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A Comparative national tasks database

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A Comparative national tasks database

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Abstract

The present study offers an original and unique database collecting information on task profiles using national data across five European countries (France, Germany, Italy, Spain and UK) in order to assess the existence of cross country variability in terms of tasks content, methods of work and tools used at work. Overall, the comparative component contributes to better understanding nature of work, effects of technical change, institutional and cultural variations across countries, a dimension often neglected in the literature especially for limitation in data availability at the national level. The creation of task indicators follows the overall approach and methodology developed in Fernández-Macías, Hurley and Bisello, 2016; Fernández-Macías, Bisello, Sarkar, Torrejón, 2016 and its updated version by Fernández-Macías and Bisello (2020). In order to provide consistent cross-country data enabling comparisons, we applied the weighted ranking method already established in the literature and often used in the job-based approach. Using the ordered ranking resulting from the standardisation adopted, we analysed national employment structures focusing on tasks profile as well as on the employment distribution by task-terciles. The descriptive analysis performed highlights two main patterns. First, a certain degree of similarity in employment structures by tasks content terciles emerges, especially once compared across occupational groups. The task content of jobs reflects the technical nature of the production process - which is directly related to the type of product or service that is produced – and, in principle, is less affected by national differences. Second, countries show more heterogeneity in terms of work organization, namely "methods of work". This can in turn be explained by the fact that work methods reflect (relatively more than content itself) the socio-organizational structure in which they are embedded and are affected by idiosyncratic behavioral patterns of routines, cultural values, institutional frameworks.

Keywords: tasks; technical change, cross-country comparative analysis.

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Contents

Introduction

Since the 1990s, as income structures start becoming increasingly polarized, political debate and academic research looked for explanations consistent with the mainstream economic view. Initially, the focus was on the complementarity/substitutability between workers' skills and Information and Communication Technologies (ICT) as a driver of such polarizing patterns. Popularized as the 'Skill Biased Technological Change' (SBTC) theory (Katz and Murphy, 1992; Berman et al. 1994; Machin and Van Reenen, 1998; Katz, 1999), this approach points to a generalized process of skill upgrading with demand increasing for those at the top of the distribution, due to strong technology-skill complementarities; and decreasing for those at the mid-bottom, due to low-complementarity.

From an empirical point of view, trends in employment and occupational structures highlight a pattern of polarization with an increase in employment both at the top and bottom of the skill distribution (for a review, see Autor, 2015). However, a non-negligible set of contributions focusing on Europe – see, among others, Bogliacino and Lucchese (2015); Fernández-Macías et al. (2016); Fernández-Macías and Hurley (2017); Cirillo (2016); Oesch and Piccitto (2019) – reports different structural patterns (e.g., upgrading or deskilling dynamics instead of polarization).

In order to be more consistent with the empirical evidence (i.e. job polarization or upgrading), the theoretical focus needed to be revised. Framing jobs as 'bundles of tasks', the focus shifted on the very object of potential substitution by machines and ICT devices: tasks. This approach – whose related literature (see, for example, Autor, 2013 and Autor and Dorn, 2013) is known as 'Routine Biased Technological Change' (RBTC, hereafter) – ranks jobs no longer based on their generic 'skill endowment' but according to the relative share of some particular type of tasks characterizing them. More specifically, according to the RBTC literature, what matters to predict the rise (or the fall) of jobs is the share of 'routinary' tasks – i.e. repetitive and encodable tasks expected to be more easily replicable by a machine or a computer, and thus increasing the risk of technological unemployment – bundled in it. From a theoretical point of view, RBTC is grounded on the marginalist framework interpreting labour, capital and technology as mere production inputs with a degree of substitutability based on the comparative cost advantage among them (Autor et al., 2003; Autor, 2013).

The importance of tasks as an analytical object is also recognized by the strand of literature studying the employment implications of the processes of international production fragmentation and the Global Value Chain (GVC) participation (Grossman and Rossi-Hansberg, 2006; 2008). By framing offshoring production as a 'trade in tasks', this literature assumes that routine tasks are more easily performable away from the main production loci than less routine tasks. As a result, jobs characterized by a relatively large share of routine-task are 'threatened' twice: by the risk of substitution by machines as well as by the risk of being offshored (Leamer and Storper, 2001; Levy and Murnane, 2005; Blinder, 2009).

Despite representing a significant analytical advancement as compared to the SBTC theory, the RBTC approach neglects to account for several relevant socio-economic, organizational and institutional factors contributing to explain key structural labour market developments.

First, there is no account for what Fernández-Macías et al. (2016) refer to as 'human agency'. Accounting for human agency, in turn, means overcoming the analytical constraints of the neoclassical 'production function approach' upon which both SBTC and RBTC theories are built. In so doing, it is possible to shed light on the role of human relationships among co-workers in the exchange of knowledge – recalling some intuitions of the evolutionary theory of the firm (see for a review Teece, 2019) – as well as on the relevance of social relations between different layers in the firm hierarchy – ownership, management and employees. This allows enriching the conceptualization (and thus the understanding) of production processes jointly considering technological, economic, institutional and sociological elements that are equally important in explaining the dynamics of work and labor markets.

Once 'human agency' is taken into account, factors such as human adaptability, flexibility and specific experience make some tasks 'irreplaceable' by machines even if their degree of repetitiveness and standardisation makes them technically replaceable. By the same token, Pfeiffer (2018) puts in question the distinction between cognitive and manual tasks that is at the basis of the RBTC conceptualization, emphasizing the importance of knowledge accumulation and subjective experience in the execution of the work activity. Bringing back a classical view of the workplace and of its internal functioning (Braverman, 1974), Fernández-Macías et al. (2016) emphasize that the tasks spectrum goes far beyond those needed to the material and technical input transformations. Indeed, supervisory tasks are not part of the technical process of transformation but of the social dimension of work: to ensure workers' obedience and cooperation towards firm' goals. Furthermore, the level of routine embodied in a task reflects the way work is organized and not, as claimed by the RBTC proponents, the content of the task itself.

As emphasized by Fernández-Macías et al. (2016) and in tune with the conceptualization of work put forth by Braverman (1974), task routinisation should be understood in itself as part of the process of organisational change and, therefore, it is dependent to institutionally and historical-contingent models of work organizations. The level of routine involved in a job can be as much the result of social and technical constraints. Taylorism used standardisation and routinisation of work as a tool for increasing the degree of managerial control over the labour process (Braverman, 1974). However, routine and repetitiveness have been often conceptualized in influential empirical contributions (Autor, 2001; Autor and Dorn, 2003) as synonymous of task automation, disregarding the specificities of institutional contexts and patterns of adoption of digital technologies among sectors and countries. Recent evidence on Italian data highlights that routinisation per se cannot be associated with automation unless it goes along with the application of digital tools at the workplace level (for recent evidence on the interplay of digitalization, routines and employment in Italy, see Cirillo et al., 2020).

These elements have been explored also by Cetrulo et al. (2020: p. 6). Discussing the limitation of the RBTC approach, these authors highlight four additional key aspects defining work, namely: 'the degree of autonomy in performing activities, whereby autonomy captures the extent to which workers have the possibility to set their own rules; second, the degree of control over the production process, which when full even allows the worker to stop the execution of tasks in case of errors; third, degrees of collective knowledge inside the organization deriving from the existence of learning processes and team working; fourth, degrees of hierarchical power, space of control of the supervisors, space of individual actions and goal setting, and in general the social organization structure'.

Second, cross-country and cross-industry heterogeneity concerning labour market institutions – as the degree of unionization, the cost of dismissal or the level of workers' protection against layoffs – also plays a crucial role in explaining the magnitude and direction of the technology-employment relationship, irrespective of the degree of routineness of tasks (Mishel et al., 2013; Cirillo et al. 2020). Such heterogeneity can be very important to explain the different results stemming from the empirical studies analyzing technological change and its impact on employment and income structures.

Third, firm-level heterogeneities regarding techno-organizational idiosyncratic arrangements and capabilities are also essential to understand why the same job might shrink in terms of relevance in a specific firm; while consolidating its importance in another one. To find an answer, a proper conceptualization of the firm is necessary. Since the path-breaking contribution of Edith Penrose, we learnt that firms are radically heterogeneous concerning their organizational set-up, their endowment in terms of capabilities, their routines and knowledge-base. As stressed by authors as Winter (1997), Coriat and Dosi (1998) and, more recently, Cetrulo et al. (2020), firms are heterogeneous hierarchical entities wherein knowledge is differently distributed among organizational units and individuals. In these contexts, technological and organizational change entails processes of uneven learning and adaptation of the different hierarchical layers. As a result, firm-level heterogeneity matters to understand the type of learning regimes that workers tend to face as well as the intertwining between

companies' organizational characteristics, on the one hand, and the way work is performed, on the other.

Fourth, jobs as "bundles of tasks" enclose several work activities requiring different combinations of tasks – e.g. manual and social type of tasks for doctors – meaning that a complete replaceability of jobs should involve the whole set of work activities performed (Autor and Handel, 2013; Arntz et al., 2016; Pouliakas and Russo, 2015).

A step beyond the RBTC approach, able to capture the above-mentioned aspects, is made by the JRC-Eurofound framework (JRC-EF, hereafter) developed by Fernández-Macías et al., (2016), recently updated in Fernández-Macías and Bisello (2020) which will be discussed more in detail in the next section. In order to provide an empirical counterpart to concepts as those proposed by the RBTC or the JRC-EF approach, a large amount of sound and detailed data providing information – at a sufficiently granular level – on qualitative characteristics of work is needed. Key elements are skills, tasks, technologies, work attitudes, industrial relations, organizational characteristics of the workplace. For the US economy, this type of information is provided by the O*NET database1, upon which a large amount of empirical analysis correlating work's qualitative characteristics, employment and income dynamics has been realised (see Autor, 2015 for a review). Unfortunately, a comprehensive database similar to O*NET is not available for the whole European economy. European data sources, as the European Working Conditions Survey (EWCS) or the OECD's Survey of Adult Skills (PIAAC), provide only parts of the information and with a lower detail, particularly concerning the disaggregation at the occupation-sectoral level. Fernández-Macías et al. (2016) adopts a task-based approach and pools together EWCS, PIAAC and O*NET data to answer the question "What do Europeans do at work?". One of the major limitations of this first empirical exercise concerns the fact that the information provided by the adopted data sources are collected in different countries according to different aims and sampling strategies - O*NET bases its measurement on US workers, while the EWCS is a European survey and PIAAC covers different OECD countries. Moreover, the set of task measures developed in Fernández-Macías et al. (2016) refer to advanced western economies, a group of countries with similar levels of economic development and comparable socioeconomic structures, but still divergent work organization models.

There is still limited availability of country-specific data on tasks. Most researchers continue to use the O*NET repertoire - that is characterized by a remarkable richness regarding the amount of qualitative information for each US occupation. The common strategy is that of associating US-based variables to non-US occupations. This is done (as in the case, among others, of Goos et al. 2014) relying on occupation-based cross-walks. This allows, on the one hand, to access the richness of the O*Net repertoire also to analyze non-American occupational structures. On the other hand, however, it implies assuming that the American occupational structure perfectly overlaps a different one as, for example, the European. This of course might affect the quality of the analysis and the degree of generalization associated to it. Despite the fact that some country-specific task databases do already exist – see for instance the O*Net type Indagine Campionaria delle Professioni (ICP) conducted by the National Institute for the Analysis of Public Policies (INAPP) in Italy (Gualtieri et al. 2018; Cetrulo et al. 2020; Cirillo et al. 2020) and the French *Enquête Conditions de travail* run since 1979– most

[1] The O*Net database builds upon the Dictionary of Occupational Titles (DOT, hereafter) which since 1939 reported information on occupations with a specific focus on the skills required in the public employment service. The O*Net is based on the SOC providing for each elementary occupation variables on knowledge, skills, abilities and tasks. The key dimensions included in the O*Net are the following: worker characteristics – permanent characteristics affecting workers' performance as well as their propensity to acquire knowledge and skills; worker requirements – workers characteristics matured by means of experience and education; experience - characteristics mostly related to past work experience; occupation – a large set of variables referring to requirements and specific features of the various occupations.

empirical studies continue to make use of the US O*NET database to analyse occupational dynamics in Europe.[2]

The present study offers an original and unique database developed to overcome the limitations mentioned above. Indeed, it collects information on task profiles using national data across five European countries in order to assess the existence of cross country variability in terms of tasks content, methods of work and tools used at work.

The database – whose main features are described in this report – is the output of a joint research project carried out in 2019 by the JRC-Seville, the National Institute for the Analysis of Public Policies (INAPP), the Federal Institute for Vocational Education and Training (Bibb), Pompeu Fabra University and the Warwick Institute for Employment Research3. The Comparative European Tasks Database resulting from the merge of five country-specific task databases (France, Germany, Italy, Spain and the United Kingdom) follows the overall approach and methodology of the earlier Eurofound work on this issue (Fernández-Macías, et al., 2016; Fernández-Macías, Bisello, Sarkar, Torrejón, 2016)[4] and its updated version by Fernández-Macías and Bisello (2020).[5] The research project has attempted to generate comparable data on tasks across five European countries paving the way to assess cross-national variability in tasks contents, methods of work and tools; better understanding of nature of work, effects of technical change, institutional and cultural variations[6].

After a brief description of the JRC task framework as updated in Fernández-Macías and Bisello (2020) performed in Section 2, national sources used to construct national task indicators and the methodology applied to harmonize country-specific data are explained in Section 3. Section 4 provides descriptive evidence on distributions of task indicators by professions for each country using raw data. Section 5 applies the ordered-ranking method to tasks indicator and inspects correlations among task indicators' rankings to check the consistency of indices across countries, and discusses tasks' characterization of "big jobs" – those employing the largest share of workers among the five European countries covered in this report. Finally, using the jobs-approach, Section 5 describes employment distribution by task indicator-tercile providing a comparison of task and employment structures across countries. Section 5 concludes highlighting the strengths and limitations of the JRC-EU database and discusses future avenues for task research. The Appendix includes the correspondence table between NACE Rev. 2 two-digits level and the aggregated macrosectors used in this study, a table presenting

[2] Some notable exceptions are Spitz-Oener (2006) focusing on Germany and using individual-level 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); Green (2012) providing evidence on the UK and relying on skill survey data; and Matthes et al. (2014) analyzing the fourth wave of the German Socio Economic Panel which includes a specific module on tasks.

[3] The project has been developed under the Call for Tender - JRC/SVQ/2018/B.4/0022/NC – "COMPILATION OF TASKS DATA AT THE NATIONAL LEVEL AND SUPPORT IN THE DEVELOPMENT AND TESTING OF A TASKS QUESTIONNAIRE".

[4] The database has been enriched with French task data.

[5] The national sources used to build the 'Comparative national tasks database' are the following: the Indagine Campionaria sulle Professioni (Italy); the Enquête Conditions de travail - Risques psycho-sociaux (France); the Employment Survey conducted by the Federal Institute for Vocational Education and Training (BIBB) in cooperation with the Federal Institute for Occupational Safety and Health (BAuA) (Germany); the surveys conducted by the Centro de Investigaciones Sociológicas (CIS) and five waves of the Encuesta de Calidad de Vida en el Trabajo (ECVT) conducted by the Spanish National Statistical Office (Spain); the Skills and Employment Survey (SES) (UK). An accurate description of the national sources included in the analysis is provided below.

[6] In detail, the project has aimed to: (i) provide feedback to the JRC team in the development, enrichment and update of the JRC-EF tasks framework; (ii) construct national-specific databases on tasks following the JRC-EF tasks framework; (iii) compare the results with those of the JRC-EF international tasks database; (iv) assist the JRC team in developing a model questionnaire on tasks contents, methods and tools using the updated JRC-EF framework (see Fernández-Macías and Bisello, 2020) and test it in four Member States.

tasks indicators available in each country according to the JRC-EF framework and additional descriptive statistics.

The JRC-EF tasks framework: an overview

The JRC-EF framework enriches the standard task-based approach and puts organizational and social aspects at the centre of the stage. In the task-based approach, tasks are considered as units of work activity producing output, whereas jobs are bundles of tasks. What such approach neglects, instead, is the social and organizational embeddedness of tasks within an institutional and work environment. Work is framed as input into the production process and can be performed by human beings or machines, depending on the respective costs. In other words, capital and labour are equated, leaving aside the role of human agency. However, human agency does play a role, and the coordination of various humans' effort into the production process is, itself, a generator of work-related tasks; tasks that are not technically but *socially* necessary for production (e.g. managerial, supervisory and control tasks). Moreover, such coordination induces various forms of work organization to emerge, each endowing jobs with different levels of social power and resources (Fernández-Macías et al., 2016).

The JRC-EF wovens together these elements, stemming from the RBTC literature, labour process theories and organizational studies. It focuses on tasks; it takes into account the role of demand and consumption, and it embraces the organizational and social aspects of production. In the attempt to combine these streams of literature, the JRC-EF framework defines a link between classical functional and skill approaches to measure what people do at work and how they do it – which is the novelty. With the aim of "opening the black box" (Rosenberg, 1982) of the production process, the framework connects the substantive content of work – the extent to which tasks require working with objects, data or people and if workers engage in physical, intellectual or social tasks – with its organizational content – methods and tools required to perform the tasks.

The "Content of tasks" depends on what is the object of the production/transformation process and, therefore, is strongly related to the structure of demand expressed by sector of economic activity (NACE sectors). "Methods and tools" represent how a task is carried on, hence describe production processes as historically and institutionally contingent. This second dimension unravels crucial heterogeneities concerning the division of labour and work organization: the same product may be the result of a variety of production processes established in different countries and cultures.

The key domains of the JRC-EF framework included in the Box that follows are (for a detailed discussion see Fernández-Macías and Bisello, 2020):

- ✓ Physical [Strength, Dexterity, Navigation]
- ✓ Intellectual [Information processing, Problem-solving]
- ✓ Social [Serving, Selling, Teaching, Managing, Caring]
- ✓ Methods [Autonomy, Teamwork, Routine]
- ✓ Tools [Non-digital machinery, Digitally-enabled machinery, Others]

An early application of the JRC-EF framework to European-level data (see Fernández-Macías et al., 2016) highlights that each job is characterised by a particular combination of tasks, rather than just one at a time.

Box 1. The JRC-EF task framework.

A. In terms of the content:

1. **Physical tasks:** aimed at the physical manipulation and transformation of material things:
    a. *Strength:* lifting people and heavy loads, exercising strength.
    b. *Dexterity:* precisely coordinated movements with hands or fingers.
    c. *Navigation:* moving objects or oneself in unstructured or changing spaces

2. **Intellectual tasks:** aimed at the manipulation and transformation of information and the active resolution of problems:
    a. *Information processing:*
        I. Visual and/or auditory processing of uncodified/unstructured information
        II. Processing of codified information
            i. Literacy:
                a. Business: read or write letters, memos, invoices,…
                b. Technical: read or write manuals, instructions, reports, forms,…
                c. Humanities: read or write articles or books.
            ii. Numeracy*:*
                a. Accounting: calculate prices, fractions, use calculators,…
                b. Analytic: prepare charts, use formulas or advanced maths
    b. *Problem-solving:*
        I. Information gathering and evaluation.
            i. Information search and retrieval
            ii. Conceptualization, learning and abstraction
        II. Creativity and resolution
            i. Creativity
            ii. Planning

3. **Social tasks:** whose primary aim is the interaction with other people:
    a. *Serving/attending:* responding directly to demands from public or customers
    b. *Teaching/training/coaching:* impart knowledge or instruct others
    c. *Selling/influencing:* induce others to do or buy something, negotiate
    d. *Managing/coordinating:* coordinate or supervise the behaviour of colleagues
    e. *Caring:* provide for the welfare needs of others.

B. In terms of the methods and tools of work:

1. **Methods:** forms of work organisation used in performing the tasks:
    a. Autonomy
        I. Latitude: ability to decide working time, task order, methods and speed.
        II. Control (in reverse): direct control by boss or clients, monitoring of work.
    b. Teamwork: extent to which the worker has to collaborate and coordinate her actions with other workers
    c. Routine
        I. Repetitiveness*:* extent to which the worker has to repeat the same procedures
        II. Standardisation: extent to which work procedures and outputs are predefined and encoded in a formalised system
        III. Uncertainty (in reverse): extent to which the worker needs to respond to unforeseen situations

2. **Tools:** type of technology used at work:
    a. Non-digital machinery (analog)
    b. Digitally-enabled machinery
        I. Autonomous (robots)
        II. Non-autonomous
            1. Computing devices
                a. Basic ICT (generic office applications)
                b. Advanced ICT (programming, admin)
                c. Specialised ICT
            2. Others

Source: Fernández-Macías and Bisello (2020)

National tasks databases

This section aims to briefly present the national sources used to build the Comparative National Tasks Databaseand the main variables used to measure task indicators of the JRC-EF as illustrated in Box 1.

Although the national surveys used to construct the Comparative National Tasks Database are collected either at the individual level, as it is for Spain, France, the United Kingdom and Germany, or at the professional level, as for Italy, the Comparative National Tasks Database has been collapsed at the job level.

A job is defined as an occupation in a given sector capturing both the sectoral and occupational dimensions of change (Hurely et al., 2019) e.g. a salesperson in the retail sector or a doctor in the health sector. This approach enables to capture both dimensions of the division of work: the horizontal one referring to economic activities (sector) and the vertical one referring to the hierarchical position of workers within each organization (professional group). Moreover, in order to get consistency, the different databases have been re-aggregated using employment weights at two-digits ISCO08 and macro-sectoral level[7].

After an in-depth inspection of all dimensions covered in the national surveys, task indicators have been constructed in each country by using at least one question (in most cases, more than one) for each element in the JRC-EF framework. Most of the JRC-EF indicators are built over different sub-indicators, each capturing a specific and detailed facet. To avoid losing valuable information, we use the maximum amount of information (sub-indicators) for the construction of each indicator. However, national surveys provide very diverse information; therefore, some task (sub-)indicators do not have an adequate proxy in some countries, and often the same (sub-)indicator emerges from the aggregation a different number of questions by country. In detail, we have followed three steps in the construction of JRC-EF task indicators building on Fernández-Macías, et al. (2016) and Fernández-Macías, Bisello, Sarkar, Torrejón (2016) :

Selection of variables: variables from national surveys have been selected to cover task (sub-) indicators of the JRC-EF framework through a textual analysis of national questionnaires;

Data inspection: parametric and non-parametric descriptive statistics have been used to explore correlations of variables referring to the (sub-)indicator (correlogram, scree plot, principal component analysis, density plot);

Aggregation of variables: indicators are averaged at the job level (weighted with survey weights or employment shares, depending on the survey)[8].

[7] The classification used in this paper aggregate the one used by Eurostat to classify manufacturing and service industries according to their technological intensity. The resulting aggregation consists in nine macro-sectors: Primary; Construction; Low-tech Industries; High-tech Industries; Low knowledge-intensive sectors; Knowledge-intensive sectors; Public administration; Education and Health (see Table A2 in the Appendix). The original Eurostat source can be found at https://ec.europa.eu/eurostat/cache/metadata/Annexes/htec_esms_an3.pdf.

[8] Upon request, it is available the deliverable 3 of the project containing for each national database: a synthetic description of data source, adopted criteria, description of the selected variables and illustration of the procedure followed to weight and aggregate variables. In addition, an item-by-item data inspection relying on parametric and non-parametric descriptive statistics is provided.

Furthermore, given different scales and for the sake of coherence, each indicator has been converted into a continuous variable ranging between zero and one. Zero captures the lowest and one the highest level. Table A1 in the Appendix summarises task indicators available in each country.

Although this approach ensures some conceptual coherence across dimensions and countries, the underlying differences in the construction of the indicators make it impossible to compare raw scores across countries. Therefore, descriptive statistics based on raw scores should be evaluated internally, within each country, investigating their distribution across sectors and occupations. It is then possible to check the overall coherence along the relevant dimensions of the vertical and horizontal division of labour exploring, for example, whether the distribution of tasks content behaves similarly across economic activities in the five countries, as will be shown later in this paper.

French database

The French database uses the *Enquête Conditions de travail - Risques psycho-sociaux* 2016 (CT-RPS 2016) conducted by the DARES- Ministry of Labour. In particular, the survey represents the last wave of the French *Enquête Conditions de travail* established in 1984 and held every seven years until 2013 and every three years after. It is a representative survey, including individuals over 15 years old both employed and unemployed. For the latter group, information on the last job has been recorded. Data are collected using the international classifications both for occupations and economic activities at four and three-digits level respectively, enabling the analysis at a finer granular level than what required in the present study. However, for the present study, we restrict the sample to employed people, excluding self-employed. Moreover, the survey covers all dimensions of working conditions (i.e. working time, work organization, physical strength and risks) but tools used at work. More specifically, while the survey deeply inquires tasks content in term of physical activities, it lacks most of the dimensions related to intellectual tasks, literacy and numeracy, as well as some detailed information on social tasks (like teaching or caring activities). On the contrary, one of the main strengths of the survey is the set of questions referred to methods of work, enabling to cover all sub-indicators of the JRC-EF framework.

German database

The German database is built upon the Employment Survey 2012 conducted by the Federal Institute for Vocational Education and Training (BIBB) in cooperation with the Federal Institute for Occupational Safety and Health (BAuA) every six years since 1979. The survey is a representative survey providing information on fully employed persons and on paid employment (at least 10 hours per week). Data are collected at the NACE Rev. 2 (two-digits level) and ISCO08 (two- and three-digits level). More specifically, the survey covers the content and implementation of occupations, the requirement levels of jobs and the qualification backgrounds of employed persons. Other information relates to employees' mental and physical strains.

Italian database

The Italian database is derived from the INAPP-ISTAT *Indagine Campionaria sulle Professioni* (ICP), the only European survey replicating extensively the American O*NET, which has been until now considered the most comprehensive source reporting qualitative-quantitative information on tasks, work context, organizational features of workplaces at a very granular level. Both the American O*NET and the Italian ICP focus on occupations (i.e. occupation-level variables are built relying on both survey-based worker-level information as well as on post-survey validation by experts' focus groups). The Comparative National Tasks Database uses the 2012 wave of the ICP covering the whole spectrum of the Italian five-digits occupations excluding armed forces. The survey ensures representativeness for sector, occupation, firm size and geographical domain (macro-regions). The

data has been weighted using the Italian LFS at the ISCO08 and NACE Rev. 2, both at the two-digits level. Overall, the Italian database results are the most complete in covering the task framework used in this study. Indeed, it allows covering not only the main indicators but also most sub-indicators. The methods of work are only partially covered, while standardisation as a form of bureaucratic control is missing.

Spanish database

The Spanish database is built upon three different surveys conducted by the *Centro de Investigaciones Sociológicas* (CIS) and five waves of the *Encuesta de Calidad de Vida en el Trabajo* (ECVT) conducted by the Spanish National Statistical Office. For each survey, the sample used to build the task profile includes both employed and unemployed persons with previous experience in order to increase the number of observations. The decision to include unemployed individuals with previous experience is an exception with respect to all other databases but has been unavoidable because of the small sample size of the Spanish data. Given the set of available surveys, the CIS 2634 conducted in 2006 covering detailed questions regarding one's job tasks, such as working conditions and abilities has been included, it is based on a sample of 4,662 observations. The CIS 3112, administered in 2014, has been used to capture the physical dimension of dexterity with a sample size of 1,528 observations while the CIS 3135, administered in 2016, includes questions about one's work orientation, as well as some questions regarding work organization whose sample size is of 1,136 observations. Finally, the ECVT (2006-2010) has been used to capture other information related to working day, environment, stress, and salary. However, the Comparative National Tasks Databasecollects the most recent years only for consistency reasons. Spanish data have been provided at ISCO-08 three-digits by Nace Rev. 2 one-digit for most of the selected variables, while in some cases – that is where the conversion to ISCO08 was not available- data have been provided at the ISCO88 two-digits level. The impossibility to codify all jobs under the same classification widely reduce the conformity of the Spanish dataset with respect to the others: indeed, although the aggregation at a higher level of analysis (one-digit level) in terms of occupations is still valid in itself, the employment weighted analysis reveals a high degree of inconsistency.

UK database

The UK database is drawn from the UK Skills and Employment Survey 2012 (SES 2012), originally funded by the UK Economic and Social Research Council (ESRC), the UK Commission for Employment and Skills (UKCES) and the Wales Institute for Social and Economic Research (WISERD) (GhK NOP, 2013). The one used in this study is the sixth cross-sectional survey in the SES series. The SES 2012 is a representative sample survey of the working-age population in paid work living in private households in Great Britain living below the Calendonian Canal (GhK NOP, 2013). It includes both employees and self-employed workers as long as they met the eligibility criteria of being aged between 20 and 65 years of age inclusive, and currently having a paid job at which they worked for at least one hour a week. The sample includes 3,200 observations. The database has been aggregated at two-digits ISCO08 by macro-sectors. The major drawback of this national database is its limitations in terms of job coverage. Indeed, not all jobs are covered, leaving almost 30% of employment out of the database (missing cells). Several important occupations are therefore missing, among all Food preparation assistant, Numerical and material recording clerks, Personal care workers and ICT Professionals, accounting for 3.8 million workers in the UK.

Task indicators over occupations and sectors by country

This Section describes the distribution of the task indicators over occupations and macro-sectors by country. The empirical exercise has been performed only on those indicators available in all selected countries. Overall, by construction the framework has a nested structure in which macroindicators are built as averages of lower level indicators. This means that the comparison of indicators like problem solving (average of "information gathering and evaluation" and "Creativity and resolution") is made although not all the sub-indexes are available at the national level, hence its distribution by sector and occupation might be biased towards certain aspects.

By doing so, we assess each indicator's reliability according to two criteria: how much the distribution matches expectations, and how much it is consistent in relative terms across countries. As mentioned, summary statistics at the job level by country are computed using employment weights from LFS data for 2012[9].

It is essential to emphasize that indicators' scores (in absolute terms) should not be compared across countries. More specifically, cross-country comparisons of raw scores are misleading and should not be run as such, because of the heterogeneous structure of the national surveys included in the task database.

Therefore, the focus of this section is each indicator's relative distribution across occupations/sectors within each country. In other words, we try to assess whether the *relative* scores are consistent across countries. For example, one might ask if Managers rank above/below Technicians in the problem-solving type of tasks both in France and Spain, or conversely, they diverge.

We expect more consistency of tasks profiles across occupations rather than economic sectors. Indeed, the occupation is a classification capturing patterns of specialisation and division of labour within organisations, whereas the sector classifies different markets and types of products and services. For example, we expect that tasks bundle characterizing managers and clercks to be similar regardless of the economic sectors; while on the contrary we expect more heterogeneity among unqualified workers between the Public sector and Low Knowledge Intensive Services. Moreover, we foresee that tasks content behaves more consistently across countries than methods of work. The reason is that methods of work embody both cultural and institutional factors rooting deep in national idiosyncrasies.

Analysis across occupations

The following paragraph reports a detailed description of the analysis across occupational groups at the ISCO08 one-digit level for physical tasks – see Figure 1. It will serve as guidance to explore the other figures, reported in the Online Appendix.

In Figure 1, a high degree of consistency in the relative scores across countries emerges, being occupations ordered by definition[10]. Indeed, moving from Managers to Service and Sale Workers profession, the median score of both physical strength and dexterity increases. In almost all countries, the maximum median score characterizes Skilled Workers in the Primary sector, while Craft, Machinery operators and Elementary occupations occupy an intermediate position. It is interesting to

[9] We used the 2012 data as it is the nearest or the same year in which the national waves have been administered.

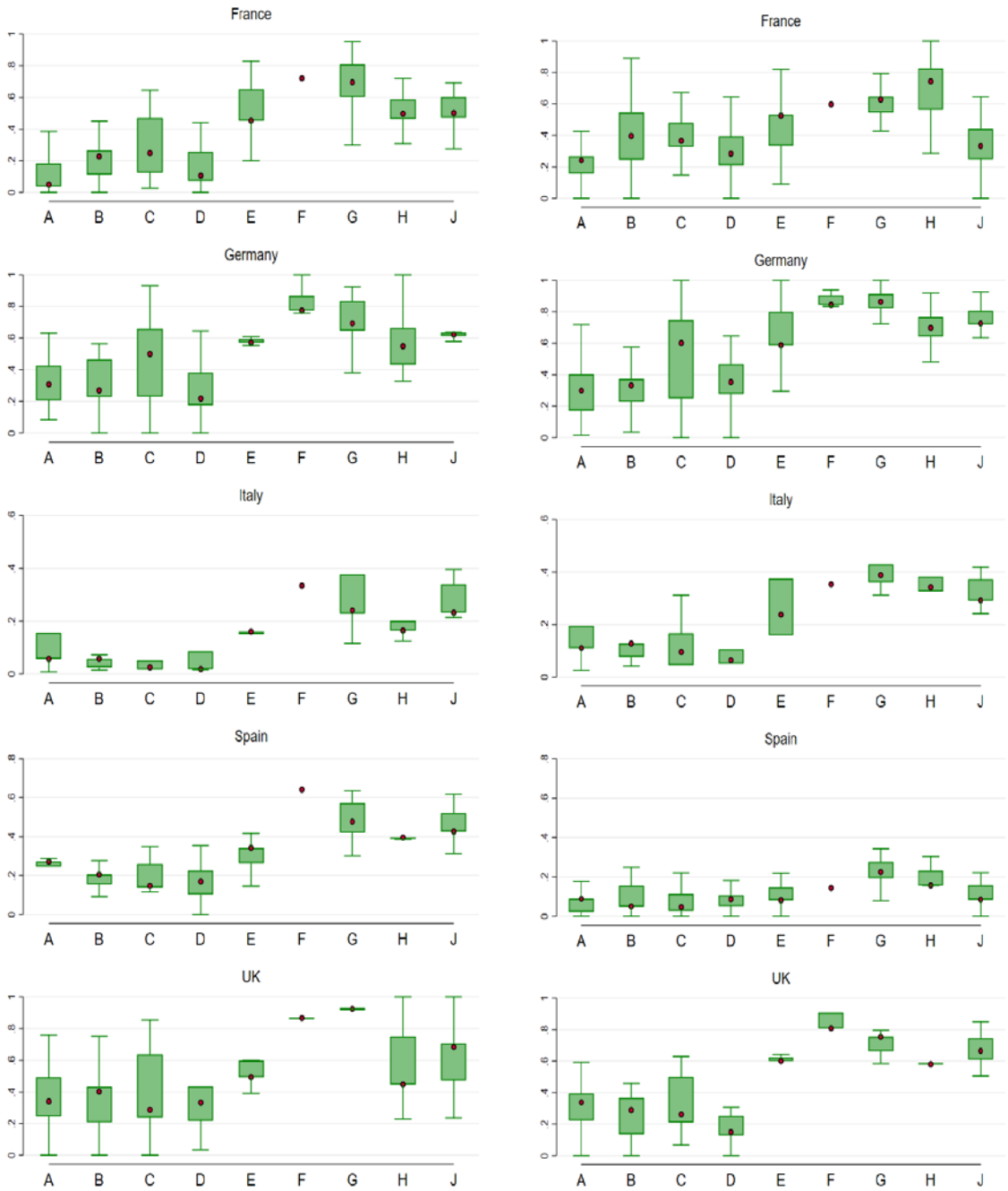
[10] ISCO classifies jobs according to two main dimensions: the level of skills, measuring the complexity and range of the tasks involved, and the specialisation of skills, which refers to the field of knowledge required, the tools and machinery used, the materials worked on and the kind of goods and services produced (see Elias, 1997).

note that countries are all characterized by very similar patterns in relative terms, while relevant differences emerge looking at the absolute median scores and the overall dispersion.

Moving on the other indicators, the distribution across occupations of the degree of problem-solving is more heterogeneous in absolute median scores and interquartile ranges. These differences may reflect measurement issues but also underlying cross-country differences. For instance, different wording and phrasing of the questions, as well as differences in the scales for the corresponding answers, may play a role in absolute scores. However, especially in the case of questions related to intellectual and social tasks, some of the observed differences in the scores probably reflect cultural differences in terms of work organisation practices and attitudes. For instance, if some countries allow more autonomy at work than others, the levels of problem-solving of jobs will be higher as well, capturing the intrinsic positive correlation between this type of intellectual tasks and organizational methods.

While the updated JRC-EF task framework (Fernández-Macías and Bisello, 2020) includes five different indicators capturing the social content of work, information available for each country covers only serving-attending and managing-supervising. In contrast with the expectations, for example, serving-attending does not seems to characterise workers employed in the service sector as expected. A straighter picture emerges by looking at managing-coordinating, whose median values decrease along with the ISCO08 ranking, with very few exceptions across countries. Finally, the analysis across occupational groups highlights that the activity of coaching and training people is distributed among different professions, although with different intensity. More specifically, relative median scores are decreasing along with the ISCO08 ranking: in three out of four countries, Germany, Italy and the UK, intermediate occupations spanning from Clerks to Crafts and related Workers show similar median values.

Figure 1: Physical strength (left) and dexterity (right) across occupational groups by country.



Note: Professional groups are coded according to the ISCO08 one-digit as follows: A Managers; B Professionals; C Technicians and Associate Professionals; D Clerical Support Workers; E Services and Sales Workers; F Skilled Agricultural, Forestry and Fishery Workers; G Craft and Related Trades Workers; H Plant and Machine Operators and Assemblers; I Elementary Occupations.

The second macro dimension of the task framework takes into consideration the methods of work – *how* things are produced and services provided– which define both the technological and social organization of production. According to the conceptual framework, methods of work include workers' autonomy, routinisation and teamwork. However, the measurement of such dimensions is not straightforward within national surveys, and there exist remarkable differences across them. More importantly, while the material transformation of inputs into outputs from the technical point of view

is often very similar for a specific job, the way production is organized does not pertain to technical aspects only but mainly to the social organization. Therefore, it is more subject to cultural and socio-political differences in work attitudes.

Back to the results, the degree of teamwork across occupational groups show a linear and declining association in both Italy and France, although less pronounced in the latter. The degree of workers' latitude shows a double trend across the vertical division of labour. In all countries (but Spain, where the indicator is not available) we notice a linear and negative pattern from Managers to Service and Sales workers, and from Skilled workers in the primary sector to Elementary occupations. However, the relative position between Clerical and Services and Sale workers differ, the latter characterizing with a higher median score both in Italy and the UK. Finally, Craft workers and Technicians are more or less aligned everywhere. As expected, reported levels of repetitiveness at work are inversely related to the ISCO ranking.

Analysis across macro sectors

Finally, we replicate the descriptive exercise looking at the distribution of task indicators across macro sectors by country. Physical strength and dexterity behave consistently across sectors in almost all countries: the relative positions of the sectoral median score are, indeed, similar, while the same does not hold for social tasks. Workers' autonomy, instead, does not appear to be remarkably consistent. The relative distribution of control (in reverse) does not follow a clear pattern across sectors over the five countries. Latitude shows more consistency in relative terms compared to control for all countries but Spain, for which the indicator is not available. In particular, the Primary sector displays a relative higher score for latitude, followed by the KIS in all countries. Public administration, Education and Health score higher than LKIS in all countries but France. France is the only country for which the weighted median value of latitude in LKIS is higher than HTI, something rather odd.

Regarding routine (operationalised as a compound indicator involving repetitiveness and standardisation, where the latter is a proxy for bureaucratic and technical control), Germany differs in the sectoral distribution of repetitiveness with respect to all other countries. In the remaining ones, some similarities emerge. Indeed, the median scores for HTI al KIS are always lower than, respectively, LTI and LKIS, but for Spain. That is, more repetitiveness in low tech and knowledge intensive sector than the more technological counterparts.

Finally, teamwork shows a more or less similar relative pattern across sectors in Italy, Spain, France and the UK with Primary sector scoring the lowest. The HTI show a median value higher than both LTI and LKIS but lower than KIS in all of them but France. Public Administration, Education and Health display higher values compared to KIS apart from France, where the median values are almost the same.

From the analysis performed in this Section, following our expectation and previous literature (Fernández-Macías, Hurley and Bisello 2016), the relative distribution of task indicators across occupations is similar with some exceptions in the five countries, while the same distribution appears to be less consistent once evaluated across macro-sectors.

Differences in levels and distribution can derive from a variety of factors: measurement issues; underlying differences in tasks content within sectors and occupations across countries; organizational and cultural differences resulting in heterogeneous organizational practices; the employment composition across macro-sectors. More specifically, our results show that the degree of consistency varies across indicators. Some are very consistent in relative terms (strength and dexterity), some are somewhat consistent (social tasks), some not very consistent at all (work organisation indicators). These differences might correlate with the types of task indicators. Those indicators that are more "technical" (reflecting tasks that are strongly determined by the type of product or process) tend to be more consistent than indicators which are more "organisational" or "social" (reflecting differences in cultural or socio-political orientations to work and work organisation).

Overall, though, indicators' consistency is satisfying. It means that they represent the best raw information to be used for an investigation both across jobs and countries, employing a particular standardisation method explained in the remaining of the article.

Employment weighted ranking of task indicators

As stressed in the Introduction, theoretical research on occupations and tasks usually lack adequate data to inspect tasks' distribution across countries. For instance, most empirical studies on the impact of digitalization on employment in Europe have relied on the American O*NET survey to infer occupational dynamics of specific tasks for the European labour markets. Although European and American labour markets show similar employment and tasks structures, a high degree of heterogeneity is well-documented between the two areas (Cirillo et al., *forthcoming*). It follows that using country-specific data is crucial to investigate the jobs' content and methods of works that are historically and institutionally contingent. To this purpose, we pooled together national databases and standardise task indicators across countries to allow tasks' comparisons. Data harmonization consists of a weighted ranking methodology used in the *jobs approach*, applied to the qualitative dimension captured by task indicators. Following the 1990s' work by Joseph Stiglitz during the '90s, this approach became populare and increasingly adopted to study the evolution of occupational structures (within and between countries) with respect to the distribution of wages (Olin Wright and Dwyer, 2003; Fernandez Macìas, 2012; Fernández-Macías and Hurley, 2014; Hurley et al. 2019), education (Fernandez Macìas, 2012) or job quality (Hurley et al. 2013). We extend the scope of this statistical approach applying it to a key qualitative dimension of work: tasks.

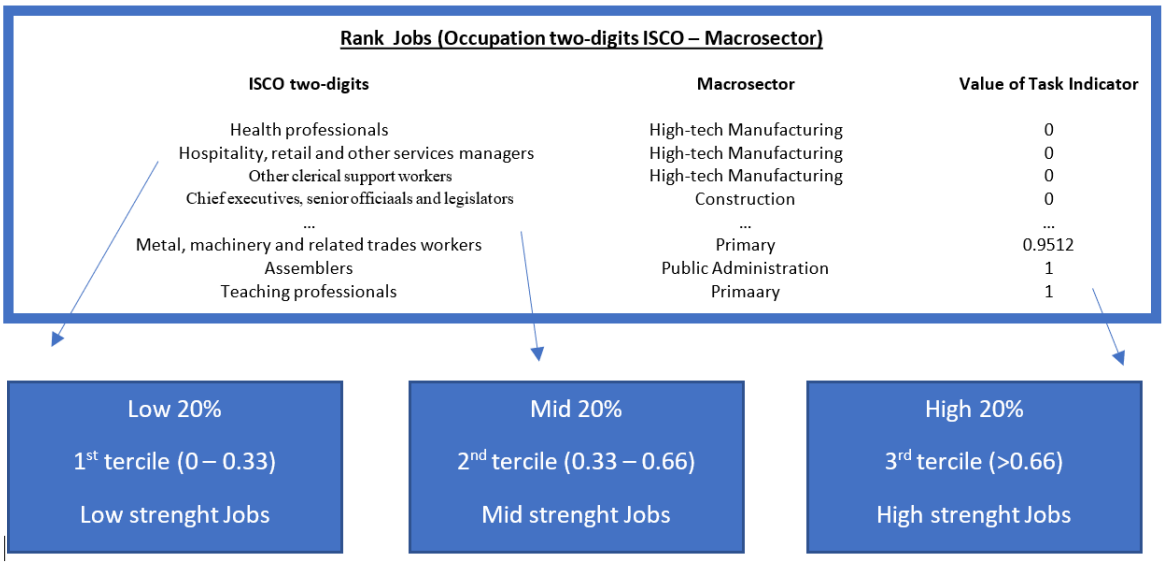
The *jobs approach* entails three main steps.

First, a two-digit ISCO08 and macro-sector (i.e. a job) matrix is created in each country, each cell reporting the corresponding job's employment. The bigger the workforce, the greater is the variety of possible job combinations that can be identified using LFS data (Hurley et al. 2019).

Second, jobs are ranked over a scale from 0 to 100 for each task indicator, where zero defines the lowest position in the ranking and 100 the highest one. The job-task rankings for each country are based on the national data described in Section 3.

Third, jobs are allocated to tasks terciles in each country based on the job-task ranking for that country. The distribution of each task indicator is divided into terciles meaning that jobs having the highest values for a specific task are located at the top tercile, while those registering lowest values go at the bottom. Each tercile in each country should represent as close as possible to 30% of employment, i.e. jobs are assigned to terciles based on their employment weights. Figure 2 below shows, for example, the allocation of jobs in France according to the ranking of strength.

Figure 2. Job rankings and tercile assignments carried out for each country[11]



Once we have normalized the task indicator distributions in each country (step 2), it is possible to compare the relative position of a specific job across countries and explore how tasks differ across institutional contexts. For instance, if in the country *i* the score for a specific task (i.e. "repetitiveness") of Service and Sales workers in LKIS (Less Knowledge Intensive Sectors) is 60% and in the country *j* is 65%, one can assess that the Service and Sales workers in the two different countries are relatively quite similar in terms of "repetitiveness" given the specific national employment structure.

It is worth recalling that our unit of analysis is the job, defined as the sector-occupation pair, in each country. Since our job matrix uses information on countries' task profiles, not all country matrices have the same dimension because of missing information for some jobs; this is particularly relevant for the United Kingdom and Spain[12]. The derived ranking for these countries has to be used and interpreted with caution.

The rest of this chapter divides into three main parts aimed at (i) presenting the results of correlation and factor analyses performed on employment weighted rankings of tasks across countries; (ii) inspecting such task rankings of "big jobs" across countries; iii) exploring employment distributions over task indicators- terciles across sectors and countries, using a terciles approach (step 3).

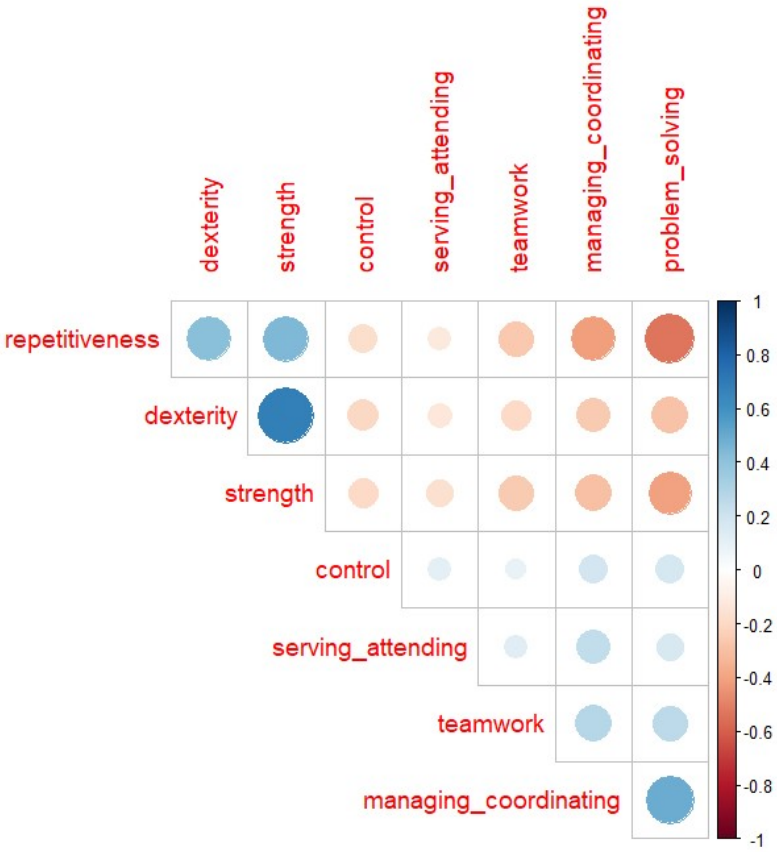
[11] Figure 2 recalls the one in the Methodology of European Jobs Monitor for job-wage quintiles https://www.eurofound.europa.eu/it/observatories/emcc/european-jobs-monitor/methodology

[12] The unmatched cases for Spain depend on the use of ISCO88 as explained in previous section and account for 8.7% of the sample. For UK missing data are more severe and represent the 32.5% of the employment in 2012 due to small sample size covered in the surveys. More importantly, tasks information are missing for some relevant occupations like, among all, ICT professionals, Numerical and Clerical Support Workers, Personal Care Workers and Food Preparation Assistants.

An exploration of employment weighted rankings of tasks

How and to which extent do task rankings correlate? Task indicators have been normalized as described above to provide an answer to such a question. A simple pairwise correlation –Figure 3 and Table 1 – shows that all rankings display a statistically significant correlation to each other except for serving/attending and repetitiveness. In particular, scores for physical strength are positively correlated with dexterity and repetitiveness, while negatively correlated with all other indicators. The rankings for problem-solving correlate positively with social tasks (serving/attending and managing/coordinating) as well as the scores of workers' control and teamworking. However, the correlation is negative with repetitiveness. Similar results emerge regarding social tasks and work organization: higher workers' control is associated with lower repetitiveness and higher teamwork, suggesting that jobs requiring a certain level of autonomy are usually performed in teams and do not show patterns of repetitiveness.

Figure 3. Correlogram across selected task rankings.



Note: while colour captures the sign of the correlation, size of the bubbles refers to the magnitude of the association between variables.

Further, we explore correlations among task rankings across countries by implementing a factor analysis. Both statistical diagnostics (Kaiser criterion) and visual inspection (scree plot) suggest retaining three factors accounting for 62% of the total variance. Table 2 shows the rotated loadings of selected factors and uniqueness of the explained variance for each task ranking. As shown in the

table, the explained common variance (computed as 1-*Uniqueness*) is above 60% for all indicator rankings but those related to methods of work. The relatively low uniqueness for methods of work indicators suggests that they are less consistent across countries and, therefore, specific national features play a more critical role.

Factor 1 (rotated) correlates strongly with physical strength, dexterity and, to a lesser extent, to repetitiveness. It seems to capture features of jobs requiring intense use of strength and physical activities, although not only repetitive. These tasks might characterize specific jobs in manufacturing and are usually related to low and mid-skill professions.

Factor 2 (rotated) mirrors rankings for problem-solving, managing/coordinating and team working. Jobs at the top of the ranking for problem-solving register high scores for managing/coordinating activities and team working. It is likely to expect that these jobs are more concentrated in professional or business services and refer to high-skill occupations.

Finally, Factor 3 (rotated) correlates the most with the ranking for serving, attending and control over workers. These jobs are more likely to be those performed in low-qualified services such as wholesale and retail trade. It is, for example, the case of Service and Sales workers, the most populated jobs in almost all countries, whose level of workers' control is low except for Germany.

The results of the factor analysis hint that tasks are bundled into single jobs, and differences in work organization across countries matter and deserve peculiar attention and country-specific data. In other words, each job exhibits a multidimensionality of tasks. At the same time, normalized scores for different task dimensions are highly correlated, suggesting the relevance of jobs as a unit of analysis.

Table 1. Factor scores

	Rotated Factor 1	Rotated Factor 2	Rotated Factor 3	Uniqueness
strength	.8379734	-.2464631	-.066137	.2326824
dext	.8799438	-.1310201	-.0549273	.2055156
probsolving	-.3185373	.7077435	.1144362	.3845374
servatten	-.0183514	.1649015	.8177963	.3036799
managcoord	-.1283796	.7160092	.3211305	.3677248
team	-.0671674	.6104847	.113991	.609803
control	-.4132569	-.0774099	.5362413	.5356718
repetit	.3896967	-.6315305	.2571018	.3832043
Observations	1226			

Indicator rankings of tasks by "big jobs"

Which tasks characterise the European "big jobs"? Which tasks dominate the occupational structures of the largest European economies? In this subsection, we study the tasks profile of the so-called "big jobs", those jobs employing the highest share of workers. In particular, we focus on the four largest jobs in terms of total employment share. Taken together, they represent 19% of employment (23.5 million workers) in our five countries according to 2012 LFS data. First, we notice that the four jobs

under scrutiny are heterogeneous across sectors and occupations. Two of them belong to the Low Knowledge Intensive services (Sales Workers and Cleaners and Helpers). One is Teaching Professionals in the Educational sector and finally, Stationary plant and machine operators in the low-tech industries.

For instance, according to the horizontal division of labour, these four jobs relate to the production of highly heterogeneous good and services in the economy; however, they also differ in terms of hierarchical position across professions and skills. This general characterization induces some expectation on how and to which extent tasks profile differ across jobs and within the same "big job" across the five countries. In particular, one would foretell consistency in tasks content within the same job across countries, with higher physical strength characterising Sales workers and Cleaners, but also high serving and attending social tasks for Teaching professionals. Moreover, while we expect more heterogeneity in terms of organizational methods across the two dimensions, one might conjecture that Teachers are less routinized and more autonomous than all others.

Figure 4, 5, 6*, 7* report big jobs' task profile. The largest job is the one including Sales Workers employed in the Less Knowledge Intensive Services (LKIS), on average 7% of total employment, ranging from 5.1% in France to 9.3% in the UK. As expected (see Figure 4), serving/attending is the prevailing task – the rank position is above 90 for most countries except Germany, whose score is relatively low compared to the other countries (67). A more pronounced divergence appears in score rankings for managing and coordinating activities within social tasks. Similarly, intellectual tasks turn out to be heterogeneous in terms of by-country ranking: problem-solving ranks around 15 in Italy and between 27 and 38 the UK and in France, Germany and Spain. Regarding tasks content indicators, the distribution of physical strength ranking is relatively more homogeneous: around 60 for all the considered economies but Spain (37). In the case of physical dexterity, the UK differs from the rest of the sample: Sales Workers employed in LKIS are characterized by a rank score at least 10 percentage points higher than what is observable in the other countries. Finally, concerning methods of work, Sales Workers in the LKIS display similar scores in terms of repetitiveness and control. The only exception is Germany, where the control's score rank (88) more than doubles the average score of the other countries. Differences also emerge looking at the rank position for teamwork where Italy and Spain score respectively 15 and 5, France 35 and both Germany and the UK around 60. It is worth remembering that while differences in tasks content may reflect technical heterogeneity in working activities, the resulting differences in terms of methods of work may reflect different organizational characteristics which are mainly related to human agency and social relations within the production process.

Teaching professionals - Figure 5- employing 4.5% of the total working population (corresponding to 5.77 million workers across the selected European countries) are the second big job. In all countries, with few exceptions, their tasks percentiles are low for physical tasks and higher for problem-solving. Social tasks are similar (with high percentiles) with respect to managing and coordinating activities, while, surprisingly, serving/attending varies a lot, from 13 in Spain to 94 in France. Finally, Teaching Professionals are characterized by low repetitiveness in all countries while diverging more in both control and teamwork.

Figure 4. Ranking position across countries within Sales Workers employed in the LKIS.

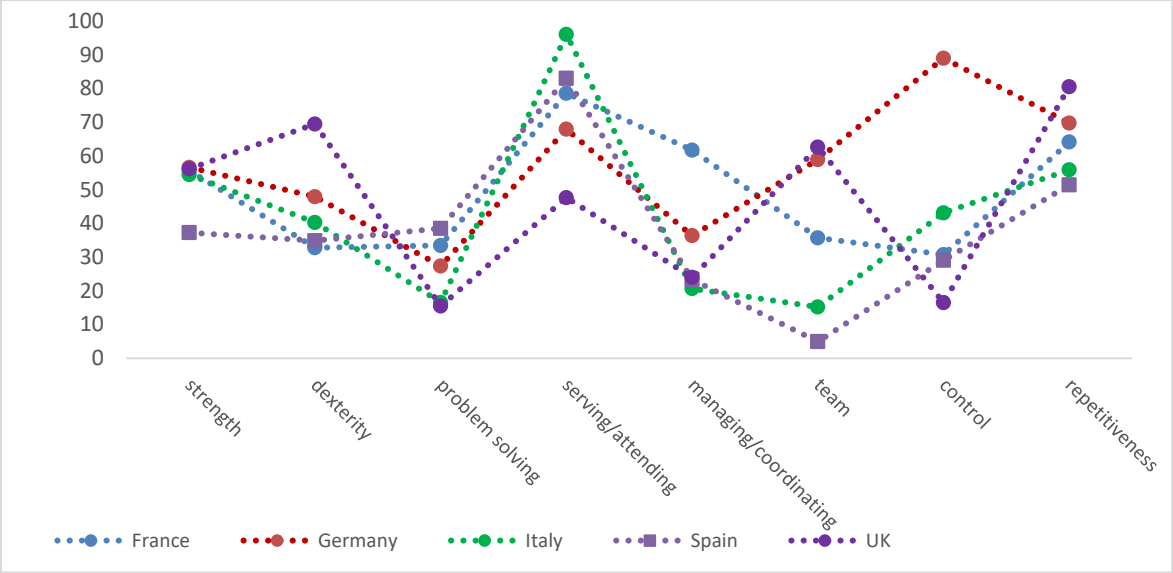
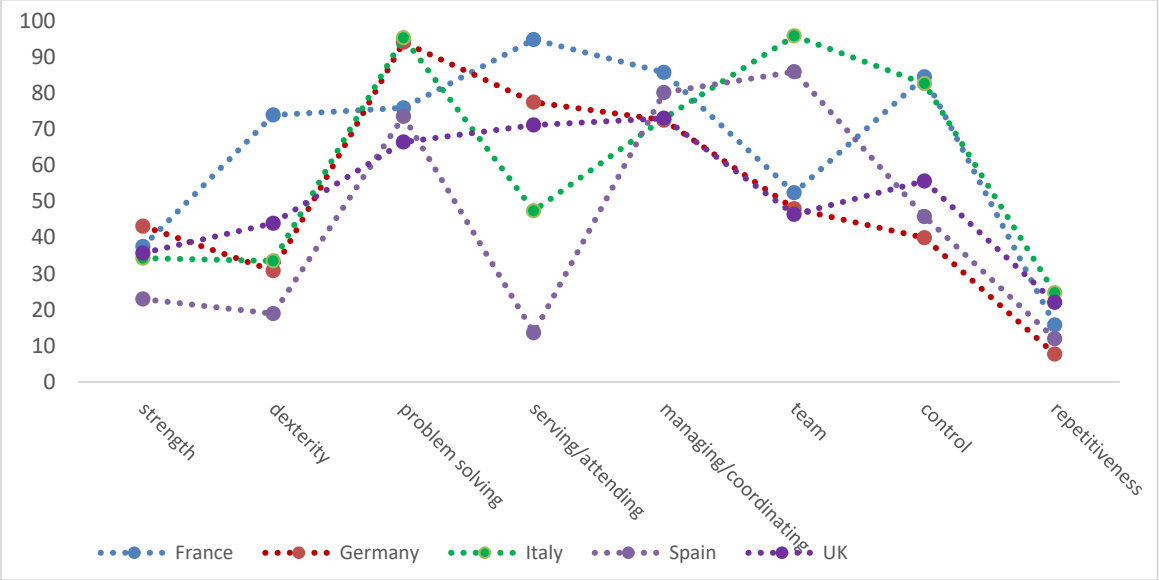
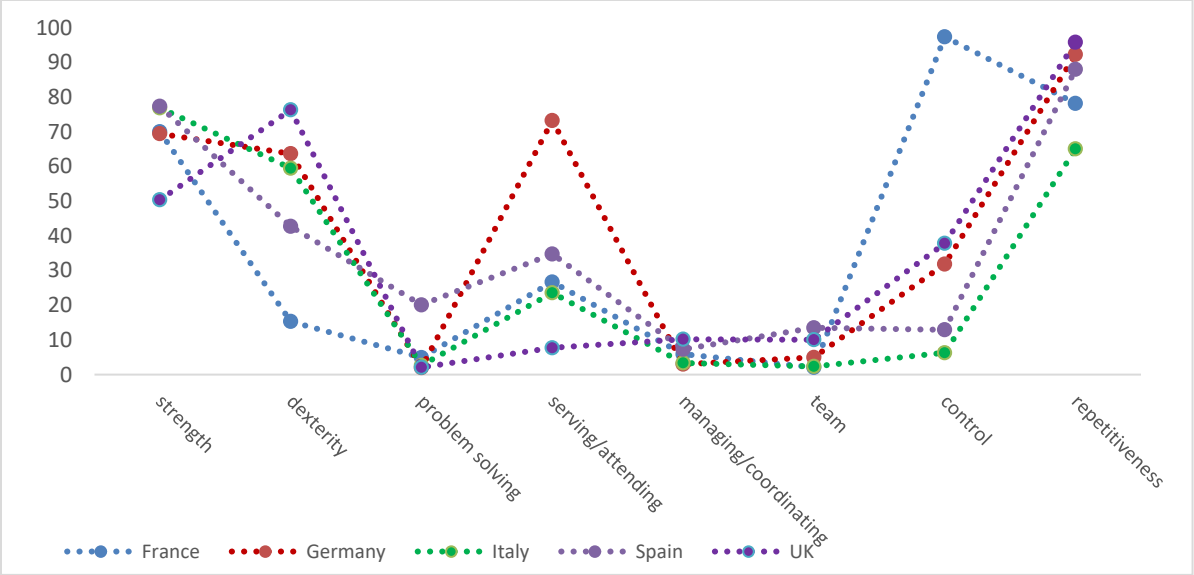


Figure 5. Ranking position across countries within Teaching Professionals employed in Education.



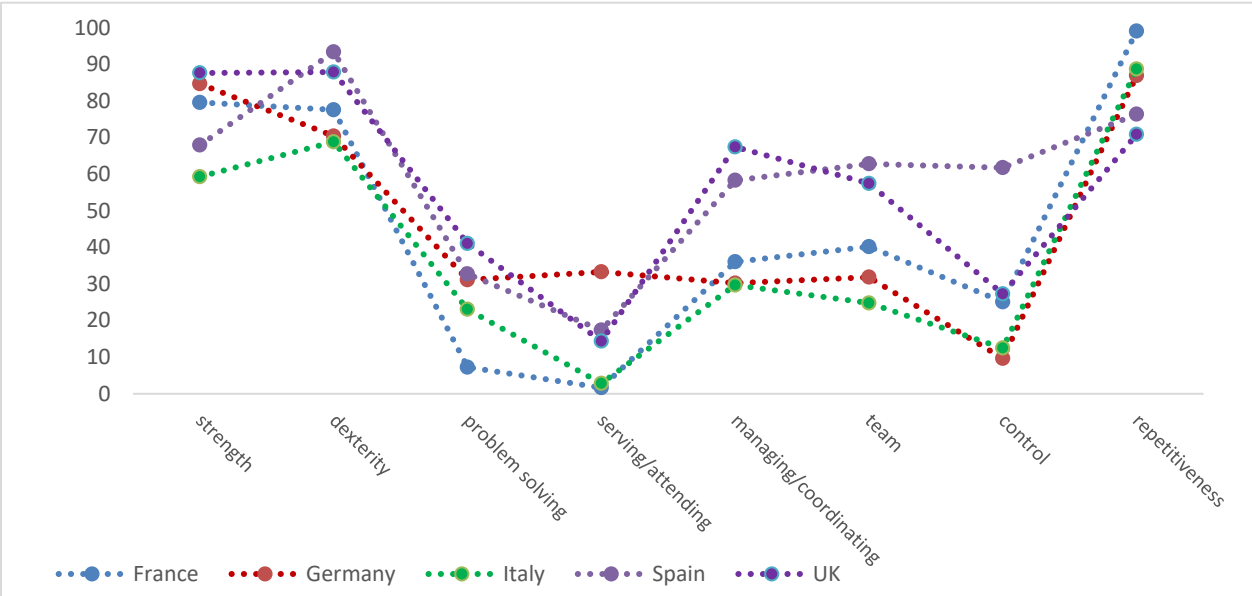
The third big job includes Cleaners and helpers employed in the LKIS corresponding to 3.84 million workers (3,1% of total employment) in the countries under analysis according to 2012 LFS data. Focusing on country-level heterogeneities, some significant differences emerge regarding the role played by single jobs into the national occupational structure – see Figure 6. Indeed, Cleaners and helpers represent (within the LKIS) the 1.9% of total employment in Germany while the 5.8% in Spain. These workers are characterized by very high physical strength percentiles in all countries but low problem solving and social tasks (with only the German exception concerning serving/attending). Looking at methods of work, as expected, control is low in all countries (except Spain) as well as teamwork, while repetitiveness varies although rating above 50% in all countries.

Figure 6. Ranking position across countries within Cleaners and Helpers employed in the LKIS.



Finally, Stationary plant and machine operators employed in the low-tech industries – see Figure 7 – account for 1.5% of total employment across the selected five European countries. It emerges that the indicators related to manual tasks occupy a substantial higher position compared to intellectual tasks (problem-solving) as well as serving and attending in all countries, which comes at no surprise as these workers do not interact directly with the public. They are in fact mostly involved in the physical production of goods taking place in highly routinized workplaces. Although we cannot measure the degree of standardisation, our analysis shows that Stationary Plant and Machine Operators employed in the KIS are characterized by high repetitiveness (another dimension of routine) and low workers' control in most of the countries. However, a high degree of heterogeneity emerges in the country comparison for teamwork and managing/coordinating, reflecting diverse organizational structures.

Figure 7. Ranking position across countries within Stationary Plant and Machine Operators employed in the KIS.



The evidence reported so far highlights that, in our five countries, a strong consistency for manual, intellectual and routine tasks percentiles is present in all big jobs, but a to a lesser extent for Teaching professional. Moreover, social tasks percentiles appear to be more divergent across countries although most of the heterogeneity is due to UK and Spain, for which data at the job level are less reliable, as explained earlier. Last but not least, within all big jobs analysed, the one task percentile showing systematic differences is workers' control, once again pointing to national idiosyncrasies in work organisation across different types of jobs.

Job-task terciles across sectors and countries

To what extent do European countries differ in the distribution of employment along the task dimensions? As highlighted by Fernández-Macías and Bisello (2020), tasks are socially embedded because the structures of production and services provision of any economy reflect patterns of consumption of society and social relations. The change in tasks contents and methods of work might reflect how societies differ in their tastes and preferences, in their institutions and organizational forms. Therefore, even within similarly developed capitalist economies significant differences in the prevalence of different types of tasks in their productive structures (sectors) are expected to exist. In this respect, the Varieties of Capitalism literature (Hall and Soskice, 2001) documented the existence of salient differences among so-called Social-Democratic models, which have expanded public provision of social services and reduced the incidence of low-paid jobs compared to market-oriented models. However, recent works highlight a 'neo-liberalisation trend' characterising all European countries towards market-oriented models (Baccaro and Howell, 2017) or even hybridization of models within countries where various types of industrial relations and work organization can coexist (Brandl and Bechter, 2019). To some extent, employment structural configuration of countries' occupational-sectoral structures reflect the prevalent socio-institutional model. For instance, as suggested by Oesch (2015), job polarization resulting in a smaller weight of routine tasks tend to characterise market-oriented economies; while in the opposite holds (with specific reference to manual tasks) for Social-Democratic countries.

In this section, we dig into these research questions and explore – from a statical point of view – employment distributions by focusing on job-task terciles. Therefore, we apply the job approach to inspect similarities and differences in national occupational structures based on two specific qualitative attributes: tasks content (physical, intellectual, social tasks13) and methods of work (autonomy, teamwork, repetitiveness).

More specifically, we analyse the employment distribution of tasks across sectors and countries. To this aim, for each country and task indicator, we allocate jobs to terciles based on the national job-task ranking (step 3 described at the beginning of Section 5). Furthermore, employment structures of countries according to task indicators terciles are investigated by focusing on specific macro sectors: primary, construction, low-tech and high-tech manufacturing, low knowledge-intensive services, knowledge-intensive services, public administration, education and health[14]. In practice, we show the employment composition in terms of task-terciles in each macro sector-country pair. For example, the Primary sector in country *j* can be characterised by 50% or more of employment whose physical

[13] As explained in previous section when referring to intellectual tasks we restrict our analysis to problem solving, while for social tasks only serving/attending.

[14] See Table A2 in the Appendix for a detailed list of two-digits NACE sectors included in the analysis.

strength ranking is above 70 (high-tercile), 10% of employment with a ranking position of 50 (medium tercile) and the remaining share characterised by a shallow level of physical strength (low tercile). We can then compare whether the share of employment in the high physical strength tercile is similar or different across sectors and countries[15].

Such an exercise allows us to gather information on: (i) the prevailing type of employment in terms of jobs' tasks content and methods of work across countries within the same macro sector (e.g. tasks requiring high physical strength employ higher share of employees in the Spanish low-tech manufacturing compared to the French low-tech manufacturing); (ii) differences between sectors among countries concerning both jobs' tasks content and methods of work (e.g. Health and Education show divergent distributions of workers in the high-dexterity type of tasks in France and Spain, which might be due to how a nurse carries out her duties and which types of operations she is required to do).

We sketch two hypotheses. Hypothesis 1: *Although differences should emerge among national distributions of employment in the task ranking, countries still show fundamental similarities in the distribution of workers according to the content of tasks they perform on the job (i.e. use of strength by a craft worker in the metal sector).* Hypothesis 2: *Major differences emerge when focusing on tasks referred to work organization, such as the level of routineness of a job or, for instance, the degree of autonomy related to how a specific task is carried out (i.e. the degree of team working for a shop assistant in a supermarket).*

In the following pages, we present a descriptive analysis based on job-task percentiles expressing the average percentile position of jobs ranked by tasks and weighted by employment. It will help us to assess similarities and divergences among countries respect to jobs' tasks content and work organization and provide an answer to H1 and H2.

Job-task terciles in terms of content

Strength is an indicator capturing physical activities such as lifting people and carrying heavy loads. We expect to find strong similarities across countries in the shares of employment by strength-tercile, whereas differences could depend on: (i) dissimilarities in the task scores by occupations; (ii) differences in the occupational structures because job-terciles also reflect the relative distribution of employment of one sector with respect to the whole economy. To the extent that we analyse five European countries having quite similar employment structures, we expect the main differences in the strength-terciles to be due to dissimilarities in the task scores of jobs across countries.

Figure 8 clearly shows the presence of strong similarities between sectoral employment shares across countries. For instance, the primary sector and construction are those characterized by the highest share of workers performing tasks requiring extensive use of strength, therefore belonging to top strength's tercile (about 90% of workers in the primary sector perform tasks requiring a high level of strength). Conversely, KIS show the highest incidence (on average 80% of employment) of low-strength activities across countries, highlighting the existence of strong similarities among main European sectors (H1).

A certain degree of heterogeneity comes from the second strength's tercile: in the Spanish high-tech manufacturing about 40% falls in this tercile, compared to France, Germany and the United Kingdom

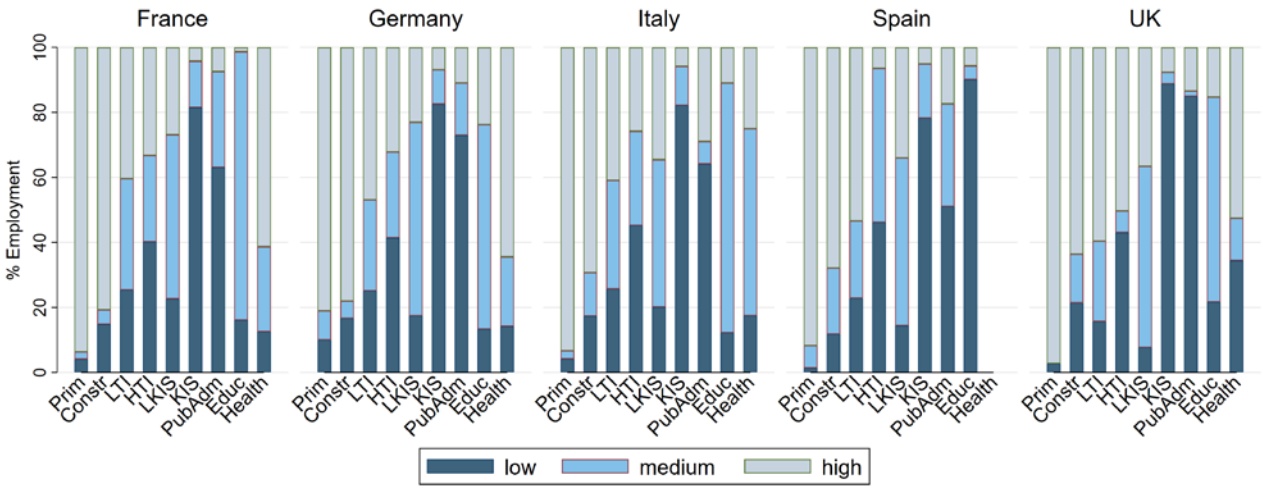
[15] For instance, a value of 90 for a job (i.e., nurse in the Health sector) means that specific job is located around the 90th percentile of the "serving/attending" task distribution considering also the number of employees in a country performing that specific job.

where the share of workers is about 15%. Education in Spain is characterized by the highest share of employment in the low-strength tercile (around 75%) whereas, in France, Germany, Italy and the United Kingdom medium-strength activities prevail in education employing around 80% of workers.

As a macro pattern, the share of workers employed in high-value-added services in the low-strength tercile doubles the share of workers in the low-strength tercile of manufacturing and low-value-added services (except for the UK)[16]. This pattern is consistent across all countries.

Differences are to be found in the distribution of workers in the medium-strength tercile in high-value-added services among countries which may depend both on the specific job content of occupations or on the numerosity of workers employed in Education and Public Administration, for example.

Figure 8. Employment share (%) by strength-tercile over sectors and countries.



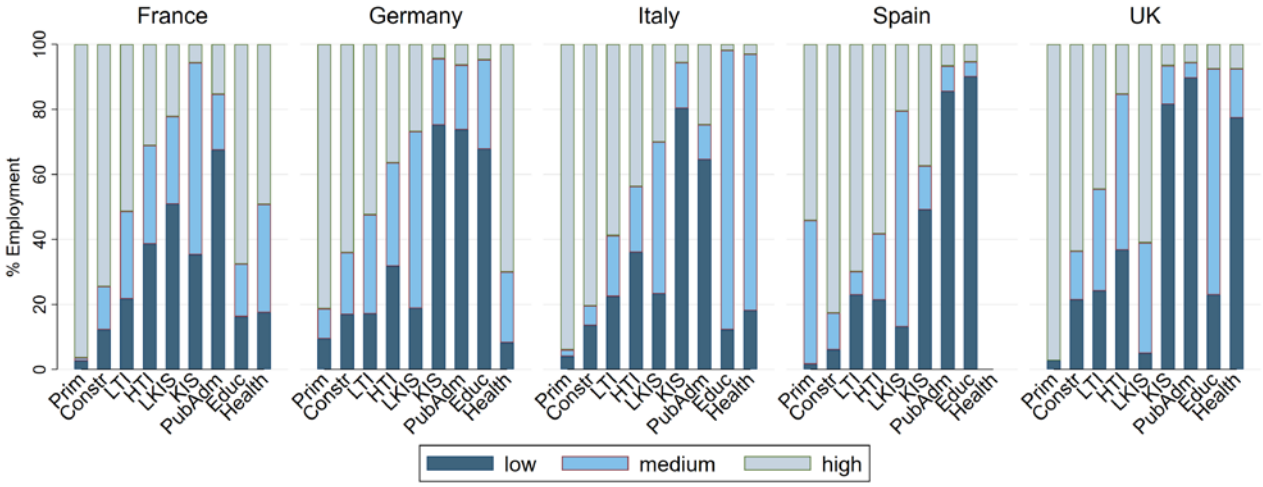
Dexterity refers to activities characterized by precise movements and a high degree of harm-hand-fingers coordination. As in the case of the strength indicator, countries show similarities in the by-dexterity distribution of employment across sectors – Figure 9. As expected, the primary sector and manufacturing are those employing the highest share of workers performing a high-dexterity type of tasks, and this is a typical pattern across countries.

Among services, the Health sector is the one employing the largest share of high-dexterity type of tasks, although with salient differences. The highest heterogeneity characterizes the Italian Health sector as compared to the French and German ones. While the former displays a higher incidence of workers in the medium-dexterity tercile, in France and Germany about 40% of workers employed in the Health sector perform activities involving high-dexterity, which might be due to the specific types of professions involved as well as on the peculiarities regarding how work is executed. Overall, the highest employment incidence of high-dexterity tasks is detectable in the primary and construction sectors (85% of workers). Instead, the lowest incidence is detectable in KIS and the public administration, where about 80% of workers fall in the low-dexterity tercile. Most professions (and

[16] To identify technology-intensity of sectors, Eurostat follows a sectoral approach that is a particular aggregation of the manufacturing and service industries according to the level of their technological intensity (R&D expenditure/value added), using the Statistical Classification of Economic Activities in the European Community (NACE Rev.2) at the 2- or 3-digit level for compiling groups. Service activities are mainly grouped together into 'knowledge-intensive services (KIS)' and 'less knowledge-intensive services (LKIS)', where the former register more than double value added with respect to LKIS sectors (see for detail European Commission, Joint Research Centre (2015): Value added in services by knowledge intensity. European Commission, Joint Research Centre (JRC) [Dataset] PID: http://data.europa.eu/89h/jrc-10113-rio_va_for_serv).

employees) in high-value-added services seem to require a low-level of dexterity, and this is a common pattern across countries.

Figure 9. Employment share (%) by dexterity-tercile over sectors and countries.



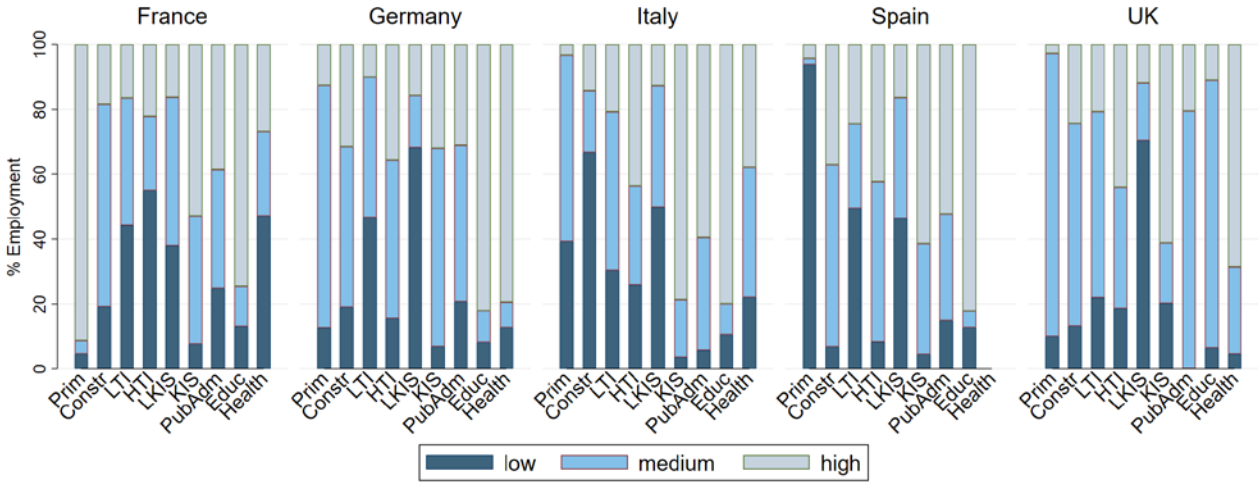
Shifting to the intellectual type of tasks described as those aimed at the manipulation and transformation of information and the active resolution of problems, involving several activities ranging from information processing to problem-solving, a higher level of heterogeneity across countries emerges compared to what has been depicted for physical activities.

Figure 10 focuses on problem-solving, which in turn synthesises tasks such as information gathering and evaluation, creativity and resolution. At a first glance, some differences emerge across sectors and countries: jobs in the primary sector show the highest share of workers characterized by a rank score lower than 70% in all countries except France, where the share of workers in the top tercile is the highest in the primary sector (about 90%). However, it is likely to expect that countries differ in terms of the number of employees in agriculture; therefore, one might argue that these differences are driven simply by the employment structure.

Overall, manufacturing activities, both in high and low-tech industries, show a higher incidence of employment in low and medium problem-solving terciles, while in KIS the share significantly decreases. Compared to physical tasks, intellectual type of activities displays a higher degree of heterogeneity across sectors and countries, which is confirmed by the share of employees in problem-solving-terciles by main professional groups across countries (Figure A1 in the Appendix).

Except for France, it should be noted that low-value-added services show the highest shares of employment in low-problem-solving tercile, meaning that employees in these jobs are not involved in the resolution of problems or intellectual types of activities. Interestingly enough, this is relatively consistent across countries.

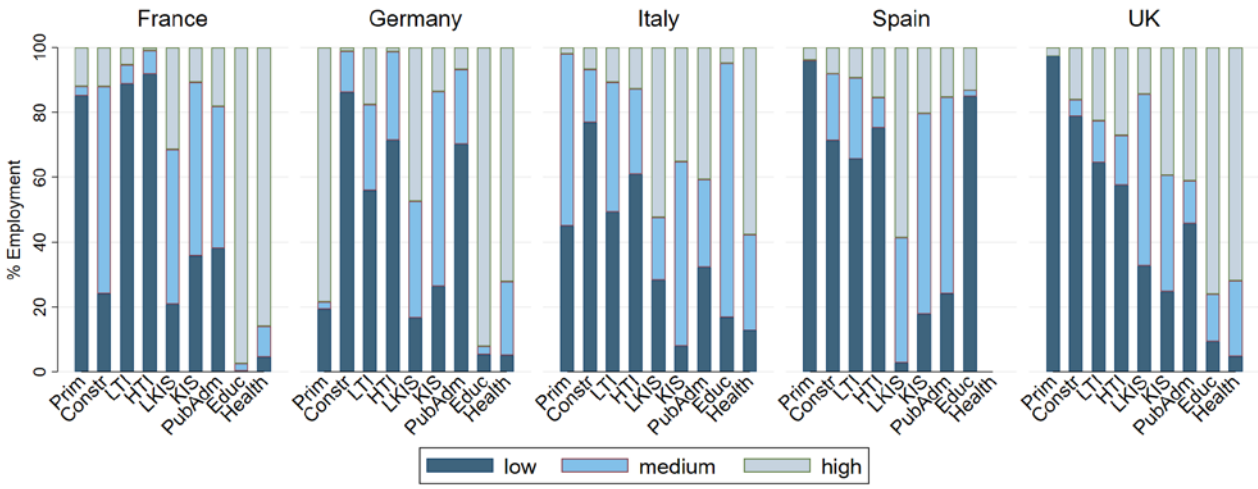
Figure 10. Employment share (%) by problem-solving-terciles over sectors and countries.



The analysis ends by focusing on social tasks, defined as those activities whose primary aim is the interaction with other people, including a wide range of tasks such as serving/attending, teaching/training/coaching, selling/influencing, managing/coordinating and caring. As for serving/attending, Figure 11 shows a certain degree of heterogeneity across sectors and countries, although differences are weaker compared to the problem-solving type of task.

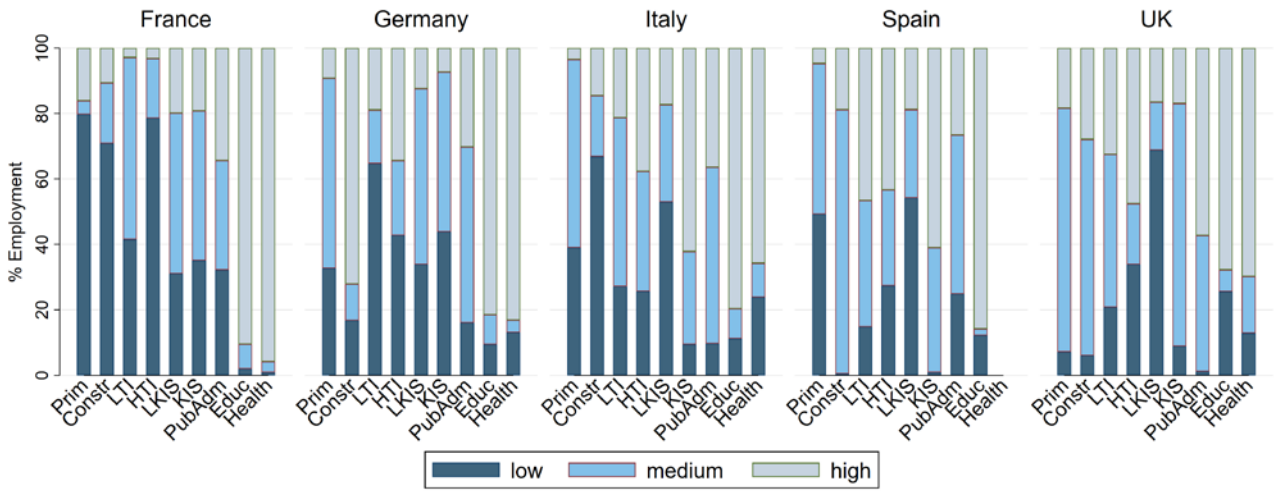
While in France, Spain and the United Kingdom, the primary sector accounts for a high share of employment in the of low-serving/attending task tercile, in Germany and Italy, there is a substantial share of workers registering high and medium levels (in ordinal terms) in the same sector. One explanation might be the nature of activities performed or the prevailing employment status of workers in this sector (self-employed vs employee). As expected, Education and Health display the highest share of workers involved in high-serving/attending type of tasks (on average 80% except for Spain), although with essential heterogeneities across countries. On average, almost 80% of workers in Education and Health perform tasks requiring a high level of serving/attending. Conversely, almost 70% of workers in manufacturing activities is involved in low-serving/attending type of tasks compared to KIS and LKIS sectors.

Figure 11. Employment share (%) by serving attending-terciles over sectors and countries.



Within social tasks, a critical dimension is given by the extent of coordination or supervision of the colleagues' behaviour, that is the relevance of managing/coordinating activities. Figure 12 displays several differences across sectors and countries but also essential similarities: Health and Education show the highest share of workers (about 80%) in high-managing and coordinating type of activity, and this is a typical pattern across all countries. The opposite occurs in the primary sector, construction and low-tech manufacturing where the share of workers involved in low-managing/coordinating type of activities is about 50% with same nuances among countries: in the United Kingdom a medium-level of managing/coordinating type of tasks prevails compared to France where almost 80% of workers perform a low-coordinating type of task in agriculture and mining. To a certain extent, employment appears to be more polarized toward low managing-coordinating tasks in France, while in the UK it concentrates in the medium tercile. Some country-level heterogeneity also emerges in the high-tech manufacturing and KIS sectors, suggesting the coexistence of different models of jobs in the same sectors, that can link to institutional patterns and hierarchy of professions within sectors.

Figure 12: Employment share (%) by managing/coordinating-tercile over sectors and countries.



Job-task terciles in terms of methods of work

As already argued, methods and tools of work refer to how work is organized; and to the physical and digital objects used for aiding the production or service provision process. As detailed in Fernández-Macías and Bisello (2020), methods and tools do not univocally reflect the type of good and services that are produced. They can in fact also mirror the way production is heterogeneously organized at the country, sector and firm-level. Therefore, we hypothesise the existence of large differences across countries due to the coexistence of different organizational modes, or at least different nuances of how a specific task can be performed (H2). Dissimilarities across country-sector may depend on the diffusion and adoption of technologies as well as on the changing ratio between labour and capital over time; differences across countries within the same sector can suggest the relevance of historically and socially determined national peculiarities. In turn, the diffusion and adoption of technology may depend precisely on these institutional factors operating as drivers or barriers of technological change (Mowery e Rosenberg, 1979; Dosi, 1991).

In this subsection, we focus on three crucial dimensions referring to the level of control, teamwork and repetitiveness of jobs. One of the leading dimensions defining how a specific work is carried out has to do with the degree of control (reversed), intended as the relative lack of autonomy in performing working activities (i.e. being directed, supervised and/or monitored by boss or clients). In Figure 13, we show the distribution of employment by terciles of the control indicator by sector and

country. Several patterns emerge. First, the primary sector is characterized by the largest share of employees (about 60%) endowed with high autonomy in terms of control, and this is a shared pattern across countries, although this share ranges between 80% in France to 40% in Spain. Second, construction displays interesting dissimilarities across countries (probably due to the number of employees in this sector in each country). In France, Spain and the United Kingdom, jobs in the construction sector employ a high share (about 70%) of workers performing high-controlled tasks. In Germany and Italy, instead, jobs in the construction sector might require a large degree of autonomy (low-control), and therefore less than 20% of workers declare to perform a high-controlled type of tasks.

Third, German manufacturing jobs (mostly in high-tech industries) display a remarkable degree of autonomy as compared to services, while in Italy, Spain and the United Kingdom, LKIS jobs employ the largest share of workers performing the low-controlled type of tasks (about 60%). Fourth, public administration, education, and health exhibit a large share of workers performing high/medium-controlled tasks. Overall, in Germany and Italy, we detect the largest share of workers performing the high-controlled type of tasks in manufacturing rather than services. It may be related to how industrial relations at the workplace level regulate employer-employee relations, and by the intensity of codetermination and micro-management type of practices implemented at the workshop level.

Another relevant dimension concerning how work is organized and performed is the level of teamwork that different tasks might entail. Teamwork refers to workers' collaboration and coordination and may vary among sectors, but also within sectors across countries.

Although significant differences in the distribution of employment by job-task tercile among countries exist, Figure 14 reports some interesting common patterns: (i) the primary sector is everywhere the one employing the lowest share of workers performing high-teamworking type of tasks; (ii) the largest share of workers in construction perform tasks requiring low intensity of teamwork (more than 60% in France and the United Kingdom) or tasks requiring a medium intensity of teamwork (Germany and Italy); (iii) teamwork seems to characterize more jobs in the high-tech manufacturing and knowledge-intensive sectors than low-tech manufacturing and less knowledge intensive sectors – and this is relatively consistent across all countries; (iv) the organization of education and health services varies across countries: in Italy and Spain, teamwork is more widespread compared to France, Germany and the United Kingdom. It is particularly evident in services, where marked differences emerge between Italy and Germany in the public administration.

Figure 13. Employment share (%) by control-tercile over sectors and countries.

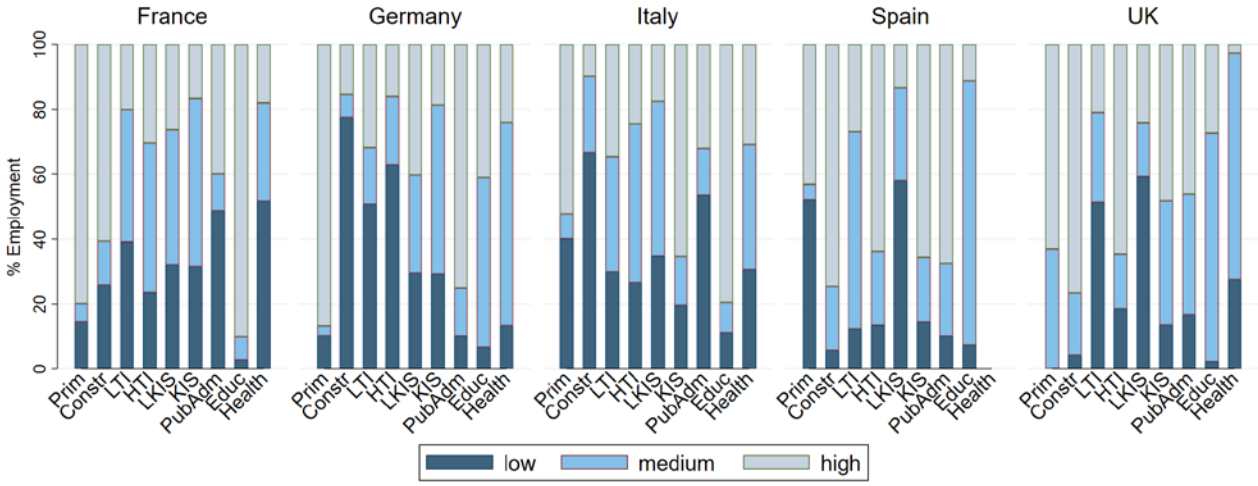
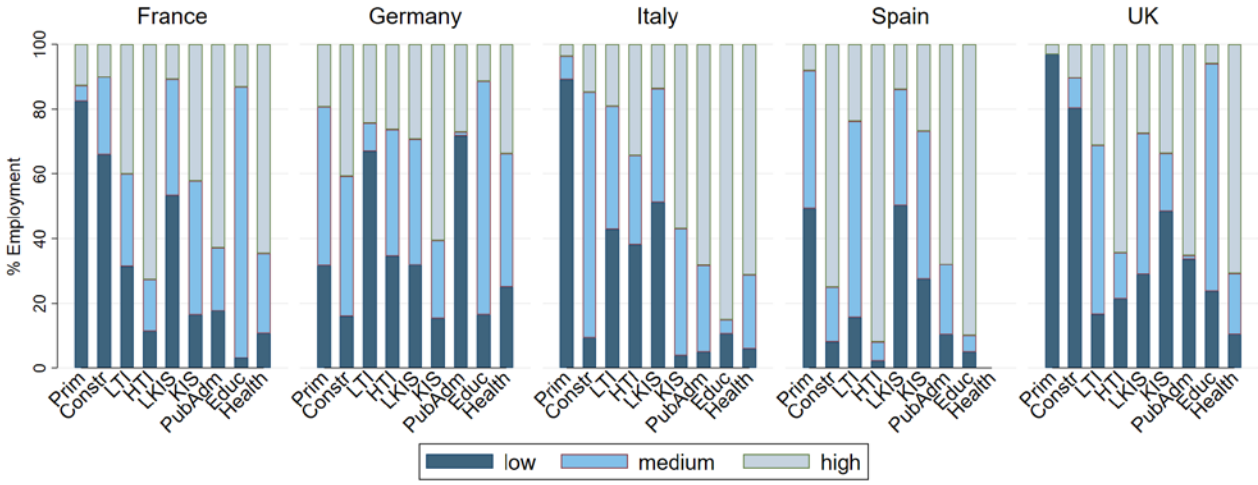


Figure 14. Employment share (%) by teamwork-tercile over sectors and countries.



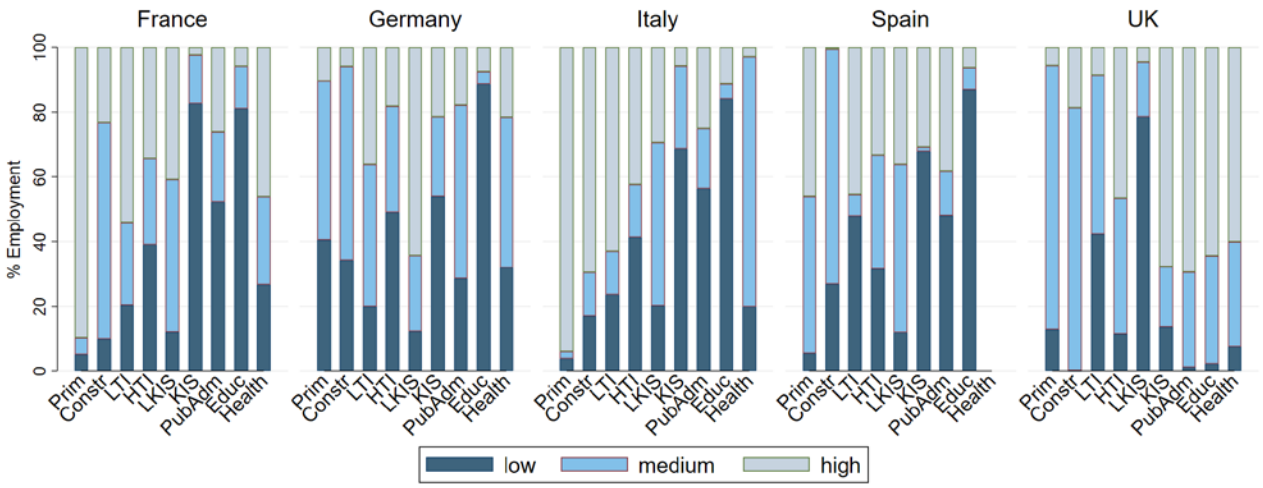
Lastly, we focus on repetitiveness (the extent to which the worker has to repeat the same procedures during the execution of her tasks). This dimension displays the highest by-country heterogeneity, ranging from the largest share of workers employed in high-repetitiveness jobs in the primary sector in France (about 90%) to a small fraction in the United Kingdom (less than 10%).

Repetitiveness, together with standardization, is part of the routine type of work. As highlighted in Fernández-Macías and Bisello (2020), the inclusion of routine in the domain of "methods and tools of work" represents a novelty with respect to most studies developed so far classifying routine like a job content instead of a method of work. Routinisation of a task should be understood in itself as part of the process of organisational change and, therefore, it is dependent to institutionally and historical-contingent models of work organizations. Routine and repetitiveness have been often conceptualized in influential empirical contributions (Autor, 2001; Autor and Dorn, 2003) as synonymous of task automation, disregarding the specificities of institutional contexts and patterns of adoption of digital technologies among sectors and countries. Recent evidence on Italian data highlights that

routinization per se cannot be associated with automation unless it goes along with the application of digital tools at the workplace level (for recent evidence on the interplay of digitalization, routine-task and employment, see Cirillo et al., 2020).

The evidence on the degree of repetitiveness is reported in Figure 15. First, the highest heterogeneity in the distribution of employment by tercile of the repetitiveness indicator is dected in the service sector.In the Health sector, the share of workers involved in the high-repetitiveness type of activities ranges between 60% in the United Kingdom to 25% in Germany. This pattern is confirmed by the inspection at the 1-digit ISCO professional groups reportd in the Appendix. In France, Germany and Italy, the share of high-skilled and high-paid occupations – Managers, Professionals, Technicians – carrying out low-repetitiveness tasks overcomes 50%; while workers employed at the bottom of the distribution – mostly craft workers and Elementary occupations – perform high and medium repetitiveness type of tasks. Overall, there is a negative correlation between the degree of tasks' repetitiveness and the position of a specific profession in the hierarchical ladder, that is the higher the position, the lower the repetitiveness of tasks performed. Furthermore, it should be noticed that in all countries except the United Kingdom, the share of workers involved in the low-repetitiveness type of tasks is sensibly lower in manufacturing activities than in services. The only exception is the health sector, where each country seems to follow a different model of work organization. A typical pattern across countries comes to light when one focuses on the differences between KIS and LKIS: the latter is characterized everywhere except in the United Kingdom by a large share of workers in the second and third terciles of the repetitiveness distribution.

Figure 15. Employment share (%) by repetitiveness-tercile over sectors and countries.



Summing up, the main patterns emerging from the descriptive analysis above can be synthesized as follows.

First, job-task terciles related to job content display more similarities across countries compared to job-task terciles expressing methods of work. This evidence suggests that, despite jobs do not differ that much concerning their task content, national peculiarities matter in the organization of work resulting in significant (organization-driven) cross-country heterogeneities(e.g., a nurse in the Health sector performs a job which requires a high level of serving/attending type of tasks across all countries; however, she can perform her duties in a more or less repetitive way because she experiences schedules changes over time that make her tasks less repetitive in a German hospital compared to a French hospital).

Second, despite countries' similarities in job content and mostly physical tasks, divergencies are detected in the intellectual and social type of tasks. It means that countries display more similarities in manufacturing than in services and more in craft occupations than in technical and scientific professions. For instance, job-task terciles of strength and dexterity show the most similar distributions across countries.

Third, the main dissimilarities concern control and repetitiveness. Comparing macro sectors across countries (manufacturing vs services), we detect sharp differences in high-value-added services.

Taking stock of this evidence, one might argue that employment structures of some of the largest European economies are rather similar with respect to the object of work, conceived as a transformative activity involving things (in case of physical tasks), ideas (in case of intellectual tasks) or social relations (social tasks), being in turn significantly heterogeneous in terms of how work is done. This general result is consistent with previous evidence on European countries based on EWCS and PIAAC data detected by Fernández-Macías et al. (2016) p. 67 highlighting that "most of the discrepancy in task scores tends to concentrate in the indicators of task methods, whereas content and tools are generally more consistent across countries".

If one argues that technological change might only occur through an organizational change - or, technological change involves a reorganization of work because the decision to adopt new technologies entails the organisation of labour (Nelson and Winter 1982; Osterman 1994) - then we can envisage different rates of adoption of technologies across countries. It is evident in the case of new enabling technologies implying digitization and automation of production processes. Process technologies, such as 'Industry 4.0', tend to be accompanied by organisational changes consistent with the principles of 'lean production' (Womack *et al.* 2007; Cirillo *et al.* 2020; Fabbri, 2018; Cirillo and Zayas, 2019). Descriptive evidence developed so far highlights that strong heterogeneities exist in how jobs are performed mainly in European service industries requiring different levels of autonomy or entailing more or less repetitiveness of tasks. This evidence indicates that the adoption of technologies would have uneven effects across sectors and countries depending on the level of complementarity between a particular type of work organization and the specific technology a firm/sector is more likely to introduce.

Conclusions

Since the early 2000s, labor market analyses have switched their focus from skills to tasks in order to explain the relationship between technology and work and the related changes in terms of occupational structures. This opened the way to what has been popularized as the 'Routine Biased Technological Change' (RBTC) approach, characterising jobs no longer based on their generic 'skill endowment' but according to their task content. However, this approach neglects a set of key factors that are of paramount importance in shaping jobs and labor markets: the multifaced nature of technologies; the organizational characteristics of the workplace; country and sector-specific institutions, norms and regulations; power and hierarchical relationships.

In order to fill this theoretical gap, Fernández-Macías and Bisello (2020) propose an enriched task framework accounting for most of the dimensions neglected by the RBTC approach. This framework (i.e. the JRC-EF framework) goes beyond technical (i.e. deterministic) views of the production process taking explicitly into account the role of elements as the companies' organizational set-up and human agency. In a nutshell, the JRC-EF framework aims at comprehensively characterize two main dimensions of work: i)what people do at work? – i.e. the extent to which tasks require working with objects, data or people, and thus workers engage in physical, intellectual or social work; ii) how tasks are carried out? – i.e. the organizational content of work.

The unit of observation around which the JRC-EF is built (i.e. the occupation-sector cell) allows considering both supply and demand-side factors, adding realism to standard representations of work. Not less relevantly, the JRC-EF is a crucial instrument to compare occupational structures across selected European countries allowing to highlight differences in terms of technological, organizational and institutional features of labour markets.

Although its conceptual relevance and usefulness to study ongoing transformations as the diffusion of AI or the unfolding of digital platforms, few databases allow to operationalise the dimensions included in the framework. This is due to the lack of country specific data providing a detailed disaggregation of tasks (the Italian ICP – *Indagine Campionaria delle Professioni* – and the French *Enquête Conditions de travail* are a valuable exception at the European level).

The Comparative national tasks database described in this paper is a first attempt to fill this gap and allows to: (i) inspect distribution of tasks across jobs in each country and (ii) compare national employment structures focusing on tasks.

This work presents a new tasks database providing information on five European economies (i.e. the Comparative national tasks database) - France, Germany, Italy, Spain and the United Kingdom - and allowing to empirically account for most of the JRC-EF dimensions. The database merges different national sources that are illustrated in detail. In this respect, although the data are consistent to several robusteness check, researchers should acknowledge that the database pools together heterogeneous national surveys – characterized by a different sample designs and questionnaire formulations. Therefore, cross countries comparisons should be carried out with caution.

In order to provide consistent cross-country data enabling comparisons, we applied the weighted ranking method already established in the literature and often used in the *job-based approach* (Olin Wright and Dwyer, 2003; Fernandez Macìas, 2012; Fernández-Macías and Hurley, 2014; Hurley et al. 2019). Using the ordered ranking resulting from the standardisation adopted, we analysed national employment structures focusing on tasks profile as well as on the employment distribution by task-terciles. The descriptive analysis highlighted two main patterns.

First, a certain degree of similarity in employment structures by tasks content terciles emerges, especially once compared across occupational groups. This evidence suggests that France, Germany, Italy, Spain and the United Kingdom have similar structures concerning work contents (i.e. nature and composition of tasks, in particular). The task content of jobs reflects the technical nature of the

production process - which is directly related to the type of product or service that is produced – and, in principle, is less affected by national differences.

Second, countries show more heterogeneity in terms of work organization, namely "methods of work" consistently with previous evidence on European tasks shown in Fernández-Macías et al. (2016). This can in turn be explained by the fact that work methods reflect (relatively more than content itself) the socio-organizational structure in which they are embedded and are affected by idyosyncratic behavioral patterns of routines, cultural values, institutional frameworks. According to the empirical analysis presented in this work, such a divergence in methods of work is relevant in high-value added services where most of the heterogeneity is detected. This can be related to the differentiated rates of growth of high-value added services across the countries included in the analysis; and to the increasing dispersion of firm performances within sectors (Bartelsman and Wolf, 2017). The coexistence of high-productive and low-productive firms characterized by heterogeneous organizational models entailing different lean organizational practices (teamwork, job rotation, etc.) might explain why tasks change across countries, even within the same sector.

From this point of view, the Comparative national tasks database described so far provides sound empirical evidence on the diffusion and adoption across sectors, occupations and countries of several work practices. This is of primary importance in the current scenario. The availability of data covering the whole spectrum of the labour process is paramount to analyse the effects of COVID-19 pandemic on work re-organization and to explore efficacy and efficiency of policies, for example those promoting the spread of remote working.

Finally, the Comparative national tasks database offers so far a static picture of the distribution of employees by tasks in European sectors and occupations disregarding changes over time in job contents and methods of work. Therefore, as a future step of the research, a dynamic analysis should be performed in order to explore the evolution of work organization over time. This will allow to grasp information, for example, on the intensification of repetitiveness of some jobs in some countries with respect to others depicting patterns of deskilling, increasing control and monitoring, or conversely patterns of de-routinization. This is still an open research question that has been poorly explored through a quantitative approach and that is worth investigating.

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Appendix

Table A1. Task indicators covered by country.

	France	Germany	Italy	Spain	UK
A. In terms of the content:					
1. **Physical tasks:** aimed at the physical manipulation and transformation of material things:					
a. *Strength:* lifting people and heavy loads, exercising strength.	x	x	x	x	x
b. *Dexterity:* precisely coordinated movements with hands or fingers.	x	x	x	x	x
c. *Navigation:* moving objects or oneself in unstructured or changing spaces	x				
2. **Intellectual tasks:** aimed at the manipulation and transformation of information and the active resolution of problems:					
a. *Information processing:*					
I. Visual and/or auditory processing of uncodified/unstructured information			x		
II. Processing of codified information					
i. Literacy:					
a. Business: read or write letters, memos, invoices,…		x	x		
b. Technical: read or write manuals, instructions, reports, forms,…			x		
c. Humanities: read or write articles or books.		x	x		
ii. Numeracy:					
a. Accounting: calculate prices, fractions, use calculators,…			x	x	x
b. Analytic: prepare charts, use formulas or advanced maths		x	x		x
b. *Problem-solving:*					
I. Information gathering and evaluation.					
i. Information search and retrieval	x	x	x		x
ii. Conceptualization, learning and abstraction	x		x	x	x
II. Creativity and resolution					
i. Creativity		x	x	x	x
ii. Planning	x	x	x	x	x
3. **Social tasks:** whose primary aim is the interaction with other people:					
a. *Serving/attending:* responding directly to demands from public or customers	x	x	x	x	x
b. *Teaching/training/coaching:* impart knowledge or instruct others		x	x	x	x
c. *Selling/influencing:* induce others to do or buy something, negotiate		x	x	x	x
d. *Managing/coordinating:* coordinate or supervise the behaviour of colleagues	x	x	x	x	x
e. *Caring:* provide for the welfare needs of others.		x	x	x	x
B. In terms of the methods and tools of work:					
1. **Methods:** forms of work organisation used in performing the tasks:					
a. Autonomy					
I. Latitude: ability to decide working time, task order, methods and speed.	x	x	x		x
II. Control (in reverse): direct control by boss or clients, monitoring of work.	x	x	x	x	x
b. Teamwork: extent to which the worker has to collaborate and coordinate her actions with other workers	x	x	x	x	x
c. Routine					
I. Repetitiveness: extent to which the worker has to repeat the same procedures	x	x	x	x	x
II. Standardisation: extent to which work procedures and outputs are predefined and encoded in a formalised system	x	x			
III. Uncertainty (in reverse): extent to which the worker needs to respond to unforeseen situations				x	
2. **Tools:** type of technology used at work:					
a. Non-digital machinery (analog)			x	x	
b. Digitally-enabled machinery					
I. Autonomous (robots)					
II. Non-autonomous					
1. Computing devices					
a. Basic ICT (generic office applications)		x		x	x
b. Advanced ICT (programming, admin)			x		
c. Specialised ICT					
2. Others			x		

Table A2. Correspondence table between NACE Rev. 2 at 2-digits and macro-sector.

NACE Rev.2 two-digits	Sector
Crop and animal production, hunting and related service activities	Prim
Forestry and logging	Prim
Fishing and aquaculture	Prim
Mining of coal and lignite	Prim
Extraction of crude petroleum and natural gas	Prim
Mining of metal ores	Prim
Other mining and quarrying	Prim
Mining support service activities	Prim
Manufacture of food products	LTI
Manufacture of beverages	LTI
Manufacture of tobacco products	LTI
Manufacture of textiles	LTI
Manufacture of wearing apparel	LTI
Manufacture of leather and related products	LTI
Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	LTI
Manufacture of paper and paper products	LTI
Printing and reproduction of recorded media	LTI
Manufacture of coke and refined petroleum products	LTI
Manufacture of chemicals and chemical products	HTI
Manufacture of basic pharmaceutical products and pharmaceutical preparations	HTI
Manufacture of rubber and plastic products	LTI
Manufacture of other non-metallic mineral products	LTI
Manufacture of basic metals	LTI
Manufacture of fabricated metal products, except machinery and equipment	LTI
Manufacture of computer, electronic and optical products	HTI
Manufacture of electrical equipment	HTI
Manufacture of machinery and equipment n.e.c.	HTI
Manufacture of motor vehicles, trailers and semi-trailers	HTI
Manufacture of other transport equipment	HTI
Manufacture of furniture	LTI
Other manufacturing	LTI
Repair and installation of machinery and equipment	LTI
Electricity, gas, steam and air conditioning supply	LTI
Water collection, treatment and supply	LTI
Sewerage	LKIS
Waste collection, treatment and disposal activities; materials recovery	LKIS
Remediation activities and other waste management services	LKIS
Construction of buildings	Constr
Civil engineering	Constr
Specialised construction activities	Constr
Wholesale and retail trade and repair of motor vehicles and motorcycles	LKIS
Wholesale trade, except of motor vehicles and motorcycles	LKIS
Retail trade, except of motor vehicles and motorcycles	LKIS
Land transport and transport via pipelines	LKIS
Water transport	KIS
Air transport	KIS
Warehousing and support activities for transportation	LKIS
Postal and courier activities	LKIS
Accommodation	LKIS
Food and beverage service activities	LKIS
Publishing activities	KIS
Motion picture, video and television programme production, sound recording and music publishing activities	KIS

Programming and broadcasting activities	KIS
Telecommunications	KIS
Computer programming, consultancy and related activities	KIS
Information service activities	KIS
Financial service activities, except insurance and pension funding	KIS
Insurance, reinsurance and pension funding, except compulsory social security	KIS
Activities auxiliary to financial services and insurance activities	KIS
Real estate activities	LKIS
Legal and accounting activities	KIS
Activities of head offices; management consultancy activities	KIS
Architectural and engineering activities; technical testing and analysis	KIS
Scientific research and development	KIS
Advertising and market research	KIS
Other professional, scientific and technical activities	KIS
Veterinary activities	KIS
Rental and leasing activities	LKIS
Employment activities	KIS
Travel agency, tour operator and other reservation service and related activities	LKIS
Security and investigation activities	KIS
Services to buildings and landscape activities	LKIS
Office administrative, office support and other business support activities	LKIS
Public administration and defence; compulsory social security	PubAdm
Education	Educ
Human health activities	Health
Residential care activities	Health
Social work activities without accommodation	Health
Creative, arts and entertainment activities	KIS
Libraries, archives, museums and other cultural activities	KIS
Gambling and betting activities	KIS
Sports activities and amusement and recreation activities	KIS
Activities of membership organisations	LKIS
Repair of computers and personal and household goods	LKIS
Other personal service activities	LKIS
Activities of households as employers of domestic personnel	LKIS
Undifferentiated goods- and services-producing activities of private households for own use	LKIS
Activities of extraterritorial organisations and bodies	LKIS

Figure A1. Employment share (%) by problem-solving-tercile over occupations and countries.

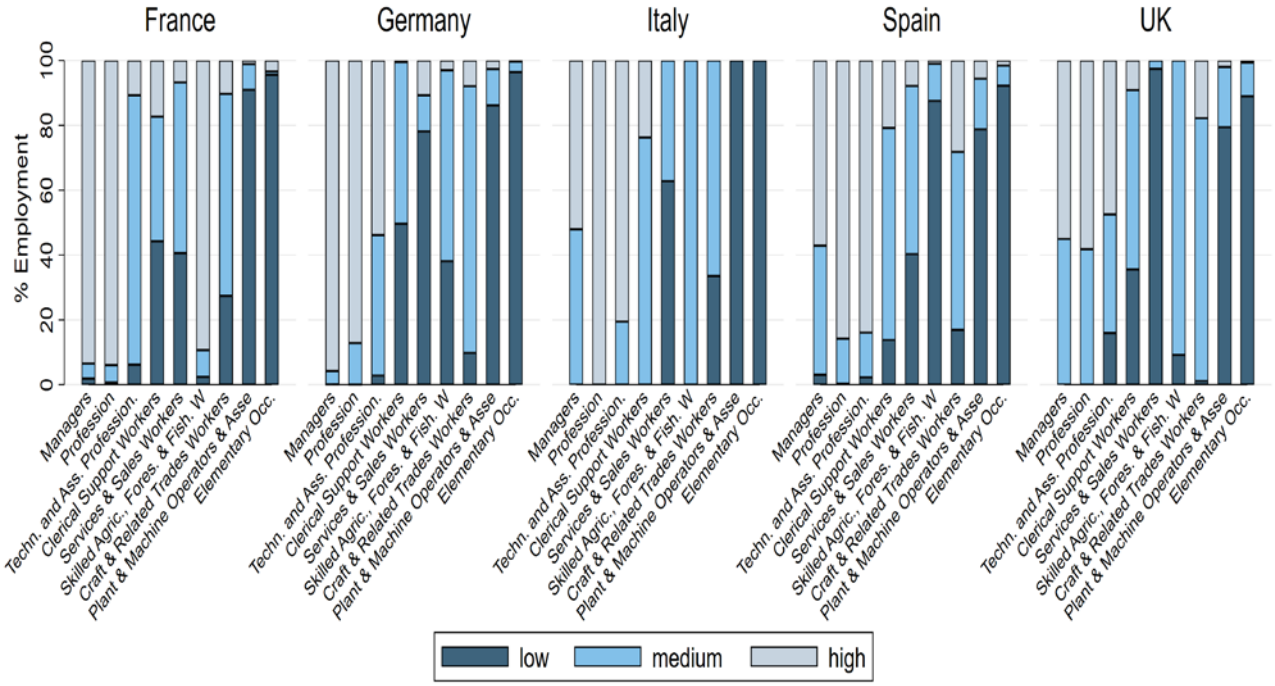
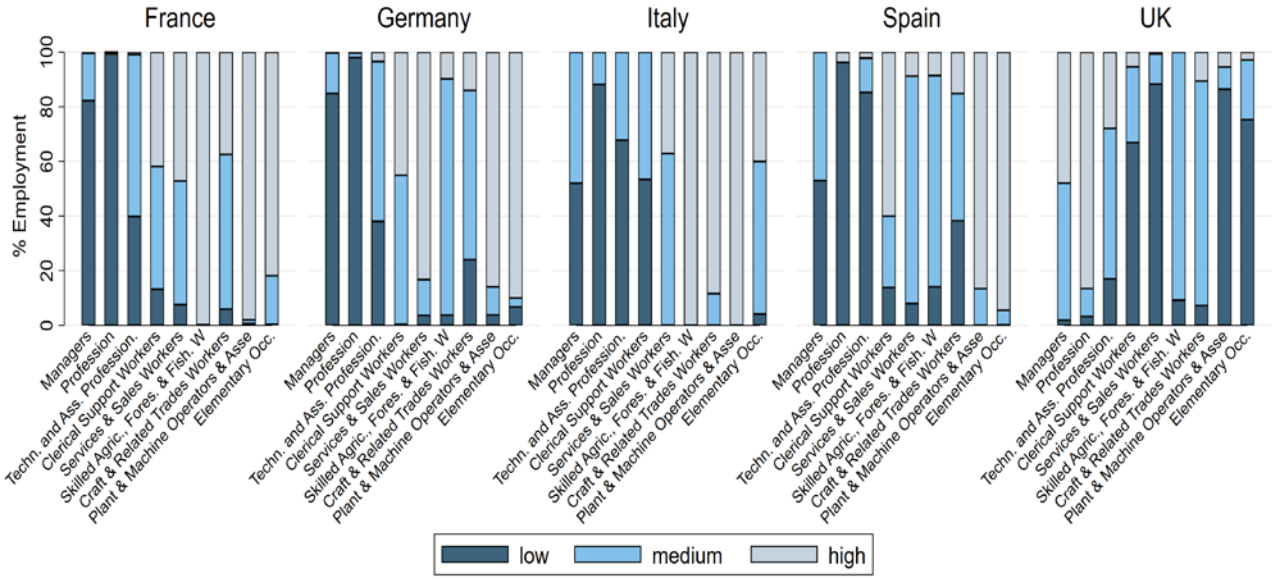


Figure A2. Employment share (%) by repetitiveness-tercile over occupations and countries.



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