the result of changes in the shares of employment across jobs (for instance, if jobs that involve physical tasks have declined in relative terms in recent years) or changes in the averages within-jobs (for instance, if jobs are requiring fewer physical tasks

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[1] https://ec.europa.eu/eurostat/web/digital-economy-and-society/data/database

[2] Without financial sector, 10 persons employed or more.

to be performed), or both. Using an econometric approach, it also tries to investigate more formally the relationship between computer use at the task contents and methods. The empirical analysis also provides a detailed breakdown of changes from a sectoral, occupational and job perspective which further shed lights on the impact of automation on employment.

The remainder of the paper is organised as follows. The next Section presents a brief literature review of the tasks approach to labour markets and empirical applications looking at within-occupation heterogeneity of the task composition and its evolution over time. Section 3 illustrates the taxonomy that is used in this paper to describe the distribution and evolution of employment across different types of task and to assess the potential impact of automation on the employment structure. Section 4 presents an application of the taxonomy of tasks to European data, with a detailed description of the sources and the construction of each task index. Section 5 looks at how the content, methods and tools of work evolved in Europe over the period 1995-2015. By means of a decomposition analysis, this Section discusses to what extent the overall changes in the values of the task indices can be attributed to employment shifts between jobs or to within-jobs dynamics. To complement and further investigate some of the findings, this Section also tries to establish a more direct link between changes in computer use and changes in the task content and methods. Section 6 deepens into the changes in task measures in different ways, by exploring more specifically trends at the sectoral and occupational level. It also illustrates these changes for some selected jobs, which are understood as a combination of sectors and occupations, by complementing quantitative information with some qualitative assessment. Finally, Section 7 presents a summary of the main findings and concluding remarks.

## Literature review

### The 'task-approach' to labour markets

There is abundant economic literature highlighting the role of technological shocks as a driving force behind changes in the employment structure. While early studies focused more on the supply side, explaining how technological change would either complement or substitute workers on the basis of their skills levels[3], more recent literature advanced the hypothesis that workplace tasks are a better unit of analysis to investigate the impact of computerisation on employment[4].

This so called 'task-approach' to labour markets allows indeed for a more nuanced and detailed understanding of which specific aspects of human work can be more easily automated. It shows that the effect of technological change on labour demand depends on the type of task content involved in a certain job (so, essentially what people actually do at work), rather than exclusively on the workers' skills. While skills are the human abilities to perform specific tasks, tasks are 'units of work activity that produce output' (Autor, 2013). This definition reflects the fact that conceptually a task can be performed either by a worker or by a machine: which one of the two factors, whether labour or capital, will be adopted to perform a task in a production process does not only depend on the technological feasibility, but also on the principle of comparative advantage and on the social organisation of the production process.

Tasks are coherently bundled into jobs[5], which also represent positions within the social structure of productive organisations, giving access to differential social power, resources and life chances. So, while one may think about tasks as units of labour (or machine) input from the perspective of production, jobs are the unit of labour demand from the perspective of firms and workers.

### The routinisation hypothesis

The concept of routine tasks has become prominent in research and policy debates on the future of work. An influential 2003 MIT paper (Autor et al., 2003) argued that computerisation facilitates the automation of tasks and jobs involving a high degree of routine, which are usually more frequent in the middle of the occupational structure. Routine tasks are indeed easier to codify and therefore 'can be accomplished by machines following explicit programmed rules' (p. 1283). This early definition reveals the theoretical challenge posed by the concept of routine itself, since it raises the question on what it is meant by 'explicit programmed rules'. Furthermore, it is tautological to explain the impact of technological change on jobs depending on their degree of routine, while at the same time defining routine tasks as those that are easier to be carried out by ICT machines (see also Fernández-Macías and Hurley, 2016).

[3] On the skill-biased technological change hypothesis, see for instance: Bound and Johnson (1992); Katz and Murphy (1992); Berman et al. (1998); Machin and Van Reenen (1998); Goldin and Katz (1998).

[4] This is particularly relevant when discussing the polarisation of the employment structure (that is, a relative employment increase of low and high-paid jobs with respect to the middle-paid) that several advanced economies experienced in recent decades (see for instance Goos and Manning, 2007; Autor and Dorn, 2009; Goos et al., 2010; Fernández-Macías, 2012).

[5] Although in principle, one could also isolate tasks and particularly in the context of platform work, casual work or voucher-based work there is evidence of some trends of de-bundling and fragmentation of tasks.

## Classification of tasks

Apart from the categorisation of tasks into routine versus non-routine, Autor et al. (2003) introduce an additional distinction between the manual and the cognitive dimension of tasks. In the case of cognitive tasks the authors do not provide a definition, but a further breakdown into two subgroups of tasks: the analytical ones - mainly capturing reasoning skills – and interactive tasks – reflecting both interpersonal and managerial skills. While non-routine cognitive tasks - carried out mainly within managerial and professional occupations - are productive complements to computers, non-routine manual tasks have limited opportunities for either substitution or complementarity as they require eye-hand-foot coordination. On the contrary, routine tasks (both manual and cognitive) are relatively easier to substitute by ICT: the former category being typical of clerical and administrative occupations, the latter of production and operative occupations.

Based on examples such as the driverless cars described by Brynjolfsson and McAfee (2011), Frey and Osborne (2013) argue that also tasks currently considered non-routine could be automated in the future: automation will depend on the capability of codifying the rules governing those tasks. They identify three engineering bottlenecks: perception and manipulation, creative intelligence tasks (for example creating artefacts, poems, and paintings) and social intelligence tasks (for example 'real time recognition of natural human emotions' or verbal communication). These bottlenecks will be overcome with advances in programming and pattern recognition but according to the authors these events are not likely to occur in the next decade or two. Hence the importance of studying the task content of a job: a job's susceptibility to automation depends not only on its degree of routine but on the presence of tasks included in the engineering bottlenecks (Frey and Osborne, 2013).

Starting from the Autor et al. (2003) seminal paper, the literature on 'task-biased' technological change has rapidly evolved and expanded. This has contributed both to redefining some categories of tasks (vis-à-vis the original classification) and to problems in the operationalisation of the concept of routine. With respect to the first point, the definition and scope of social interaction varies among studies, with some focusing more on internal interaction, others on external (or both). Goos et al. (2009, 2010) refer for instance only to those tasks that involve social interaction with clients. Similarly, Blinder (2006, 2009) also refers to those work activities that involve dealing with clients and customers and require direct physical proximity or flexible interpersonal communication. Deming (2017) classifies social tasks as those requiring cooperation and interaction with colleagues and/or dependants. Spitz-Oener (2006) includes in the definition of interactive tasks both aspects of internal and external interaction (such as managing personnel or advising customers, respectively). Eurofound (2016) provides instead a much finer breakdown, differentiating social tasks into four subcategories: serving/attending, teaching/training/coaching, selling/influencing, managing/coordinating.

Regarding the operationalisation of the concept of routine tasks, the conceptual difficulties (related for instance to subjective connotations of the term as 'boring' or 'monotonous') make its measurement very difficult (Autor, 2013, p. 16). The actual operationalisation of the concept of routine in the literature is often inconsistent and based on quite diverse measures of job attributes (Fernandez-Macias and Hurley, 2013). In some operationalisations, it includes for instance measures of 'finger dexterity' and 'operating or controlling machines', two aspects which are very unlikely to capture the same concept. A critical review of the operationalisation of the concept of routine for occupational task measurement in four influential papers is presented in Fernandez-Macias and Hurley (2013, p. 584-585).

## Within-occupation heterogeneity of the task composition

An important aspect that is well-reported in several studies is that, within the same broad occupational groups, there is a significant heterogeneity in the tasks performed by workers (Autor and Handel, 2013; Arntz et al., 2016; Pouliakas and Russo, 2015). Indeed, each job is characterised by a particular combination of tasks across different dimensions. This means that each worker performs a variety of tasks on the job, although to a different extent depending on the role and job description. This 'task bundling' can be very specific and sometimes even counter-intuitive: for instance, despite the generally negative association between physical and intellectual tasks, there is a significant association between physical dexterity and technical literacy for some particular types of jobs, such as health professionals and associate professionals, engineering associate professionals and metal industrial workers. What this means is that the different types of tasks cannot be understood in isolation and that a key factor for the resilience of particular occupations to technical change is not so much the types of task content that they do, but the variety of tasks they typically involve (Eurofound, 2016).

This is a crucial element to take into account when estimating the potential for automation of jobs, which otherwise could potentially exaggerate the extent of job displacement. Arntz et al. (2016) use PIAAC[6] survey data to assess the potential of automation taking into account the heterogeneity of workers' tasks within occupations. Their estimates of the probability of automation of jobs are far lower than those of Frey and Osborne (2017) which consider the entire occupations as units of analysis and therefore assume that these, rather than single job-tasks, are fully substituted by technology. Yet, because even those occupations often considered as having a high potential to be automated still can contain an important share of tasks that are more difficult to be substituted, the estimates of Arntz et al. (2016) drop from half of the workforce to around 10% (with the highest and lowest share recorded in Korea and Austria, 6% and 12% respectively).

## Within-occupation task changes over time

While most of the literature focused mainly on how technological change drives changes in the labour market structure (in terms of job creation and destruction) by applying task indices to employment data, the evidence of the evolution of tasks within jobs over time is much more limited.

Indeed, while there is agreement that labour in routine-intensive tasks and occupations is declining because of a higher risk of automation, it is far less understood how computerisation affects the task composition within jobs. This is mainly due to data limitations which make it more challenging to investigate changes in the task content of jobs over time.

Autor et al. (2003) differentiate between the change in task indices at the intensive margin (within-occupations) and at the extensive margin (between-occupations), finding that both of them suggest de-routinisation trends. However, the limited validity of using the Dictionary of Occupational Titles (DOT) to compare evolution of tasks over time has been acknowledged by Autor (2013) himself, since the successive versions are updates of the database rather than successive waves of the same.

[6] The Programme for the International Assessment of Adult Competencies (PIAAC) developed and conducts the Survey of Adult Skills. The survey measures adults' proficiency in key information-processing skills - literacy, numeracy and problem solving in technology-rich environments - and gathers information and data on how adults use their skills at home, at work and in the wider community.

In an update of his work made 10 years later, Autor himself investigates only changes at the extensive margin (Autor and Price, 2013).

Their result is later confirmed by Spitz-Oener (2006) for the (western) German economy using individual-level data[7]. The authors show that within-occupation task shifts over the period 1979-1999 accounted for a lot more than the between-occupation change. For instance, task changes within-occupations represent around 85% of aggregate changes in the analytical task measures, while between-occupations changes account for only 15%. In case of interactive and routine cognitive tasks, the within-occupation shift is even more pronounced, representing 87% and 99% of total change respectively.

Akçomak et al. (2016) analyse between and within-occupation task changes in the UK between 1997 and 2006. They find that social tasks increase at the extensive margin but decline at the intensive one; the overall positive change of computerisation is mostly accounted for by within-occupation change rather than by between-occupation change; the decline of routine tasks[8] is documented both at the extensive margin and the intensive margin, but with the latter having an effect of around half of the size compared to the former.

The same methodology[9] is later adopted by Hardy et al. (2018), focusing on Central-Eastern Europe (CEE) countries and comparing them to Western European ones. The authors find an overall growth of non-routine cognitive tasks and a decline of manual tasks, but different patterns regarding routine cognitive tasks: rising in CEE countries while declining in Western European ones. A decomposition analysis is performed to disentangle the determinants of the overall changes in tasks: changes in the labour force structure (taking into account both occupational and sectoral changes); within-occupation changes in the task content; changes in the educational structure[10] and their interaction. Overall, the latter appears to be the most important factor determining the shift from routine to non-routine tasks in all the countries analysed, followed by structural change (in particular in CEE countries due to the decline of the agricultural sector). The within-occupation tasks change, instead, only played a role in the evolution of routine cognitive tasks and a minor positive effect on non-routine manual tasks (this was anyway more than offset by the other effects).

[7] And thus being able to use more detailed data from the German Federal Institute for Vocational Training (Bundesinstitut für Berufsbildung; BIBB) and the Research Institute of the Federal Employment Service (Institut für Arbeitsmarkt- und Berufsforschung; IAB), carried on in four waves (1979, 1985/1986, 1991/1992, 1998/1999).

[8] The operationalisation of routine tasks is very different from the rest of the literature, as also measured by a correlation with other routine indices of 0.4-0.5, mainly due to different variables available in the datasets: variables used to measure routine are mainly problem/errors/fault checking and simple calculations, against the non-routine tasks that include social tasks, specialist knowledge, writing and reading long documents.

[9] And therefore the issue when using two different versions the O*NET database in 2003 and 2014 to analyse changes over time (Autor, 2013).

[10] Change in educational structure is added, differently from the rest of the literature, in order to take into account also the labour supply side.

## A taxonomy of tasks: content, methods and tools of work

From a purely technical perspective, the production process can be seen as a combination of different inputs into outputs which have economic value. A task is a specific action of transformation or combination carried out by human operators or machines within the production process. Each specific task can be carried out in many different ways and one can define skills as the abilities and knowledge which are necessary to do a task well, which can be acquired through learning (in theory and/or practice). It is therefore possible to construct a taxonomy of tasks according to the types of skills they require. Since the tasks are bundled in jobs/occupations, such a taxonomy can be used to describe the distribution of employment across different types of tasks, using information on the occupational structure of the economy. Since the skills requirement of tasks tend to be associated with different automation suitability levels, that taxonomy can be used to assess the potential impact of existing or forthcoming technologies on the labour market.

In previous Eurofound work, a task taxonomy which tries to be more comprehensive and detailed than previous proposals has been proposed (Eurofound, 2016). It differentiates between task contents on the one hand, methods and tools on the other. In very simple terms, one can think about those two axes as the *what* and the *how* of work activity. The task content is mostly dependent on *what* is being produced (or rather, transformed in the production process), and therefore also on the structure of demand and needs that are satisfied by economic activity. The type of task contents will tend to be associated, for instance, to the economic sector to which the work activity belongs: thus, interpersonal and service tasks are (obviously) more frequent in services sectors, while manual tasks are more frequent in goods-producing sectors such as agriculture and manufacturing, and so on. However, the complexity of contemporary production processes means that the link between the actual tasks performed by workers and the final output of the overall production process is significantly blurred: there are many intermediate and meta-tasks which only have an indirect relation with the actual output.

The methods and tools of work, on the other hand, are less dependent on what is being produced and more on *how* it is produced: on the technology and social organisation of production. Therefore, they are more historically and geographically contingent. For the production of the same goods or services, different societies or organisations can use very different methods and tools. It is important to note that in this classification, the level of routine of the task belongs in this axis and not in the axis of task content. The level of routine involved in a task is the result of the unfolding of the division of labour and work organisation, not something dictated by what is being produced. The replacement of labour input by capital for the performance of routine tasks would therefore just be a further change in the division of labour and work organisation from this perspective.

### Direct effect: the impact of automation on the task content

The taxonomy of task contents (the left-hand panel of Table 1) is based on the object of work as transformative activity and on the skills typically required. At the highest level of generality, this taxonomy differentiates physical tasks (whose object is things), intellectual tasks (whose object is ideas) and social tasks (whose object is people). Within each of those high-level categories, different sub-categories of tasks are differentiated on the basis of their typical skills requirements. Although there is an obvious arbitrary element in the selection of categories and the boundaries between them, the taxonomy tries to cover the main categories identified in the specialised literature on this subject

(Eurofound, 2016). However, the main interest of this taxonomy is that one can try to map recent technological developments to it, in order to infer their potential impact on employment.

*Table 1: Eurofound (2016) task framework*

| **A. In terms of the content:** | **B. In terms of the methods and tools of work:** |
|---|---|
| 1. **Physical tasks:** aimed at the physical manipulation and transformation of material things:<br>a. *Strength*<br>b. *Dexterity*<br><br>2. **Intellectual tasks:** aimed at the manipulation and transformation of information and the active resolution of complex problems:<br>a. *Information processing:*<br>I. Literacy:<br>i. Business<br>ii. Technical<br>iii. Humanities<br>II. Numeracy*:*<br>i. Accounting<br>ii. Analytic<br>b. *Problem solving:*<br>I. Information gathering and evaluation of complex information.<br>II. Creativity and resolution.<br><br>3. **Social tasks:** whose primary aim is the interaction with other people:<br>a. *Serving/attending*<br>b. *Teaching/training/coaching*<br>c. *Selling/influencing*<br>d. *Managing/coordinating* | 1. **Methods:** forms of work organisation used in performing the tasks:<br>*a. Autonomy*<br>*b. Teamwork*<br>*c. Routine*<br>I. Repetitiveness<br>II. Standardisation<br><br>2. **Tools:** type of technology used at work:<br>*a. Machines* (excluding ICT)<br>*b. Information and communication technologies.*<br>I. Basic ICT<br>II. Programming |

Physical tasks involving *strength* (pure exertion of muscular power) is probably the category of labour input that has been most significantly replaced by technological change since the origins of human civilisation (even before machines, the domestication of animals enabled a very significant reduction of this kind of task input). On the contrary, the automation of physical *dexterity* is much more complicated, especially if it requires hand-eye coordination (as it usually does) in unstructured environments. Advanced sensors, digitally enabled machinery and AI are advancing significantly the feasibility of automating dexterity tasks, though it is still far from wide adoption.

The automation of *information processing* tasks has been rather significant in some cases and very limited in others. In particular, tasks which involve the *processing of encoded information* (text and numbers) without much problem solving associated (especially, administrative tasks) have been already automated to a large extent with the diffusion of computers. Tasks which involve not only processing but the *creative manipulation* of text and numbers are much more difficult to automate, although recent advances in AI[11] and machine learning (ML) may be rapidly changing this. Tasks which involve the *processing of uncodified information*, especially when it is ambiguous or unstructured, seems much more difficult even with the most recent technological advances. *Problem solving* tasks seem also generally safe from automation in the short and medium run, unless these tasks refer to problem solving with very clearly defined parameters, within clear boundaries and with clear objectives (for instance, the problem solving typically involved in board games such as chess or go). Most of the problem solving that exists in the real economy involves vague or undefined parameters, problems, rules and even objectives, which are beyond the capabilities of even the most advanced AI systems.

Finally, *social tasks* in general are also far from being automatable to the extent that the object of the task is a social relation as such (be it learning, persuading, etc.). If the object of the task is a social relation, only machines that can pass as humans in a reasonably satisfactory way can do them. There are, however, important exceptions and qualifications to this general point. For instance, some people may prefer that some types of social interactions are precisely carried out with a non-human agent (for instance, interactions that can involve shame or social reprobation). Also, there may be some types of tasks which would be classified as social and yet the social interaction is more a by-product than the object of the task itself. For instance, hairdressing involves social interaction (serving or attending), but for many people the social interaction aspect is secondary to the actual physical task of getting their hair done: therefore, and to the extent that the dexterity bottleneck can be overcome, many aspects of hairdressing could be automatable (although this would probably reconfigure the task contents of the hairdressing occupation - for instance, making it more focused on the creative aspects - rather than destroying it completely).

### Indirect effect of automation via work organisation

The second part of the framework refers to the methods and tools of work. This should be considered as a secondary axis of information on some attributes of work activity which are necessary for a better understanding of labour input in the production process. After all, work organisation and technology are key drivers (or determinants) of change in tasks rather than an aspect of it.

The category of ‘methods’ essentially refers to forms of work organisation, and is broken down into three categories: autonomy, which refers to the degree of latitude of workers in their tasks; teamwork, which refers to whether they work in direct collaboration with small groups of co-workers; and routine, referring to the degree of repetitiveness and standardisation of their work processes. The inclusion of routine in this domain of the framework may seem surprising, since in the literature it is often considered a type of task content (rather than a method). But the degree of routine involved in a task is not an aspect of task content as such, but an aspect of how such a task is organised in a particular work process (Eurofound, 2016). Therefore, the same type of task content can be carried out with a low or a high degree of routine.

The inclusion of elements of work organisation in the framework is relevant since the effect of technologies can be mediated by the way work is organised. For tasks to be suitable for automation, they need to be organised in a way that minimises the importance of human intelligence, generality and autonomy. If a new technology can be used to reorganise work in a more discrete, centralised

[11] By AI the authors refer to ‘narrow AI’ that is applications of techniques such as advanced deep learning or reinforcement learning.

and standardised way, it may indirectly expand significantly the range of tasks that can be automated. Digital labour platforms are a clear example of how more discrete and granular tasks, algorithmically centralised decision making and a standardisation of processes and outputs can expand possibilities of automation.

## An application of the task framework to European Working Conditions Survey data

### Sources

In order to investigate the evolution of the task content and methods in European jobs and its relationship with computerisation[12], European Working Condition Survey (EWCS) data are used. While from a conceptual perspective automation is a technological vector of change encompassing both the use of computers and robots, due to data limitation this paper will focus only on the first of the two elements.

The integrated EWCS dataset[13] contains information on the working conditions of Europeans based on face to face interviews with more than 40,000 individuals. Questions include themes such as employment status, working conditions, work-life balance, working time duration and organisation, as well as health and safety. The period from 1995 to 2015 is considered for the analysis, which is therefore restricted to EU-15 aggregate due to lack of data availability for all the current 28 Member States until 2005. Information on workers' sector and occupation is consistently available from 1995 to 2015 at the 1 digit level (ISCO-88 and NACE Rev. 1)[14].

Repeated waves of the EWCS allow analysing how the task composition of European jobs changed in the last 20 years, and relating these shifts to computerisation. Because trends in average tasks intensity at the job level may be the result of changes in tasks within jobs on the one hand, and changes in the structure of employment on the other, EWCS data are complemented with employment data from the EU-Labour Force Survey (EU-LFS). More specifically, employment data were compiled as part of the European Jobs Monitor (EJM), a longstanding and ongoing project conducted at Eurofound which tracks structural change in European labour markets[15]. It analyses shifts in the employment structure in the EU, classifying jobs by a combination of sector (NACE) and occupation (ISCO) and giving a qualitative assessment of these shifts using various proxies of job quality. The combined analysis of EWCS and EJM data allows to investigate within and between-jobs changes in the task structure (as described in the next Section).

The availability of individual-level data for European countries allows to investigate within-jobs task changes that cannot be explored with other widely used occupational databases, such as the US

[12] While from a conceptual perspective automation is a technological vector of change encompassing both the use of computers and robots, due to data limitation this paper will focus only on the first of the two elements.

[13] Available at UK data archive: https://discover.ukdataservice.ac.uk/catalogue/?sn=7363&type=Data%20catalogue

[14] Data related to the ISCO88 category '1' (armed forces) have not been included in the analysis.

[15] https://www.eurofound.europa.eu/it/observatories/emcc/european-jobs-monitor

Dictionary of Occupational Titles (DOT) and its successor the Occupational Information Network dataset (ONET)[16] , which also would impose the strong assumption of the same task composition in the US and Europe. On the basis of the literature reviewed, this is the first attempt to investigate the evolution of tasks in Europe using EWCS data between 1995 and 2015. The most similar precedent is Salvatori et al. (2018), which exploits EWCS data to measure changes in job quality and its relationship with computerisation.

## Construction of the task indices

A first empirical application of the original tasks framework was carried out building the full set of indices on information available in three different sources: the EWCS 2010 combined with ONET[17] and PIAAC[18] (Eurofound, 2016; Fernández-Macías et al., 2016). Given the scope of this study, it is only possible to replicate a reduced version of the tasks framework on the basis of the information available from 1995 to 2015 in the EWCS. Therefore, by construction the indices will be inevitably less rich due to fewer available variables from one single source and the need to ensure that these are consistent over time (exactly the same question used in each wave).

The indices adapted from the original task framework are listed in Table 2 and cover the following dimensions: physical tasks (strength); intellectual tasks (problem solving); social tasks (dealing with people); work organisation (autonomy, repetitiveness and standardisation), and technology (machines and ICT tools). Each index is formed by a set of questions which can be related to the type of tasks that the index seeks to measure. Following the approach used by Eurofound (2016), survey questions have been normalised on a scale that ranges from 0 to 1 indicating the intensity with which a task is performed (both categorical and binary variables were used).

The physical tasks index measures tasks that primarily require the exertion of energy and strength, such as assuming tiring or painful position, or carrying or moving heavy loads. The main difference compared with the original tasks framework is the exclusion of the variables on lifting people and standing, which are not consistently available since 1995, and the exclusion of the subcomponent of dexterity. The intellectual tasks index on problem solving results from the combination of two sub-indices: one measuring information gathering and evaluation of complex information (that is, whether the job involves learning new things and performing complex tasks); the other, creativity (measured as solving unforeseen problems on your own). The other subcomponent of intellectual tasks in the framework, information processing, is entirely missing in this adaptation because of data limitations.

Compared to the original task framework, the most important discrepancy from a conceptual point of view is related to the social dimensions. Indeed, this had a much finer breakdown into four different sub-categories (serving/attending, teaching/training, selling/influencing and managing/coordinating) due to the richness of ONET data, which is not possible to replicate exclusively with EWCS data for an analysis over time. The variable on 'dealing directly with people

[16] These are databases that compile standardised assessments from occupational specialists on a range of variables measuring task content, skill requirements, job characteristics, etc.

[17] Occupational information provided by the U.S. Department of Labor/Employment and Training Administration https://www.onetonline.org/

[18] OECD Survey on Adult Skills.

who are not employees at your workplace' was instead used as no other suitable variables were available for the full period considered.

The dimension on technology used at work is captured by two separate indices, one on ICT tools and the other on (non-ICT) machines. The question on the use of 'computers at work'[19] is used to create the index on ICT tools. The index on the 'use of machines at work' is instead built using information on exposure to machine vibrations and work determined by the pace of machines. While this is not ideal because it only captures indirectly the presence of machinery, this is the only available information. Some reflections are worth in relation to this point. First of all, the reduction of machine vibration exposure could be related to a decrease in the use of machines at work but also due to improvements in machines themselves. In the latter case, there could be scenario where the number of machines actually increased but vibrations diminished or a setting where the machine can be operated at a distance or remotely so the vibrations exposure is reduced. The same reasoning applies to the 'pace of the machine' variable: the reduction in this measure could depend on the fact that there are fewer machines, or on the improvement of machines which, for example, require less input or a less frequent input by the worker.

Finally, with respect to work organisation, two specific sub-dimensions were considered: autonomy at work and the extent of routine with which tasks are performed, both in terms of repetitiveness and standardisation. The index on autonomy captures the degree of latitude of workers in their tasks, methods and speed of work. The index on routine instead captures the degree of repetitiveness and standardisation of work processes. These two sub-dimensions are separately investigated throughout the paper.

*Table 2: Task indices*

| INDEX | DESCRIPTION |
|---|---|
| **Physical: strength** | Tasks that primarily require the exertion of energy and strength. |
| **Intellectual: problem solving** | Tasks that involve finding solutions to complex problems: information gathering and evaluation of complex information, and resolution. |
| **Social: dealing directly with people** | Tasks that require dealing directly with people who are not employees at the workplace such as customers, passengers, pupils, or patients. |
| **Autonomy** | The extent to which the worker is free to carry out the task as they need. |
| **Routine: repetitiveness** | The extent to which the task is repetitive and monotonous. |
| **Routine: standardisation** | The extent to which the work depends on numerical production targets or performance targets, and meeting precise quality |

[19] The question is fully consistent until 2010. It was then slightly modified in the 2015 wave: from '*Working with computers: PCs, network, mainframe'* to '*Working with computers, laptops, smartphones etc*.'. This change does not prevent the use of the variable since the aim is to capture the use of technology at work. A closer inspection of the variable between 2010 and 2015 does not show major changes in the patterns.

| | |
|---|---|
| | standards. |
| **Machines** | The exposure to vibrations from tools or machinery and the extent to which the pace of work depends on machines. |
| **Computers** | Use of computers and internet. |

*Notes: A detailed description of the variables used for the construction of the indices can be found in the Annex. Source: EWCS data.*

## Changes in tasks: a decomposition analysis

This Section looks at how the content, methods and tools of work evolved in Europe in the last 20 years. Table 3 reports the overall change in the standardised values of the task indices at the EU-15 level between 1995 and 2015. The numbers in the second and third columns show the average scores of each of the eight tasks indices in 1995 and 2015 respectively; the third column presents the trend over time; the fourth and fifth columns show the change in that score, both as a simple difference of the averages and as percentage change. Finally, the asterisks indicate whether the change is statistically significant or not.

*Table 3: Aggregate changes in average scores of task indices in EU-15, 1995-2015*

| | 1995 | 2015 | trend | change | % change | |
|---|---|---|---|---|---|---|
| Physical: strength | 0.249 | 0.231 | | -0.018 | -7.3% | *** |
| Intellectual: problem solving | 0.722 | 0.721 | | -0.001 | -0.1% | |
| Social: dealing directly with people | 0.591 | 0.551 | | -0.040 | -6.8% | *** |
| Autonomy | 0.707 | 0.709 | | 0.002 | 0.2% | |
| Routine: Repetitiveness | 0.410 | 0.433 | | 0.023 | 5.6% | *** |
| Routine: Standardisation | 0.540 | 0.586 | | 0.047 | 8.6% | *** |
| Machines | 0.183 | 0.145 | | -0.038 | -20.8% | *** |
| Computers | 0.270 | 0.444 | | 0.174 | 64.2% | *** |

*Notes: *** p-value<0.01. Source: EWCS data*

According to the EWCS, during the period 1995 to 2015 there was a very significant and consistent increase in the use of computers at work: an impressive relative change of 64.2% in 20 years (that is, from 0.270 to 0.444 in the standardised scores). Similarly, although smaller in magnitude, the average scores of routine tasks methods increased, both in terms of repetitiveness (from 0.410 to 0.433, corresponding to +5.6%) and even more standardisation (from 0.540 to 0.586, +8.6%). On the contrary, and as one would expect, during the same period there was a noticeable decline of machinery at work (from an average of 0.183 to 0.145, in relative terms corresponding to -20.8%) and physical tasks (-7.3%).

The result which instead is perhaps most surprising is the decline in the average score of external social interaction (almost 7% lower in 2015 compared to 1995). However, the trend line shows that while a considerable decrease was recorded between 1995 and 2000 (from 0.591 to 0.529), there was a steady increase until 2010 and another drop in the last five years[20]. This suggests that for the overall economy a clear pattern cannot be identified and further exploration of the data at a more detailed level of analysis may be needed to assess whether external social tasks have declined in specific sectors or occupations.

Otherwise, neither the index on problem solving nor the one on autonomy show significant overall changes and appear to have a more cyclical pattern related to overall macroeconomic conditions (decreasing in the first half of the period, from 1995 to 2005, and then increasing in the second). It may be that the more subjective nature of these indices compared to the others leads to more inconsistency in the measures (for instance, economic growth may lead to increased work intensity and thus a feeling of declining autonomy; whereas economic decline may have the opposite effect). It may also be that the apparent cyclical effects are driven by different compositional changes in employment in periods of economic growth and decline (for instance, in economic downturns low skilled jobs tend to suffer more unemployment, which may lead to a compositional increase in the share of high skilled and high autonomy jobs). Some of these possibilities will be discussed in the following pages, but in any case, it seems clear that in terms of autonomy and problem solving there is not a clear consistent trend in recent years as one can see in some of the other indicators.

These overall trends in task contents and methods can be the result of changes in the structure of occupations (for instance, if jobs that make use of machinery have declined in relative terms in recent years), of changes in the task contents and methods across occupations (if jobs are using less machinery) or both. As previously discussed, most of the recent debate on the impact of technological change on employment has focused on changes that result from occupational restructuring, so it is useful to try to disentangle both effects. To do this, EWCS data were linked with EU-LFS employment figures (EJM database) to perform a shift-share analysis and indirectly compute within-jobs changes in task indices as a residual. Indeed, trends in average tasks intensity at the job level may result from transformations along two margins: the extensive and the intensive margin. The first one refers to changes in the structure of employment, the second one to changes in task measures within jobs. Aggregate changes in any task index *j* between time *t* and *t-1* can therefore be decomposed into a first term reflecting the reallocation of employees between jobs *k* (change that would occur solely through 'between' changes in employment shares) and a second term reflecting changes in tasks within jobs (the variation attributable to task changes 'within' jobs, if employment shares remained constant).

$$\Delta T_{jt} = \Delta T_{jt}^{b} + \Delta T_{jt}^{w} + \varepsilon \qquad (1)$$

The unknown term in the decomposition above is $\Delta T_{jt}^{w}$ , capturing within-jobs task changes. Indeed while the aggregate changes $\Delta T_{jt}$ can be computed at the EU-15 level using EWCS data, this is not possible within each detailed job in the economy for sample size limitations, as previously discussed. However, using employment data, one can calculate the between-jobs component represented by $\Delta T_{jt}^{b}$. Consequently, $\Delta T_{jt}^{w}$ is derived as a simple difference of the two observable terms. A possible interaction effects between $\Delta T_{jt}^{b}$ and $\Delta T_{jt}^{w}$ would be incorporated in the residual term $\varepsilon$.

[20] An increasing trend in the external social interaction is also recorded at the EU-27 level from 2000 until 2010, with a decline instead in the last sub-period.

More specifically, one can expand the decomposition formula (1) as follows:

$$\sum_{k=1}^{K}(\Delta task_{kjt} \times \Delta E_{kt}) = \sum_{k=1}^{K}(\Delta E_{kt} \times task_{kj,t*}) + \sum_{k=1}^{K}(\Delta task_{kjt} \times E_{k,t*}) + \varepsilon \qquad (2)$$

In formula (2), the subscript t* refers to the year which is kept fixed. In the analysis, the 2010 values of task indices at the job level are chosen (and kept constant) to compute the between-jobs component. While in principle any wave of the EWCS could be selected, 2010 is explicitly adopted due to the fact that double coding both for sectoral and occupational classifications are available. The double coding means that both the NACE first and second version, and the ISCO 88 and 08 are present. This allows overcoming problems due to two major classification breaks in 2008 (NACE from version 1 to 2) and 2011 (ISCO from 88 to 08) which undermine comparability of employment data over time. For the computation of the between-jobs component of the task indices, these EWCS 2010 average task scores are applied to data on employment by occupation and sector between 1995 and 2015 from the EU-LFS (EJM database). The use of EU-LFS data for employment weights ensures a more reliable calculation of between-job changes in the task indices, since the EU-LFS has a much larger sample size that allows more detailed occupation and sector analysis.

Performing a shift-share analysis has the advantage of explicitly comparing changes in task indices at the intensive and extensive margin. This is very useful to assess to what extent changes in task content and methods were the result of developments independent from the structural shifts in employment. Table 4 presents the main findings of the shift share analysis conducted at the EU-15 level, together with the previously discussed aggregate reported changes to facilitate the comparison. In some cases, the compositional changes and the aggregate reported changes are very similar, suggesting a similar interpretation of the underlying trends. But in some cases they do not, and they are the most interesting ones.

For instance, Table 4 shows that the evolution in recent years of tasks requiring the exertion of physical strength and use of machinery are similar in terms of compositional change and in terms of the directly reported levels of both variables in the EWCS. In compositional terms, physical strength tasks have declined by 7% (in other words, the decline in jobs involving a high degree of physical strength reduces the overall level of strength tasks by 7%), which coincides almost exactly with the change in reported levels in the same period (7.3%). For machinery use, the compositional decline is 13.5% whereas the reported one is 20.8%, of a larger but similar order of magnitude and direction. This implies that the main driver of the decline in strength tasks and machine use in Europe in the last 20 years is compositional change: just by looking at the latter, this accounts for the full decline in reported levels of strength tasks, and for two thirds of the decline in machinery use. An interesting corollary of this is that although there has been a significant reduction of employment in jobs requiring strength and using machines, the task content of those jobs has changed only marginally in the last 20 years.

The opposite happens with computer use at work. Also in this case, aggregate reported change and compositional change go in the same direction and suggest a similar interpretation. But in this case, the effect of compositional change is tiny compared with a massive change within occupations. Compositional change in computer use is nearly 6%: in other words, there was an increase in jobs making more use of computers, which increased the average computer use by 6%. But this is dwarfed by an actual reported increase in the use of computers of 64.2% overall. What this means is the increase in computer use was spread across most occupations in the economy, and was mostly a within-job expansion. In other words, it is not that computer-intensive jobs grew faster than the rest (although they did) but that all jobs expanded in their use of computers what explains the large expansion of computer use in the last two decades in Europe.

There is also consistency between the compositional and the reported trends in tasks change for problem solving and autonomy, although a consistency of a very different nature. In this case, both types of trends suggest no significant change over the period. But as previously said, the really interesting results are those where compositional and reported changes go in the opposite directions. One can see that is the case for social tasks, repetitiveness and standardisation.

In the case of social tasks, in the period 1995 to 2015 there was a significant compositional growth accounting for more or less 6% (a similar magnitude as the compositional growth in computer use, for instance). In other words, jobs with more social task content expanded more than jobs with less social content. This is perfectly in line with existing literature, which suggests that social tasks tend to grow in relative terms because they are neither easy to automate nor to offshore, and are thus relatively protected from routine-biased technical change and globalisation (Blinder, 2006, 2009; Goos and Manning, 2007). But it contrasts quite strikingly with a *decline* in the reported levels of social tasks at work in the EWCS for the same period, a decline which is of a similar magnitude as the compositional growth (-6.8%). What this necessarily means is that simultaneously with an increase of social-intensive jobs, there is a decline in the amount of social tasks people actually do in those (and other) jobs. In other words, compositional and intrinsic changes in social task content go in opposite directions. These results should be taken with caution because the decline in social tasks is not recorded if an alternative periodisation 2000-2015 is considered. However, even looking only at the 2000-2015 period the significant compositional increase is slightly bigger than the aggregate change in reported levels, which also implies a small compensating decline in social tasks within jobs.

A similar contradictory trend can be observed in the two variables measuring repetitiveness and standardisation. Whereas both are marginally declining in compositional terms, they are increasing significantly in reported levels. As in the case of social tasks, the compositional trend that is observed in Table 4 is consistent with the literature, which refers to a decline in the amount of employment in jobs which involve a high degree of routine (Autor et al., 2003; Goos et al., 2009). But the opposite trend in reported levels suggests a more than compensating increase in the amount of routine tasks in the remaining jobs. This contradiction is particularly surprising in the context of the current debates on the impact of technological change on employment, because it implies an actual increase in the total levels of routine at work notwithstanding marginal compositional declines.

In short, there is a contradiction between the compositional trends and the actually observed changes for three particularly important categories of tasks: social task content (with some caveats), and routine task methods (both repetitiveness and standardisation). What shall one make of this contradiction? What trend is the most relevant or significant one? If the goal is to understand the implications and nature of structural change in labour markets, as captured by changes in the levels of employment across different occupations and sectors, then the picture given by compositional change is the relevant one. Indeed, jobs involving social tasks are growing, and jobs involving routine task content are declining. But if the goal is to understand how the content and methods of work are changing as a result of technological change or other factors in advanced economies, looking only at the compositional picture can be quite misleading. Work is becoming more, rather than less, routine;

and social task content is marginally declining in many specific occupations and sectors (see more details in next Section).

But how can this be explained? Throughout the rest of the report, the analysis will deepen into the changes in the task indices in different ways, and explore the links between changes in technologies in particular and the other task indices, to try to understand better the difference between compositional and reported changes in task contents and methods. But one can already advance a plausible hypothesis that has to do with the way technology affects the amount of work needed across different task categories on the one hand, and the nature of tasks on the other. This plausible hypothesis focuses on the likely impact of the largest and most widespread change indicated in Table 3 above, surely one of the key changes in the world of work in recent decades: the increase in computer use at work.

Computers have a paradoxical effect on tasks. On the one hand, as is widely discussed in the specialised literature reviewed in Section 2, computers can replace many types of routine tasks. Most directly, computers can replace routine tasks which involve information processing, because that is essentially what computers are: machines that can do routine information processing tasks. Indirectly, in recent decades computers have also allowed the automation of routine physical tasks that had been not previously automated by mechanical devices, because the use of programming in industrial machinery increases its flexibility and scope. But on the other hand, and this is less often discussed in the specialised literature, computers both facilitate and require the standardisation and routinisation of work procedures, and (especially since the arrival of the internet) reduce the need of direct social interaction for the provision of some services. The massive increase in the use of computers at work in the last 20 years, which took place across most sectors and occupations, are thus very likely to be related to the reported increases of repetitiveness and standardisation of some types of work, and to the reported decline in the level of direct social interaction for some types of jobs. In the following Sections, specific illustrations of this process will be provided.

In other words, the apparently contradictory trends in the between-jobs and the within-jobs components of overall change in task contents and methods can in fact reflect two different ways in which the same technological developments (an increasing digitalisation of work) have affected work and employment. On the one hand, computers facilitate the automation of some tasks, in particular those that are more routine, thus shifting employment to other tasks such as social. On the other hand, they affect the organisation of work by standardising and bureaucratising procedures, and by facilitating new forms of service provision. Whereas automation reduces the amount of labour in routine tasks, digitisation facilitates the routinisation of some previously non-routine tasks. An interesting corollary of this is that the two aspects can ultimately reinforce each other, since the routinisation of tasks can pave the way for further rounds of automation for types of work that were not automatable before.

*Table 4: Aggregate reported and compositional change in task indices in EU-15, 1995-2015*[21]

| | Aggregate reported change | | | | Compositional change | | | |
|---|---|---|---|---|---|---|---|---|
| | 1995 | 2015 | change | % change | 1995 | 2015 | change | % change |
| Physical: strength | 0.249 | 0.231 | -0.018 | -7.3% *** | 0.259 | 0.241 | -0.018 | -7.0% |
| Intellectual: problem solving | 0.722 | 0.721 | -0.001 | -0.1% | 0.680 | 0.691 | 0.010 | 1.5% |
| Social: dealing directly with people | 0.591 | 0.551 | -0.040 | -6.8% *** | 0.520 | 0.553 | 0.033 | 6.3% |
| Autonomy | 0.707 | 0.709 | 0.002 | 0.2% | 0.670 | 0.686 | 0.016 | 2.4% |
| Routine: Repetitiveness | 0.410 | 0.433 | 0.023 | 5.6% *** | 0.463 | 0.447 | -0.016 | -3.4% |
| Routine: Standardisation | 0.540 | 0.586 | 0.047 | 8.6% *** | 0.591 | 0.581 | -0.010 | -1.7% |
| Machines | 0.183 | 0.145 | -0.038 | -20.8% *** | 0.189 | 0.164 | -0.026 | -13.5% |
| Computers | 0.270 | 0.444 | 0.174 | 64.2% *** | 0.409 | 0.433 | 0.024 | 5.9% |

Notes: **** p-value<0.01*. Source: *EWCS and EJM data*

**Box 1: Computer use, task content and methods: an econometric approach**

In order to investigate more formally the relationship between computer use and task contents and methods, a regression analysis was conducted. As discussed in previous Sections, the use of computers at work is indeed widely recognised as one of the key drivers of changes in tasks. Using different econometric specifications and drawing on existing literature, information at the individual and at the job level will be used to shed light on how computer use is related to what people do at work and how.

The simplest approach is to investigate the relationship between computer use and the task contents and methods of work exploiting the responses of individual workers in the EWCS (more than 15,000 observations per wave). To do this, a simple OLS regression model was run on pooled EWCS data from 1995 to 2015, using sampling weights and calculating robust standard errors. The following specification was used:

$$task_{kit} = \alpha + \beta comp_{it} + \sum_{t}^{T-1} \theta_t \ + \varepsilon_{it} \qquad (1)$$

Where $task_{kit}$ is the task measure *k* (physical, intellectual, social, autonomy, repetitiveness and standardisation) at the individual level *i* at time *t*; $comp_{it}$ is the computer use intensity at the individual level *i* at time *t*; $\theta_t$ is a set of time (wave) fixed effects; $\varepsilon_{it}$ is the error term. The same model was also run controlling for the use of non-ICT machines at work in order to assess how their presence can influence the relationship between computer use and other tasks. Moreover, in order to take into account heterogeneity among individuals within the same jobs, the same analysis was also performed including dummy variables for jobs.

Results are graphically depicted in Figure 1 which shows the coefficients for the task content and methods, together with their confidence intervals (at 95% significance level). Each lighter-colour bar is the coefficient of each task index regressed on computer use, while the darker-colour bar is the coefficient of the same task regressed on computer use with non-ICT machine use (not shown in the charts) introduced as a control variable.

[21] Notes: Updated on 28 May 2021. In table 4, labels for intellectual and social tasks were truncated.

Panel A shows that computer use is related positively with intellectual and social tasks, and with autonomy and standardisation, while it is negatively related with physical tasks and repetitiveness. As a general comment, one can notice that the inclusion of machine use as control variable in the regressions only marginally changes the magnitude of the coefficient for computer use, suggesting that the results are robust.

The inclusion of the jobs as dummy variables (Panel B) captures the variation of tasks not across all the workers, but across workers within the same jobs. It is therefore not surprising that in almost all the cases the results described above are confirmed with only some small differences in magnitude (with the exception of physical tasks, for which the variation appears slightly bigger) and sign (with the exception of repetitiveness). Indeed, the inclusion of dummy variables for jobs makes the coefficient for repetitiveness turning from (slightly) negative to (slightly) positive. This means that jobs with higher use of computer tend to be less repetitive than jobs with lower use of computer, but within each job a worker who uses more the computer has also more repetitive tasks than a colleague who uses it less. It is reasonable that a professional uses computer more and presents a lower level of repetitiveness than a metalworker, who does not use computer almost at all; but within professionals those who use more the computer at work present a higher level of repetitiveness than colleagues who use it less.

This result further strengthens the observation previously made in Section 5 about the importance of the within-job dimension. In particular previous results of the decomposition analysis have shown that in the last 20 years, while repetitive jobs have declined in terms of employment shares, the level of repetitiveness within jobs increased. Similarly, the regression analysis points to the fact that a significant difference in the relationship between computer use at work and repetitiveness emerges when within jobs heterogeneity is considered. This relationship is paradoxical and data present a more complex picture than the simple one of the computer as the main driver of de-routinisation of jobs, presented by the previous literature.

The above results are robust to alternative specifications where regressions were run separately for each wave rather than pooling all the waves together, which implies that the relationship between computer use and task content and methods remained fairly constant over the period of analysis.

While regressions at the individual level allow to exploit a large number of observations, the most obvious limitation is that there may be issues of omitted variable bias (that is uncontrolled confounding variables) leading to endogeneity. An attempt to control for such omitted variables is to use a panel of average task values at the job level, as in Green (2012). The author, who investigates the extent to which computer technologies promote the use of higher order cognitive and interactive skills using tasks data derived from the UK Skills Surveys, creates a 'pseudo' panel averaging information on tasks at the job level and then running fixed effects models. Once the variables of interest were collapsed at the job level, the following model was estimated:

$$\overline{task}_{kjt} = \beta\overline{comp}_{jt} + \theta_t + \delta_j + \bar{\varepsilon}_{jt} \quad (2)$$

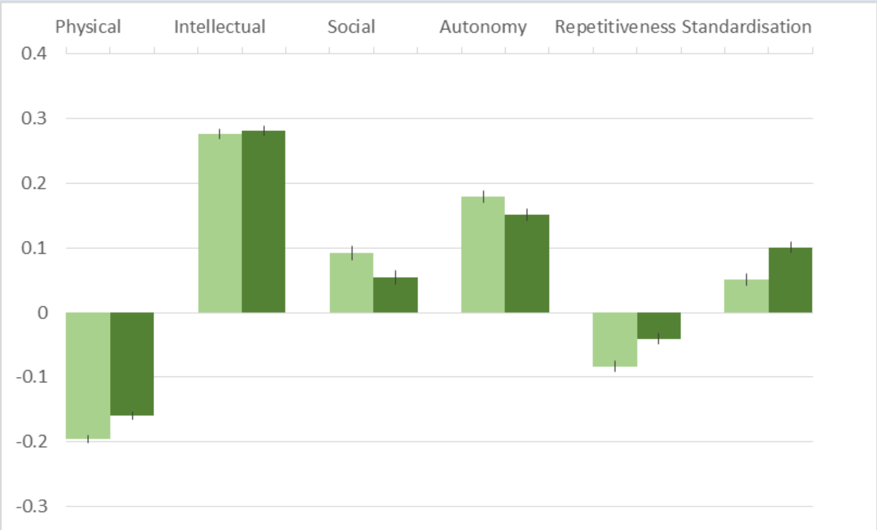
Where $\overline{task}_{kjt}$ and $\overline{comp}_{jt}$ are respectively the task content or methods index $k$, and the computer use index, measured at the job level $j$ at time $t$; $\theta_t$ is a set of time-fixed effects and $\delta_j$ is a set of jobs-fixed effects. Employment levels in each job in the initial year were used as weights. As in the case of OLS regression, an alternative specification including as co-variate the use of non-ICT machines at the job level was also considered. Time-fixed effects control for omitted variables which are constant across jobs but evolve over time; job-fixed effects are included to control for omitted variables that vary across jobs but not over time. Fixed effects estimates therefore allow to reduce the omitted variable bias and the endogeneity that may arise from it, due to the presence of unobserved factors correlated both with computer use and the other tasks measures.

Figure 2 (Panel A) reports the estimated coefficient (only those statistically significant, hence the blank space for autonomy) of the fixed-effects models (with and without controlling for machine use – respectively darker and lighter colour bars). As in the case of pooled OLS estimates, controlling for machine does not considerably affect results, with the notable exception of repetitiveness, which is significant (at 10% level) only when machine are also included as explanatory variable. In terms of task content, Figure 2 consistently indicates that computer use is significantly negatively related with physical tasks and positively with intellectual tasks. A more interesting result is the negative coefficient linking computer use and social tasks, suggesting that computers can impact negatively the degree of social task content within jobs, as hinted in previous pages also in light of the shift-share results. However, the effect is not consistent in all model specifications, so it should be interpreted with caution.

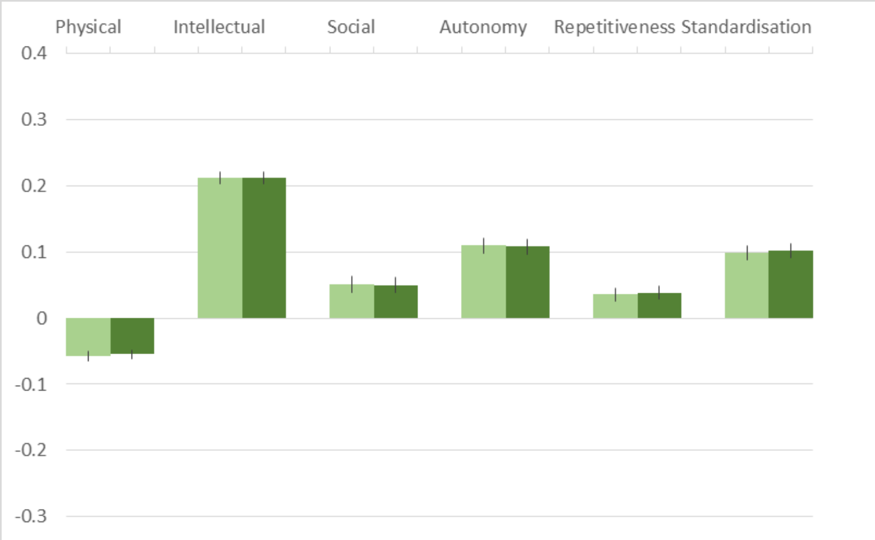
Regarding tasks methods, only standardisation is consistently and significantly related to computer use alone (without controlling for machine use), and in a positive way. In particular, and as found in previous specifications, the coefficient for standardisation is the highest among the two components of the routine index. These results for standardisation are consistent with both specifications of the pooled OLS estimates.

It is interesting to note that repetitiveness becomes significantly related to computer use alone when time-effects are removed from the regression (Panel B), suggesting anyway some positive link between the two variables at the job level (although weaker than in the case of standardisation). One could interpret the difference between results with and without time-effects as a general increase of repetitiveness in all jobs, only weakly mediated by computerisation.

*Figure 1: Relationship between computer use and tasks, pooled OLS estimates*
Panel A



Panel B

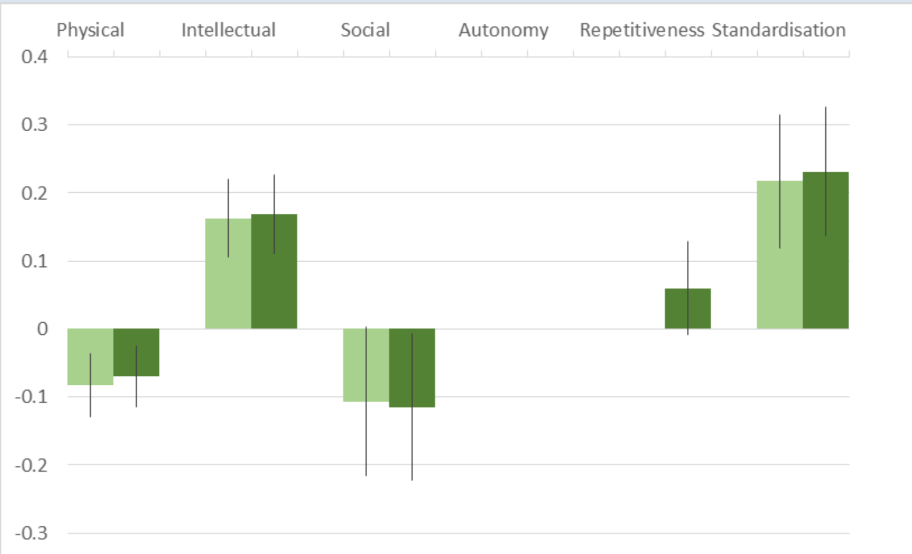



***Notes:*** *The lighter-colour bar represent the coefficient of each task index regressed on computer use, while the darker-colour bar is the coefficient of the same task regressed on computer use with non-ICT machine use (not shown in the charts) introduced as a control variable. The black lines on each bar represent confidence intervals (at 95% significance level). Panel B shows results of the models where dummy variables for each job were included.*

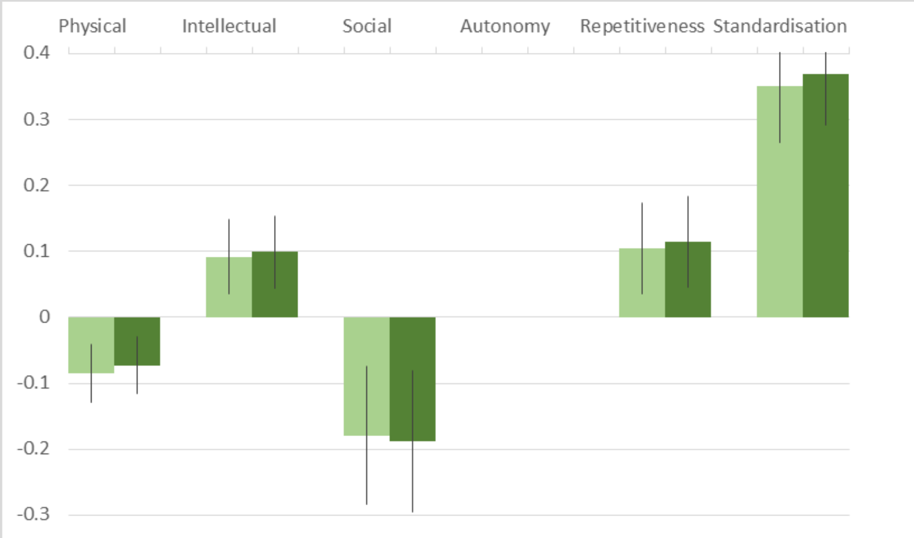
***Source:*** *authors' elaboration on EWCS data, 1995-2015*

*Figure 2: Relationship between computer use and task content and methods, fixed effects estimates*

Panel A



Panel B




***Notes:*** *The lighter-colour bar represent the coefficient of each task index regressed on computer use, while the darker-colour bar is the coefficient of the same task regressed on computer use with non-ICT machine use (not shown in the charts) introduced as a control variable. The black lines on each bar represent confidence intervals (at 95% significance level). Panel B shows results of the models where time dummy variables were excluded from the specification, therefore considering only job-specific effects.*

***Source:*** *authors' elaboration on EWCS data, 1995-2015*

## Developments at the sectoral, occupational and job level

### A sectoral perspective

After discussing the main changes in average task scores for the entire economy, differences among sectors (NACE Rev. 1 at 1-digit level) are analysed in order to identify where the most substantial changes took place. While the full set of results is reported below in Table 5, the following key findings can be identified:

- The most significant and robust results, both in terms of overall change and consistency over time, can be found more often in services compared to other sectors of the economy (especially vis-a-vis manufacturing and mining);
- The indices of external social interaction (for the task content), standardisation (for the methods of work) and computer use (for the technology used at work) are those exhibiting the most consistent changes in average scores for services: the first declining and the last two increasing;
- Financial intermediation, real estate, renting and business activities, and public administration are the specific services showing more consistently clear and interesting developments in the above-mentioned dimensions.

In terms of external social interaction, all sectors of the economy exhibit negative change. However, a close inspection of the trends reveals that a significant declining pattern over the entire period can be identified only for a limited number of services sectors, namely: financial intermediation (-22.5%), real estate, renting and business activities (-28.5%), and public administration (-20.3%). All the three sectors featured high initial average scores in this particular dimension, only second to those recorded in wholesale and retail trade, and hotels and restaurants (which also present a declining trend but slightly less consistent over time, especially the latter). In real estate, renting and business activities and public administration the biggest decline was recorded between 1995 and 2000, while for financial intermediation it was more gradual. This large and statistically significant decline in social task content for some large services sectors confirms the tentative finding of a decline in social task content tentatively discussed in the last Section. Most likely, the inconclusiveness of the results for the overall economy relates to the fact that it was a consistent trend only in these large services sectors, whereas in other sectors there was only a marginal decline.

In terms of methods of work, the sector level analysis reveals a very clear pattern towards task standardisation for all services sectors (with the exception of transport, storage and communication). This again is particularly evident in terms of magnitude and clear-cut in terms of pattern in the case of financial intermediation, where the average score went from 0.479 to 0.672 (an increase of 40.5% in 20 years). A relative increase between 20-24% was recorded in other services, namely: hotels and restaurants, real estate, renting and business activities, and public administration[22]. Differently from the case of standardisation, the index of repetitiveness for services

[22] The residual category ‘Other services’ also experienced a relative increase of 19%. However, data limitations allow reconstructing a more detailed classification only from 2000 onwards. This permits to differentiate sectors within this residual category into: education; health and social work; other community, social and personal activities; private households with employed persons. In terms of repetitiveness and standardisation, since 2000 the educational sector was the one recording the biggest increase, both in absolute and relative terms, as well as exhibiting a more consistent trend over time.

sectors shows patterns that are less consistent over time and smaller overall changes, perhaps with the exception of public administration.

Regarding the index on use of computers, it presents a remarkable and consistent increase across all sectors of the economy, with the notable exception of construction. Hotels and restaurant, the sector with the second lowest average score in 1995, recorded a relative increase of +118% (yet despite catching up, it remains the services sector with the lowest average computer use). Similarly in public administration the average scores have doubled over the entire period considered (from 0.327 to 0.675), steadily moving from a sector of mid-low computer intensity to mid-high. In the services sectors, the lowest statistically significant increase in percentage point is for financial intermediation (+33.2%), but this is the sector which already shows the highest average score at every point in time.

Another interesting sectoral development that is worth noticing is the lack of change in terms of intellectual problem solving and autonomy (although to a lesser extent) with very small differences over time. This was already recorded at the EU-15 level and the sectoral analysis does not provide additional insights.

*Table 5: Changes in average scores of task indices in EU-15 at the sectoral level, 1995-2015*[23]

| | Yearly average task index | | | | | | Reported change 1995-2015 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1995 | 2000 | 2005 | 2010 | 2015 | Trend | Change | % Change | |
| **PHYSICAL: STRENGTH** | | | | | | | | | |
| A-B Agriculture, hunting, forestry, fishing | 0.454 | 0.505 | 0.440 | 0.440 | 0.391 | | -0.063 | -13.8% | *** |
| C-D Mining, quarrying, Manufacturing | 0.257 | 0.299 | 0.278 | 0.290 | 0.258 | | 0.001 | 0.5% | |
| E Electricity, gas, and water supply | 0.229 | 0.205 | 0.248 | 0.219 | 0.170 | | -0.060 | -26.0% | |
| F Construction | 0.363 | 0.414 | 0.444 | 0.416 | 0.426 | | 0.064 | 17.6% | *** |
| G Wholesale and retail trade | 0.271 | 0.258 | 0.256 | 0.273 | 0.254 | | -0.017 | -6.4% | |
| H Hotels and restaurants | 0.296 | 0.318 | 0.316 | 0.268 | 0.292 | | -0.004 | -1.3% | |
| I Transport, storage and communications | 0.255 | 0.300 | 0.249 | 0.277 | 0.249 | | -0.006 | -2.3% | |
| J Financial intermediation | 0.112 | 0.106 | 0.073 | 0.075 | 0.068 | | -0.044 | -39.4% | *** |
| K Real estate activities | 0.160 | 0.161 | 0.136 | 0.169 | 0.140 | | -0.020 | -12.4% | |
| L Public administration | 0.166 | 0.167 | 0.157 | 0.169 | 0.151 | | -0.015 | -9.2% | |
| M-N-O-P-Q Other services | 0.210 | 0.227 | 0.197 | 0.203 | 0.202 | | -0.008 | -3.6% | |
| **INTELLECTUAL: PROBLEM SOLVING** | | | | | | | | | |
| A-B Agriculture, hunting, forestry, fishing | 0.612 | 0.608 | 0.628 | 0.554 | 0.612 | | 0.000 | 0.1% | |
| C-D Mining, quarrying, Manufacturing | 0.701 | 0.668 | 0.661 | 0.690 | 0.714 | | 0.013 | 1.9% | |
| E Electricity, gas, and water supply | 0.849 | 0.766 | 0.842 | 0.850 | 0.887 | | 0.038 | 4.5% | |
| F Construction | 0.783 | 0.743 | 0.740 | 0.723 | 0.796 | | 0.013 | 1.7% | |
| G Wholesale and retail trade | 0.658 | 0.609 | 0.592 | 0.581 | 0.646 | | -0.012 | -1.9% | |
| H Hotels and restaurants | 0.556 | 0.516 | 0.521 | 0.500 | 0.546 | | -0.010 | -1.8% | |
| I Transport, storage and communications | 0.720 | 0.632 | 0.649 | 0.601 | 0.627 | | -0.093 | -12.9% | *** |
| J Financial intermediation | 0.795 | 0.793 | 0.833 | 0.822 | 0.856 | | 0.061 | 7.7% | ** |
| K Real estate activities | 0.781 | 0.797 | 0.758 | 0.737 | 0.765 | | -0.015 | -2.0% | |
| L Public administration | 0.781 | 0.734 | 0.749 | 0.759 | 0.813 | | 0.032 | 4.1% | * |
| M-N-O-P-Q Other services | 0.757 | 0.728 | 0.729 | 0.712 | 0.756 | | -0.001 | -0.1% | |
| **SOCIAL: DEALING DIRECTLY WITH PEOPLE** | | | | | | | | | |
| A-B Agriculture, hunting, forestry, fishing | 0.279 | 0.271 | 0.186 | 0.203 | 0.275 | | -0.004 | -1.4% | |
| C-D Mining, quarrying, Manufacturing | 0.373 | 0.250 | 0.295 | 0.297 | 0.262 | | -0.111 | -29.7% | *** |
| E Electricity, gas, and water supply | 0.494 | 0.385 | 0.576 | 0.396 | 0.352 | | -0.142 | -28.7% | ** |
| F Construction | 0.428 | 0.356 | 0.478 | 0.416 | 0.438 | | 0.010 | 2.5% | |
| G Wholesale and retail trade | 0.768 | 0.715 | 0.668 | 0.716 | 0.696 | | -0.072 | -9.4% | *** |
| H Hotels and restaurants | 0.800 | 0.714 | 0.703 | 0.758 | 0.714 | | -0.086 | -10.7% | *** |
| I Transport, storage and communications | 0.604 | 0.567 | 0.611 | 0.631 | 0.549 | | -0.055 | -9.1% | ** |
| J Financial intermediation | 0.696 | 0.646 | 0.560 | 0.577 | 0.540 | | -0.157 | -22.5% | *** |
| K Real estate activities | 0.696 | 0.527 | 0.516 | 0.494 | 0.497 | | -0.199 | -28.5% | *** |
| L Public administration | 0.647 | 0.525 | 0.492 | 0.534 | 0.516 | | -0.131 | -20.3% | *** |
| M-N-O-P-Q Other services | 0.705 | 0.698 | 0.676 | 0.717 | 0.692 | | -0.013 | -1.9% | |
| **AUTONOMY** | | | | | | | | | |
| A-B Agriculture, hunting, forestry, fishing | 0.689 | 0.753 | 0.741 | 0.712 | 0.774 | | 0.084 | 12.2% | *** |
| C-D Mining, quarrying, Manufacturing | 0.630 | 0.599 | 0.582 | 0.604 | 0.633 | | 0.003 | 0.4% | |
| E Electricity, gas, and water supply | 0.688 | 0.724 | 0.811 | 0.757 | 0.746 | | 0.058 | 8.4% | |
| F Construction | 0.686 | 0.685 | 0.624 | 0.659 | 0.740 | | 0.054 | 7.9% | ** |
| G Wholesale and retail trade | 0.732 | 0.703 | 0.652 | 0.657 | 0.697 | | -0.035 | -4.8% | ** |
| H Hotels and restaurants | 0.650 | 0.620 | 0.561 | 0.588 | 0.606 | | -0.044 | -6.7% | |
| I Transport, storage and communications | 0.621 | 0.522 | 0.589 | 0.526 | 0.562 | | -0.059 | -9.5% | ** |
| J Financial intermediation | 0.716 | 0.778 | 0.761 | 0.748 | 0.782 | | 0.066 | 9.2% | * |
| K Real estate activities | 0.832 | 0.774 | 0.767 | 0.774 | 0.769 | | -0.063 | -7.6% | *** |
| L Public administration | 0.750 | 0.718 | 0.692 | 0.700 | 0.764 | | 0.014 | 1.9% | |
| M-N-O-P-Q Other services | 0.764 | 0.748 | 0.740 | 0.734 | 0.744 | | -0.021 | -2.7% | * |

[23] Updated on 28 May 2021. In table 5 some significance levels were incorrectly reported.

*Table 5 (continued)*

| | Yearly average task index | | | | | | Reported change 1995-2015 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1995 | 2000 | 2005 | 2010 | 2015 | Trend | Change | % Change | |
| **ROUTINE: REPETITIVENESS** | | | | | | | | | |
| A-B Agriculture, hunting, forestry, fishing | 0.547 | 0.555 | 0.532 | 0.519 | 0.487 | | -0.060 | -11.0% | ** |
| C-D Mining, quarrying, Manufacturing | 0.451 | 0.509 | 0.470 | 0.511 | 0.461 | | 0.010 | 2.2% | |
| E Electricity, gas, and water supply | 0.381 | 0.328 | 0.463 | 0.387 | 0.408 | | 0.026 | 6.9% | |
| F Construction | 0.427 | 0.483 | 0.529 | 0.541 | 0.503 | | 0.077 | 18.0% | *** |
| G Wholesale and retail trade | 0.421 | 0.397 | 0.434 | 0.459 | 0.453 | | 0.032 | 7.6% | ** |
| H Hotels and restaurants | 0.507 | 0.530 | 0.535 | 0.541 | 0.544 | | 0.037 | 7.3% | |
| I Transport, storage and communications | 0.444 | 0.490 | 0.431 | 0.507 | 0.515 | | 0.071 | 15.9% | *** |
| J Financial intermediation | 0.350 | 0.372 | 0.347 | 0.365 | 0.363 | | 0.013 | 3.6% | |
| K Real estate activities | 0.354 | 0.387 | 0.358 | 0.427 | 0.403 | | 0.049 | 13.9% | ** |
| L Public administration | 0.341 | 0.342 | 0.390 | 0.401 | 0.396 | | 0.055 | 16.0% | *** |
| M-N-O-P-Q Other services | 0.355 | 0.352 | 0.376 | 0.393 | 0.378 | | 0.023 | 6.4% | ** |
| **ROUTINE: STANDARDISATION** | | | | | | | | | |
| A-B Agriculture, hunting, forestry, fishing | 0.596 | 0.575 | 0.608 | 0.574 | 0.554 | | -0.042 | -7.0% | |
| C-D Mining, quarrying, Manufacturing | 0.688 | 0.708 | 0.735 | 0.722 | 0.708 | | 0.020 | 2.9% | |
| E Electricity, gas, and water supply | 0.581 | 0.553 | 0.673 | 0.696 | 0.614 | | 0.033 | 5.8% | |
| F Construction | 0.653 | 0.594 | 0.669 | 0.666 | 0.686 | | 0.033 | 5.0% | |
| G Wholesale and retail trade | 0.496 | 0.421 | 0.498 | 0.519 | 0.537 | | 0.041 | 8.2% | *** |
| H Hotels and restaurants | 0.471 | 0.476 | 0.563 | 0.552 | 0.582 | | 0.111 | 23.6% | *** |
| I Transport, storage and communications | 0.558 | 0.467 | 0.631 | 0.586 | 0.593 | | 0.034 | 6.2% | |
| J Financial intermediation | 0.479 | 0.519 | 0.643 | 0.642 | 0.672 | | 0.194 | 40.5% | *** |
| K Real estate activities | 0.496 | 0.499 | 0.575 | 0.602 | 0.595 | | 0.098 | 19.8% | *** |
| L Public administration | 0.409 | 0.351 | 0.511 | 0.492 | 0.508 | | 0.100 | 24.4% | *** |
| M-N-O-P-Q Other services | 0.449 | 0.379 | 0.518 | 0.505 | 0.534 | | 0.085 | 18.9% | *** |
| **MACHINES** | | | | | | | | | |
| A-B Agriculture, hunting, forestry, fishing | 0.335 | 0.278 | 0.282 | 0.297 | 0.255 | | -0.079 | -23.8% | *** |
| C-D Mining, quarrying, Manufacturing | 0.317 | 0.378 | 0.359 | 0.357 | 0.342 | | 0.025 | 7.9% | * |
| E Electricity, gas, and water supply | 0.198 | 0.136 | 0.185 | 0.191 | 0.147 | | -0.051 | -25.9% | |
| F Construction | 0.274 | 0.254 | 0.331 | 0.299 | 0.297 | | 0.023 | 8.5% | |
| G Wholesale and retail trade | 0.139 | 0.104 | 0.116 | 0.131 | 0.114 | | -0.025 | -18.0% | ** |
| H Hotels and restaurants | 0.099 | 0.119 | 0.117 | 0.103 | 0.129 | | 0.030 | 29.8% | * |
| I Transport, storage and communications | 0.204 | 0.234 | 0.198 | 0.209 | 0.198 | | -0.006 | -2.8% | |
| J Financial intermediation | 0.100 | 0.071 | 0.060 | 0.064 | 0.058 | | -0.042 | -42.4% | ** |
| K Real estate activities | 0.117 | 0.105 | 0.086 | 0.104 | 0.074 | | -0.044 | -37.2% | *** |
| L Public administration | 0.084 | 0.076 | 0.088 | 0.098 | 0.065 | | -0.019 | -22.3% | * |
| M-N-O-P-Q Other services | 0.095 | 0.061 | 0.073 | 0.068 | 0.063 | | -0.032 | -33.4% | *** |
| **COMPUTER USE** | | | | | | | | | |
| A-B Agriculture, hunting, forestry, fishing | 0.093 | 0.074 | 0.121 | 0.119 | 0.133 | | 0.041 | 44.2% | ** |
| C-D Mining, quarrying, Manufacturing | 0.260 | 0.270 | 0.304 | 0.363 | 0.414 | | 0.154 | 59.0% | *** |
| E Electricity, gas, and water supply | 0.376 | 0.450 | 0.494 | 0.563 | 0.678 | | 0.302 | 80.4% | *** |
| F Construction | 0.215 | 0.193 | 0.192 | 0.214 | 0.227 | | 0.012 | 5.5% | |
| G Wholesale and retail trade | 0.225 | 0.242 | 0.330 | 0.372 | 0.422 | | 0.197 | 87.4% | *** |
| H Hotels and restaurants | 0.086 | 0.090 | 0.104 | 0.193 | 0.187 | | 0.101 | 117.5% | *** |
| I Transport, storage and communications | 0.306 | 0.290 | 0.403 | 0.391 | 0.417 | | 0.111 | 36.3% | *** |
| J Financial intermediation | 0.659 | 0.696 | 0.824 | 0.827 | 0.877 | | 0.218 | 33.2% | *** |
| K Real estate activities | 0.406 | 0.588 | 0.665 | 0.663 | 0.678 | | 0.272 | 66.9% | *** |
| L Public administration | 0.327 | 0.460 | 0.556 | 0.647 | 0.675 | | 0.348 | 106.6% | *** |
| M-N-O-P-Q Other services | 0.243 | 0.252 | 0.351 | 0.404 | 0.403 | | 0.160 | 65.6% | *** |

### An occupational perspective

After discussing the main changes in average task scores for the entire economy at the EU-15 level and at sectoral level, this Section looks at changes occurring at the occupational level divided into the nine major ISCO groups. The full set of results is reported in Table 6. The key points can be summarised as follows:

- The most consistent changes are observed in social tasks (downward), computer use, standardisation and repetitiveness (upward), and can be found for the following categories: managers, professionals, technicians and associate professionals, and clerical support workers;
- In terms of routine, there is a significant increase in repetitiveness and standardisation in high skilled occupations (such as managers and professionals), despite recording the lowest routine intensity at the beginning of the period considered;
- Among the task content dimensions, the negative change for social tasks measured between 1995 and 2015 is significant for all occupations except for skilled agricultural, forestry and fishery workers;
- The average computer use increased considerably for all occupations, with the biggest percentage increases for high-skilled occupations like managers, professionals, technical and associate professionals, and for low-skilled occupations such as craft and related trades workers, plant and machine operators, and elementary occupations.

In terms of task content, the decline in external social interaction from 1995 to 2015 is more consistent for occupations such as managers, professionals, technicians and associate professionals, and clerical support workers, while it is less so for other occupational groups. Among these, managers and clerical support workers recorded the highest change in relative terms (-14.1%). For the other occupations, despite significant overall changes, the value of the index shows some inconsistency over time.

Regarding routine tasks*,* standardisation increases the most, in absolute terms, for professionals (by 0.125, a 25.3% increase), service and sales workers (by 0.073, a 16.8% increase), and for managers (by 0.69, a 13.1% increase). There was a generalised increase for all occupations (albeit to a different extent) except for skilled agricultural, forestry and fisheries occupations. Repetitiveness grew the most, in relative terms, for technicians and associate professionals (20.6%), professionals (17.6%) and for services and sales workers (15.3%).

Computer use consistently increased for all occupations. A sort of polarised catching-up pattern can be observed, with greater increase at top and bottom of occupational distribution, vis-à-vis the middle. Indeed, while in occupations such as clerical support workers computer use was already the highest in 1995 (0.606), for managers, professionals, technicians and associate professional this was not the case so there were ample margins for a more generalised computerisation (respectively +65.8%, 85.3% and 86.2%). Instead, jobs at the bottom of the occupational classification (such as craft and related trade workers, plant machine operators and assemblers, and elementary occupations) had an extremely low computer intensity in 1995 (the lowest around 0.064) but consistently increased too much higher levels, despite remaining low compared to other occupations.

Other developments at the occupational level that are worth mentioning are that physical strength decreased in occupations traditionally requiring it, suggesting a transformation towards less physically demanding jobs. This is the case for: skilled agricultural, forestry and fisheries (-24.7%); plant and machine operators (-12.9%). Similarly, the use of non-ICT machinery decreases for the period 1995-2015 for all occupations, except for craft and related trades workers.

*Table 6: Changes in average scores of task indices in EU-15 at the occupational level, 1995-2015[24]*

| | Yearly average task index | | | | | | Reported change 1995-2015 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1995 | 2000 | 2005 | 2010 | 2015 | trend | Change | % Change | |
| **PHYSICAL: STRENGTH** | | | | | | | | | |
| 1. Managers | 0.180 | 0.178 | 0.188 | 0.191 | 0.185 | | 0.005 | 2.6% | |
| 2. Professionals | 0.126 | 0.143 | 0.123 | 0.137 | 0.124 | | -0.002 | -1.9% | |
| 3. Technicians and associate professionals | 0.162 | 0.184 | 0.171 | 0.147 | 0.144 | | -0.018 | -11.1% | ** |
| 4. Clerical support workers | 0.143 | 0.146 | 0.134 | 0.169 | 0.138 | | -0.005 | -3.7% | |
| 5. Service and sales workers | 0.242 | 0.282 | 0.234 | 0.253 | 0.268 | | 0.026 | 10.7% | ** |
| 6. Skilled agricultural, forestry and fishery | 0.495 | 0.529 | 0.507 | 0.484 | 0.372 | | -0.122 | -24.7% | *** |
| 7. Craft and related trades workers | 0.367 | 0.406 | 0.440 | 0.413 | 0.405 | | 0.038 | 10.2% | *** |
| 8. Plant and machine operators | 0.371 | 0.390 | 0.369 | 0.373 | 0.324 | | -0.048 | -12.9% | *** |
| 9. Elementary occupations | 0.354 | 0.397 | 0.337 | 0.370 | 0.336 | | -0.018 | -5.0% | |
| **INTELLECTUAL: PROBLEM SOLVING** | | | | | | | | | |
| 1. Managers | 0.815 | 0.760 | 0.771 | 0.792 | 0.806 | | -0.009 | -1.1% | |
| 2. Professionals | 0.884 | 0.852 | 0.861 | 0.863 | 0.896 | | 0.011 | 1.3% | |
| 3. Technicians and associate professionals | 0.823 | 0.797 | 0.812 | 0.794 | 0.831 | | 0.008 | 0.9% | |
| 4. Clerical support workers | 0.725 | 0.694 | 0.688 | 0.655 | 0.711 | | -0.014 | -1.9% | |
| 5. Service and sales workers | 0.687 | 0.572 | 0.589 | 0.553 | 0.624 | | -0.062 | -9.0% | *** |
| 6. Skilled agricultural, forestry and fishery | 0.602 | 0.604 | 0.691 | 0.579 | 0.630 | | 0.028 | 4.7% | |
| 7. Craft and related trades workers | 0.735 | 0.726 | 0.702 | 0.721 | 0.787 | | 0.052 | 7.1% | *** |
| 8. Plant and machine operators | 0.567 | 0.568 | 0.512 | 0.546 | 0.590 | | 0.023 | 4.1% | |
| 9. Elementary occupations | 0.478 | 0.415 | 0.447 | 0.390 | 0.434 | | -0.044 | -9.2% | *** |
| **SOCIAL: DEALING DIRECTLY WITH PEOPLE** | | | | | | | | | |
| 1. Managers | 0.755 | 0.673 | 0.606 | 0.651 | 0.649 | | -0.107 | -14.1% | *** |
| 2. Professionals | 0.694 | 0.694 | 0.632 | 0.669 | 0.635 | | -0.059 | -8.5% | *** |
| 3. Technicians and associate professionals | 0.663 | 0.573 | 0.571 | 0.617 | 0.611 | | -0.053 | -7.9% | *** |
| 4. Clerical support workers | 0.610 | 0.566 | 0.524 | 0.559 | 0.524 | | -0.086 | -14.1% | *** |
| 5. Service and sales workers | 0.803 | 0.782 | 0.730 | 0.804 | 0.774 | | -0.030 | -3.7% | ** |
| 6. Skilled agricultural, forestry and fishery | 0.287 | 0.257 | 0.269 | 0.271 | 0.266 | | -0.020 | -7.1% | |
| 7. Craft and related trades workers | 0.408 | 0.305 | 0.398 | 0.369 | 0.361 | | -0.046 | -11.4% | *** |
| 8. Plant and machine operators | 0.415 | 0.333 | 0.335 | 0.415 | 0.369 | | -0.047 | -11.2% | ** |
| 9. Elementary occupations | 0.467 | 0.307 | 0.446 | 0.371 | 0.352 | | -0.115 | -24.7% | *** |
| **AUTONOMY** | | | | | | | | | |
| 1. Managers | 0.885 | 0.879 | 0.848 | 0.875 | 0.882 | | -0.003 | -0.3% | |
| 2. Professionals | 0.820 | 0.830 | 0.805 | 0.816 | 0.814 | | -0.005 | -0.6% | |
| 3. Technicians and associate professionals | 0.773 | 0.783 | 0.730 | 0.735 | 0.765 | | -0.007 | -0.9% | |
| 4. Clerical support workers | 0.711 | 0.695 | 0.657 | 0.644 | 0.707 | | -0.005 | -0.6% | |
| 5. Service and sales workers | 0.706 | 0.614 | 0.628 | 0.592 | 0.639 | | -0.067 | -9.5% | *** |
| 6. Skilled agricultural, forestry and fishery | 0.713 | 0.779 | 0.809 | 0.767 | 0.788 | | 0.075 | 10.5% | ** |
| 7. Craft and related trades workers | 0.649 | 0.625 | 0.593 | 0.614 | 0.691 | | 0.042 | 6.5% | *** |
| 8. Plant and machine operators | 0.479 | 0.430 | 0.398 | 0.444 | 0.457 | | -0.021 | -4.5% | |
| 9. Elementary occupations | 0.601 | 0.544 | 0.583 | 0.606 | 0.621 | | 0.020 | 3.3% | |

[24] Updated on 28 May 2021. In table 6 some significance levels were incorrectly reported.

*Table 6 (continued)*

| | Yearly average task index | | | | | | Reported change 1995-2015 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1995 | 2000 | 2005 | 2010 | 2015 | Trend | Change | % Change | |
| **ROUTINE: REPETITIVENESS** | | | | | | | | | |
| 1. Managers | 0.343 | 0.329 | 0.333 | 0.356 | 0.363 | | 0.020 | 5.7% | |
| 2. Professionals | 0.259 | 0.256 | 0.292 | 0.315 | 0.305 | | 0.046 | 17.6% | *** |
| 3. Technicians and associate professionals | 0.294 | 0.334 | 0.344 | 0.348 | 0.355 | | 0.061 | 20.6% | *** |
| 4. Clerical support workers | 0.427 | 0.441 | 0.430 | 0.492 | 0.487 | | 0.060 | 14.0% | *** |
| 5. Service and sales workers | 0.385 | 0.418 | 0.435 | 0.468 | 0.444 | | 0.059 | 15.3% | *** |
| 6. Skilled agricultural, forestry and fishery | 0.567 | 0.542 | 0.578 | 0.525 | 0.452 | | -0.115 | -20.2% | *** |
| 7. Craft and related trades workers | 0.479 | 0.524 | 0.537 | 0.558 | 0.497 | | 0.018 | 3.7% | |
| 8. Plant and machine operators | 0.551 | 0.598 | 0.574 | 0.591 | 0.546 | | -0.005 | -0.9% | |
| 9. Elementary occupations | 0.549 | 0.561 | 0.547 | 0.592 | 0.574 | | 0.025 | 4.6% | * |
| **ROUTINE: STANDARDISATION** | | | | | | | | | |
| 1. Managers | 0.526 | 0.504 | 0.612 | 0.647 | 0.595 | | 0.069 | 13.1% | *** |
| 2. Professionals | 0.494 | 0.435 | 0.599 | 0.597 | 0.619 | | 0.125 | 25.3% | *** |
| 3. Technicians and associate professionals | 0.533 | 0.488 | 0.593 | 0.574 | 0.582 | | 0.049 | 9.2% | *** |
| 4. Clerical support workers | 0.481 | 0.422 | 0.524 | 0.535 | 0.541 | | 0.060 | 12.4% | *** |
| 5. Service and sales workers | 0.436 | 0.390 | 0.503 | 0.469 | 0.509 | | 0.073 | 16.8% | *** |
| 6. Skilled agricultural, forestry and fishery | 0.578 | 0.593 | 0.564 | 0.545 | 0.573 | | -0.005 | -0.9% | |
| 7. Craft and related trades workers | 0.700 | 0.669 | 0.716 | 0.700 | 0.724 | | 0.023 | 3.3% | * |
| 8. Plant and machine operators | 0.626 | 0.632 | 0.681 | 0.658 | 0.667 | | 0.041 | 6.5% | * |
| 9. Elementary occupations | 0.480 | 0.441 | 0.516 | 0.489 | 0.515 | | 0.035 | 7.3% | ** |
| **MACHINES** | | | | | | | | | |
| 1. Managers | 0.101 | 0.102 | 0.129 | 0.120 | 0.095 | | -0.005 | -5.4% | |
| 2. Professionals | 0.071 | 0.040 | 0.073 | 0.060 | 0.058 | | -0.014 | -19.2% | |
| 3. Technicians and associate professionals | 0.103 | 0.115 | 0.096 | 0.082 | 0.068 | | -0.035 | -34.2% | *** |
| 4. Clerical support workers | 0.123 | 0.081 | 0.089 | 0.106 | 0.093 | | -0.030 | -24.4% | *** |
| 5. Service and sales workers | 0.089 | 0.083 | 0.076 | 0.075 | 0.086 | | -0.004 | -3.9% | |
| 6. Skilled agricultural, forestry and fishery | 0.339 | 0.283 | 0.279 | 0.306 | 0.251 | | -0.088 | -26.0% | *** |
| 7. Craft and related trades workers | 0.336 | 0.355 | 0.395 | 0.362 | 0.360 | | 0.024 | 7.1% | * |
| 8. Plant and machine operators | 0.417 | 0.431 | 0.460 | 0.434 | 0.406 | | -0.010 | -2.5% | |
| 9. Elementary occupations | 0.206 | 0.237 | 0.191 | 0.200 | 0.158 | | -0.048 | -23.2% | *** |
| **COMPUTER USE** | | | | | | | | | |
| 1. Managers | 0.361 | 0.408 | 0.490 | 0.611 | 0.598 | | 0.237 | 65.8% | *** |
| 2. Professionals | 0.359 | 0.397 | 0.565 | 0.629 | 0.665 | | 0.306 | 85.3% | *** |
| 3. Technicians and associate professionals | 0.352 | 0.421 | 0.553 | 0.638 | 0.655 | | 0.303 | 86.2% | *** |
| 4. Clerical support workers | 0.606 | 0.644 | 0.693 | 0.727 | 0.766 | | 0.159 | 26.3% | *** |
| 5. Service and sales workers | 0.215 | 0.143 | 0.249 | 0.222 | 0.257 | | 0.042 | 19.5% | *** |
| 6. Skilled agricultural, forestry and fishery | 0.067 | 0.034 | 0.071 | 0.088 | 0.095 | | 0.028 | 41.7% | |
| 7. Craft and related trades workers | 0.092 | 0.111 | 0.103 | 0.135 | 0.177 | | 0.085 | 91.9% | *** |
| 8. Plant and machine operators | 0.111 | 0.122 | 0.083 | 0.157 | 0.209 | | 0.098 | 88.2% | *** |
| 9. Elementary occupations | 0.064 | 0.071 | 0.119 | 0.077 | 0.112 | | 0.048 | 74.9% | *** |

## A focus on selected services jobs

Looking at the evolution of task indices from a sectoral and occupational perspective allows identifying the dynamics which stand out. As already discussed in Section 4, data limitations do not allow to further explore changes in average task scores at a more disaggregated level of analysis, since both the sectoral (NACE Rev.1) and occupational (ISCO-08) classifications are consistently available from 1995 to 2015 only at the 1 digit level.

However, it is possible to look at specific combinations of sectors and occupations, that is ‘jobs’. Defining a job as an occupation in a sector corresponds to the common use of the term for descriptive purposes, for example a sales worker in the retail sector (like a shop assistant for instance), a teaching professional in the education sector (primary school teacher) or a health professional in the health sector (doctor). Considering all the possible occupation by sector combinations would mean in practice looking at the evolution of all the eight task indices in 99 jobs (11x9). From a content perspective, this is not a sensible approach because it is simply too much information to be analysed in detail. Neither it is from a methodological point of view in terms of robustness of results, due to an excessively small sample size, in some cases, at the job level.

For these reasons, and in light of previous results which clearly point to the fact that some specific services sectors and occupations exhibit particularly interesting patterns, seven significant jobs were identified and selected for detailed analysis[25]. The lower threshold in terms of number of observations for the selection of these jobs was set to 100 per EWCS wave[26]. Jobs with a larger number of observations are preferable both for statistical consistency in the measurement of the indices, and because they are actually important jobs in the employment structure in Europe.

The selected jobs are the following:

1. Clerical support workers in financial intermediation;
2. Technicians in financial intermediation;
3. Clerical support workers in public administration;
4. Professionals in real estate, renting and business activities;
5. Service and sales workers in hotels and restaurants;
6. Managers in wholesale and retail;
7. Managers in hotels and restaurants.

Each job is separately presented and discussed hereafter, highlighting the most significant trends in terms of changes in the task structure.

[25] The full set of task profiles at the job level is available on request from the authors. Criteria such as sample size and skills levels were also taken into account for the selection of the seven jobs.

[26] The only exception is technicians in financial intermediation which has 63 observations in 1995 (above 100 in the other waves). Nevertheless this job has been included since there is evidence in literature that it changed considerably in the last decade and it is therefore a relevant case to be analysed (see next page).

### *Clerical support workers in financial intermediation*

Online and mobile banking and the increasing requirements of fast and seamless cash-free payments through digital interfaces have changed banking and financial processes (Cedefop, 2016a). Most, if not all, information is digitally stored and managed by banking institutions. Many tasks involving processing payments, calculations of interests and elaboration of routine sources of information, maintaining records of bonds, shares and other securities bought or sold on behalf of clients or employers are increasingly dealt with in a highly automated or algorithmic way. For this category of workers, the EWCS data show a considerable and significant decline in the external social interaction (-21.8% in relative terms), with the intensity of social interaction declining from 0.687 to 0.537. On the contrary, both repetitive and standardised tasks substantially increased by 28.3% and 33.5% respectively. In particular, the work of clerical support workers in financial intermediation became increasingly subject to standards (from 0.501 to 0.669). A steady increase in computer use, which was already high in 1995 (indeed it went from 0.752 to 0.895) also reflects the increase in the use of digital tools in these professions.

### *Technicians in financial intermediation*

Financial algorithms have become so fast that nowadays most transactions happen in a fraction of a second, to the point that a key element for a trade company is to ensure the fastest data transmission possible because the trading advantage now relies only on the speed at which data are received and processed (Nature, 2015). The increase in use of financial algorithms changed the financial trade business (Brynjolfsson et al., 2017, p. 8) bringing more reliance on computer use and reducing the amount of time spent on dealing directly with other people. In that respect, data show that the standardised score for social tasks diminished by 15.4% for this category over the period 1995-2015. In the same period, there is a very large relative increase in standardisation (+62.7%, from 0.418 to 0.680), which is even higher than for clerical support workers employed in the same sector. This could be related to some extent to the adoption of technological solutions combined with the introduction of stricter financial regulations in the EU with the MiFID (Markets in Financial Instruments) directive (2004/39/EC) which was effective from 2007 and established a comprehensive set of rules on investment services and activities with the aim to promote efficiency, transparency and better integrations of financial markets[27]. Repetitive tasks are also more frequent, although the score in 2015 was only 0.321 (only half of the score of standardisation).

### *Clerical support workers in public administration*

For clerical support workers in public administration the EWCS data show a 46.8% relative increase in computer use from an average of 0.564 in 1995 to a high value of 0.828 in 2015. The e-Government initiative 'eEurope', promoted by the EU in 2000, favoured the digitalisation of public administration across Europe which among the other goals had the establishment of online services for citizens and enterprises. By 2010 the majority of the 20 basic online services were available in

[27] In 2014, MiFID II was introduced (effective from 3 January 2018) with the aim of reinforcing aspects of MiFID that proved weak during the financial crisis, strengthening investor's protection and improving the functioning of financial markets.

most Member States (Digitizing Public Services in Europe: Putting ambition into action, 2010). The digitalisation of the public administration kept growing under the push of European and national policies and in 2016, according to OECD estimates ‘the use of digital government services has tripled in OECD countries since 2006, with around 36% of OECD citizens submitting forms via public authorities’ websites’ (OECD, 2017). If a growing number of document exchanges and processing happens in digital form this probably accounts for a decrease in face-to face service to public administration service users. Data suggest that external social interaction decreased slightly for this category, although only marginally (from 0.522 to 0.468). Repetitiveness instead recorded a relative increase of 16.3% (from 0.394 to 0.458) although not statistically significant; this is however a much clearer change compared to standardisation for which the scores at the beginning and end of the period are very similar. In other words, clerical support workers in public administration did not change too much in terms of task content and methods, especially if compared with the same occupational group in financial intermediation.

*Professionals in real estate, renting and business activities*

Professionals in real estate, renting and business activities reported a significant decline in the extent to which they are dealing directly with clients, from a score of 0.739 to 0.518 (this corresponds to a 29.9% relative decrease). The score of social tasks in this job, though, is still high indicating an important social component for this category[28], which includes real estate agents and other professionals in the real estate ecosystem such as valuators or insurance and claims inspectors. One of the possible factors in this decline could be the fact that the introduction of web 2.0 enabled real estate companies to share their catalogues online and users to filter through tagging and to receive real time updates through RSS notification[29]. EWCS data show that the increase in computer use at work over the last two decades for this profession is remarkable, going from mid to very high levels (from 0.479 to 0.839).

*Services and sales workers in hotels and restaurants*

For services and sales workers in the tourism sector, the EWCS indicator of computer use increased by 249.6% moving from a very low value of 0.037 to moderately low value of 0.129. A relative increase of 35% in standardisation also shows a consistent upward trend. Social tasks remain high in absolute terms for this job category, although it decreased from 0.839 to 0.735 (-12.4%). The main characteristics of the business, in any case, is the relationship with the customer or client visiting the restaurant or staying at the hotel; and while the business did change with the introduction of web 2.0 services and, more recently, with apps which help to manage the relationship with clients in terms of orders, booking, payments, and showcasing services (Muller, 2010), this relationships stays at the core of the hospitality sector.

[28] This might change in the future with the introduction of technologies such as Virtual Reality and Internet of Things (IOT) which could enable distance viewings and a better grouping of clients according to their preferences or interest.

[29] https://www.tandfonline.com/doi/full/10.1080/02673037.2018.1487041?scroll=top&needAccess=true& - Technological change and estate agents’ practices in the changing nature of housing transactions.

### *Managers in wholesale and retail trade*

Social task content for managers in wholesale and retail trade diminished marginally by -7.3% from 1995 to 2015, while computer use rose by 86.6% (from a very low score of 0.256 to 0.478). Similarly to services and sales workers in hospitality, the introduction of computers changed the way managers dealt with their tasks, 'management productivity was the biggest beneficiary. No longer are manual systems such as staff scheduling, credit card receipt collating, and inventory management completed by hand' (Muller, 2010). Furthermore, the wholesale sector is a high technology-intensive business; managers need to have advanced ICT skills to oversee digital system integration among different parts of the business (Forfás, 2010). The increase in business digitalisation with online websites and through social media requires new ways of dealing with customers and training staff to meet these requirements (Cedefop, 2016b).

### *Managers in hotels and restaurants*

Computer use rose by 69.2% for managers in hotels and restaurants from 0.172 in 1995 to 0.291 in 2015. As for managers in wholesale and retail, the introduction of computers changed the way managers dealt with their tasks and shifted many of their tasks from manual to computerised (Muller, 2010). The spreading of online business activities, including social media, means that also the hospitality sector has found alternate ways of communicating with their customers. For this job, social tasks somewhat declined as per the general trend in the occupational group but only marginally (especially if compared to their colleagues in wholesale and retail). Indeed, in 2015 this job still reported one of the highest levels for social tasks (i.e. 0.854).

### *A comparison of main findings across the selected service jobs*

After having explored in detail the characteristics of each job, similarities and differences between jobs within the same sector or occupation were identified.

In the financial intermediation sector, a comparison between technicians and clerical workers allows sketching out the task evolution of two jobs requiring different skills levels within the same sector. It is interesting to note that, despite different roles and responsibilities, both categories experienced a marked decline in tasks involving direct social interaction with external people and an increase in standardisation and repetitiveness: most probably these changes are due to a mix of factors such as digital transformation and an increase in external regulatory pressure. The increase in the levels of standardisation and repetitiveness has been most felt by those employed as technicians (62.7% and 36.9%, versus 33.5% and 28.3% for clerical workers).

However, if compared with their colleagues in public administration, clerical workers in the financial intermediation sector experienced a greater increase in standardisation and repetitiveness. On the contrary, computerisation was much more felt by public administration clerks for whom computer use recorded a substantial increase (from 0.564 in 1995 to 0.828 in 2015). This is because clerical workers in financial intermediation already experienced in 1995 high levels of computer use (0.752), so the increase for this category was only marginal.

An increase in computerisation is also visible for jobs entailing coordination and planning such as managers in wholesale and retail; similarly to professionals in real estate, the way information is processed and organised has progressively moved to ICT-based systems which might have partly contributed to a decline in direct external interaction (social tasks decline by -7.3%). The increase in computer use holds true also for managerial roles in the hospitality sector (+69.2%), although in this case the it went from very low to low (from 0.172 to 0.291). This is not a high-technology sector, but both service and sales workers and managers in hotels and restaurants reported a rise in computer use. The declining trend in the social task score is particularly clear for service and sales workers in hotels and restaurants compared to managers in the same sector.

## Summary of main findings and concluding remarks

This paper has investigated changes in the task content, methods and tools of European jobs in the last 20 years. The analysis is particularly relevant in the context of the discussion on the future of work and automation, since digital technologies not only determine job losses or creation but also shape the content and methods of work by changing what people do on the job, and how they do it.

Performing a shift-share analysis allowed to assess to what extent changes in tasks were the result of changes in the structure of employment (shifts in employment across jobs) or changes in the work itself (transformation in the task contents and methods within-jobs). The results presented in this paper suggest that the decline in tasks requiring physical strength and the use of non-ICT machines at work are fully accounted for by a compositional change. This means that there was a significant reduction of employment in jobs requiring strength and using machines, while changes within-jobs for those types of tasks have only been marginal.

Contrasting trends emerge instead between the actually observed changes in tasks measures within jobs and compositional shifts in employment for three particularly important categories of tasks: social task content (although with some caveats related to periodisation), repetitive and standardised tasks methods. In the case of social tasks, in the last 20 years there was a significant compositional growth (jobs with more social task content expanded relative to the rest), but this is in contrast with a decline in the amount of social tasks people actually do in those (and other) jobs over the same period. A similar contradictory trend can be observed in the two variables measuring repetitiveness and standardisation, with compositional and intrinsic changes going in opposite directions. This contradiction is particularly surprising in the context on the current debates on the impact of technological change on employment, because it implies an actual increase in the total levels of routine at work notwithstanding marginal compositional declines.

One can advance a hypothesis that has to do with the way technology affects the amount of work needed across different task categories on the one hand, and the nature of tasks involved on the other. The increase in actual reported levels in the use of computer at work between 1995 and 2015 was extraordinary compared to the other task measures (+64.2%). However, establishing a direct link between changes in computer use and changes in other tasks is methodologically challenging. In terms of task content, consistent results across different model specifications were found only for the negative relationship between computer use and physical tasks on the one hand, and the positive relationship with intellectual tasks on the other. A more complex and unclear picture emerges instead for social tasks: although in some specifications computer use seemed to be related to a decline in social tasks within jobs, other models did not find such negative relationship. In terms of tasks methods, the results of econometric analysis were more robust and consistent with the shift share analysis: standardisation and (to a lesser extent) repetitiveness appear to be positively related to computer use when controlling for job-specific effects.

The empirical analysis also provides a detailed breakdown of changes in tasks from a sectoral, occupational and job perspective. Descriptive evidence suggests that services such as financial intermediation, real estate, renting and business activities, and public administration are those sectors in the economy showing more consistently clear developments in terms of declining social interaction on the one hand, and increasing standardisation and computer use on the other. In terms of occupational developments, the most consistent changes in social task (downward), standardisation and repetitiveness, and computer use (upward) can be found for managers, professionals, technicians and associate professionals, and clerical support workers.

In other words, the results presented in this paper provide some evidence to the hypothesis that computerisation had a contradictory effect in terms of social and routine task content. A large-scale computerisation of work over the last two decades was simultaneous with a significant compositional decline in routine task methods and an increase in social task content. This finding is consistent with the hypothesis of routine-biased technical change, which argues that computers mostly replace routine tasks while complementing (or not affecting) creative and social tasks. But the results presented in this paper also show an even more significant increase, over the same period, in the reported levels of repetitiveness and standardisation of work processes (and thus the levels of routine) and a decline of social task content. And these trends seem to be directly related (most clearly in the case of task standardisation) to the increasing use of computers at work. Computers, therefore, would be both replacing routine tasks (and thus displacing labour towards non-routine tasks and occupations) and routinising the remaining tasks and occupations (by making work processes more repetitive and standardised). In a similar way (though the evidence is less robust in this case), computers would be both displacing labour towards jobs with more social tasks (because those tasks are more difficult to carry out with computers) and reducing the amount of social tasks in the remaining jobs (because some of those tasks can be carried out via online or computerised means).

## References

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Akçomak, S., Kok, S., and Rojas-Romagosa, H. (2016), 'Technology, offshoring and the task-content of occupations: Evidence from the United Kingdom', *International Labour Review*, Vol. 155.

Arntz, M., Gregory, T. and Zierahn, U. (2016), *The risk of automation for jobs in OECD countries: A comparative analysis,* OECD Social, Employment, and Migration Working Papers 189.

Autor, D. H., Katz, L. F. and Kearney, M. S. (2006), 'The Polarization of the U.S. Labor Market'. *American Economic Review Papers and Proceedings*, 96(2), 189-194.

Autor, D. H. (2013), *The 'task approach' to labor markets: an overview*. National Bureau of Economic Research, No. w18711.

Autor, D. H, Levy, F. and Murnane, R. J.( 2003), 'The skill content of recent technological change: An empirical exploration', *The Quarterly journal of economics* 118.4, pp. 1279–1333.

Autor, D. H. and Price, B. (2013), *The changing task composition of the US labor market: An update of Autor, Levy, and Murnane (2003)*, MIT working paper, Massachusetts Institute of Technology, June.

Autor, D. and Handel, M. (2013), 'Putting tasks to the test: Human capital, job tasks, and wages', Journal of Labor Economics, 31(2), 59–96.

Berman, E., Bound, J. and Machin, S. (1998), 'Implications of Skill- Biased Technological Change: International Evidence', *The Quarterly Journal of Economics*, 113(4), pp. 1245-79.

Bisello, M. and Fernández-Macías, E. (2016), 'Fewer Routine Jobs But More Routine Work', *Social Europe.* Available at [https://www.socialeurope.eu/fewerroutine-jobs-but-more-routine-work](https://www.socialeurope.eu/fewerroutine-jobs-but-more-routine-work).

Blinder, A. (2006), 'Offshoring: The Next Industrial Revolution?', *Foreign Affairs*, vol. 85 (2), pp. 113–28.

Blinder, A. (2009), 'How many US jobs might be offshorable?', *World Economics*, 10(2), pp. 41-78.

Bobek A., Wickham J. (2015), Employment in the Irish construction sector: A preliminary background report. Available at [https://www.tasc.ie/download/pdf/20150929160711.pdf](https://www.tasc.ie/download/pdf/20150929160711.pdf)

Bound, J. and Johnson, G. (1992), 'Changes in the Structure of Wages in the 1980's: An Evaluation of Alternative Explanations', *The American Economic Review*, 82(3), pp. 371-392.

Brynjolfsson, E. and McAfee, A. (2011), *The second Machine age,* W. W. Norton & Company, New York.

Braverman, H. (1974), *Labor and Monopoly Capital*, Monthly Review Press.

Cedefop (2016a), 'Customer clerks: skills, opportunities and challenges', *Skills Panorama*. Available at https://skillspanorama.cedefop.europa.eu/en/analytical_highlights/customer-clerks-skills-opportunities-and-challenges#_which_drivers_of_change_will_affect_their_skills_

Cedefop (2016b), 'Hospitality & retail managers: skills opportunities and challenges', *Skills Panorama*. Available at https://skillspanorama.cedefop.europa.eu/en/analytical_highlights/hospitality-retail-managers-skills-opportunities-and-challenges

De La Rica, S. and Gortazar L. (2016), *Differences in Job De-Routinization in OECD Countries: Evidence from PIAAC,* IZA Discussion Papers 9736, Institute for the Study of Labor (IZA).

David J. Deming, (2017). ‘The Growing Importance of Social Skills in the Labor Market’. *The Quarterly Journal of Economics*, Volume 132. Issue 4, Pages 1593-1640.

Eurofound (2016), *What do Europeans do at work? A task-based analysis: European Jobs Monitor 2016*, Publications Office of the European Union, Luxembourg.

Fernández-Macías, E.(2012), ‘Job polarization in Europe? Changes in the employment structure and job quality, 1995-2007’, *Work and Occupations,* 39.2, pp. 157–182.

Fernández-Macías, E. and Hurley, J. (2016), ‘Routine-biased technical change and job polarization in Europe’, *Socio-Economic Review*, Volume 15, Issue 3, Pages 563–585

Fernández-Macías, E., Bisello, M., Sarkar ,S.and Torrejón, S.(2016), *Methodology of the construction of task indices for the European Jobs Monito,* Eurofound, Dublin.

Forfás (2010), *Future Skills Needs of the Wholesale and Retail Sector*.

Frey, C. F., & Osborne, M. A. (2017), ‘The future of employment: How susceptible are jobs to computerisation?’, *Technological Forecasting and Social Change*, 114, 254–280.

Goldin, C. , Lawrence F. Katz. (1998), ‘The origins of technology-skill complementarity’. *The Quarterly journal of economics,* 113.3, pp. 693– 732.

Goos, M., Manning, A. (2007) ‘Lousy and Lovely Jobs: The Rising Polarization of Work in Britain’, *Review of Economics and Statistics*, 89(1), 118-133.

Goos, M., Manning, A., and Salomons, A. (2009) ‘Job Polarization in Europe’, *AEA Papers and Proceedings*, 99(2), 58-63

Goos, M., Manning, A. and Salomons, A. (2010) ‘Explaining job polarization in Europe: The roles of technology, globalization and institutions’, *CEP Discussion Paper* No. 1026, Centre for Economic Performance, London School of Economics, London.

Goos, M., Manning, A., & Salomons, A. (2014), ‘Explaining job polarization: Routine-biased technological change and offshoring’, *The American Economic review*,Vol. 104, No. 8, pp. 2509–2526.

Green, F. (2012), ‘Employee Involvement, Technology and Evolution in Job Skills: A Task-Based Analysis’, *Industrial & Labor Relations Review*, 65 (1), pp. 35-66.

Handel, M. (2012), ‘Trends in Job Skills Demands in OECD Countries’, *OECD Social, Employment and Migration Working Papers,* No 143, OECD Publishing.

Hardy, W., Keister R., Lewandowski, P. (2018). ‘Educational upgrading, structural change and the task composition of jobs in Europe’, *Economics of Transition*, Volume 26. Issue 2. Pages 201–231.

Katz, L. F. and Murphy, K. M. (1992) ‘Changes in Relative Wages, 1963-1987: Supply and Demand Factors’. *Quarterly Journal of Economics,* 107(1), 35-78.

Machin S. and Van Reenen, J (1998), ‘Technology and changes in skill structure: Evidence from seven OECD countries’, *The Quarterly Journal of Economics*, 113(4):1215-1244.

Matthes, B., Christoph, B., Janik, F., Ruland, M. (2014) ‘Collecting information on job tasks - an instrument to measure tasks required at the workplace in a multi-topic survey’, *Journal for Labor Market Research*, 47(4), 273-297.

Muller,C. (2010), ‘Hospitality technology: a review and reflection’, *Worldwide Hospitality and Tourism Themes*, Vol. 2 Issue: 1, pp.9-19.

Nature (2015), *Physics in finance: Trading at the speed of light*, 11 February 2015.

OECD (2017), *Government at a Glance 2017*, OECD Publishing, Paris. Available at: https://doi.org/10.1787/gov_glance-2017-en.

Pouliakas, K., Russo, G. (2015), Heterogeneity of skills needs in relation to job tasks: evidence from the OECD PIAAC Survey, *IZA discussion paper series*, No. 9392.

Salvatori, A., S. Menon and W. Zwysen (2018), ‘The effect of computer use on job quality: Evidence from Europe’, *OECD Social, Employment and Migration Working Papers*, No. 200, OECD Publishing, Paris.

Spitz-Oener, A. (2006), ‘Technical change, job tasks, and rising educational demands Looking outside the wage structure’, *Journal of labor economics* 24.2, pp. 235–270.

UK Commission for Employment and Skills (2014), *The Future of Work- Jobs and Skills in 2030.* Available at:

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/303334/er84-the-future-of-work-evidence-report.pdf

## Annex: Questions from Eurofound's EWCS 2015

| INDEX | EWCS question (ref. year 2015) | Text of the survey questions | |
|---|---|---|---|
| **Physical: strength** | 30a; 30c | **30a.** Please tell me, using the same scale, does your main paid job involve ...? A - Tiring or painful positions<br>**30c.** Please tell me, using the same scale, does your main paid job involve ...? C - Carrying or moving heavy loads | |
| **Intellectual: problem solving** | 53e; 53c; 53f | **53e.** Generally, does your main paid job involve... ? E - complex tasks<br>**53c.** Generally, does your main paid job involve ... ? C - solving unforeseen problems on your own<br>**53f.** Generally, does your main paid job involve... ? F - learning new things | |
| **Social: dealing directly with people** | 30f | **30f.** Please tell me, using the same scale, does your main paid job involve ...?<br>F - Dealing directly with people who are not employees at your workplace such as customers, passengers, pupils, patients, etc. | |
| **Autonomy** | 54a; 54b; 54c | **54a.** Are you able to choose or change ... ? A - your order of tasks<br>**54b.** Are you able to choose or change ... ? B - your methods of work<br>**54c.** Are you able to choose or change ... ? C - your speed or rate of work | |
| **Routine: repetitiveness** | 48b; 53d; 30e | **48b.** Please tell me, does your job involve short repetitive tasks of less than ... ? B - 10 minutes<br>**53d.** Generally, does your main paid job involve ... ? D - monotonous tasks | |

| | | | |
|---|---|---|---|
| | | **30e.** Please tell me, using the same scale, does your main paid job involve ...? E - Repetitive hand or arm movements | |
| **Routine: standardisation** | 50c; 53a | **50c.** On the whole, is your pace of work dependent on ... ? C - numerical production targets or performance targets<br>**53a.** Generally, does your main paid job involve ... ? A - meeting precise quality standards | |
| **Technology: Machines** | 29a;50d | **29a.** From now onwards all the questions are about your main paid job.<br>Please tell me, using the following scale, are you exposed at work to ...? A - Vibrations from hand tools, machinery, etc.<br>**50d.** On the whole, is your pace of work dependent on ... ? D - automatic speed of a machine or movement of a product | |
| **Technology: Computers** | 30i | **30i.** Please tell me, using the same scale, does your main paid job involve ...?<br>I - Working with computers, laptops, smartphones etc. | |

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