MEASURING THE CONTENT AND METHODS OF WORK:

A COMPREHENSIVE TASK FRAMEWORK

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Draft version

ABSTRACT

This paper aims to contribute to the development of a comprehensive framework of task indices which can be used to characterize the nature of work activity across different jobs. After discussing what we believe are important omissions in the literature, we propose a set of indices to measure the task content (*what* people do at work) and methods (*how* work is organised and done) across occupation-sector combinations. Our framework tries to cover all of the relevant aspects of work, placing a particular emphasis on the social aspect of the production process. This allows the identification of a detailed "tasks profile" for any job in the economy. For illustrative purposes, we introduce an application of our framework for European countries using existing international data sources and we highlight its usefulness for a more nuanced analysis of the distribution of tasks across jobs.

KEYWORDS: tasks, technical change, occupations, labour markets, structural change, Europe.

JEL CLASSIFICATION: J24, O33, L160.

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1. Introduction

A polarization of job growth by skill level has been observed in some advanced economies such as the US and Germany in the 1990s (Autor, Katz and Kearney, 2006; Dustmann et. al. 2009), the UK since the 1970s (Goos and Manning, 2007), and Canada in the 1980s and 1990s (Green and Sand, 2015). This has sparked a growing literature on alternative models to the canonical Skills-Biased Technical Change (SBTC) which is unable to explain such polarisation of the occupational structure, characterised by increasing employment in low and high-skilled jobs while decreasing for the middle ones.

The "routinization hypothesis" first advanced by Autor, Levy and Murnane (2003) offered a more satisfactory explanation by arguing that recent technological change, in the form of information and communication technologies diffusion, is biased towards replacing labour in routine tasks (tasks which are easy to codify and automate). It claims that routine tasks are more frequent in the middle of the skills continuum, while non-routine in the top and bottom, hence the polarizing effect (see Acemoglu and Autor, 2011 for an exhaustive discussion). With this approach, tasks become relevant to understand the effect of technology on labour demand and therefore recent key developments in labour markets. Tasks can be defined as units of work activity that produce actual output, while skills refer to the human capability to perform tasks (Autor, 2013). The mapping between skills and tasks is not necessarily a one-to-one and it can also change over time.

The "task approach" to labour markets has been adopted in many influential papers and applied to different periods and countries. Several new classifications of tasks have been proposed in the literature, in many cases departing from the original one proposed by ALM in 2003 by introducing other concepts beyond the crude routine-cognitive tasks dichotomy. Yet while additional dimensions, such as service or social interaction, are introduced depending on the particular interest of the paper and the availability of suitable data, to our knowledge the literature lacks of a comprehensive and general purpose framework of task measures which can be used to characterize, across different occupations, countries and periods, the nature of work activity in terms of its content and the methods used.

After a discussion of what we believe are important omissions in the task approach currently predominant in the literature and a critical evaluation of existing proposals for the classification of tasks, this paper aims to contribute to the development of such an encompassing and general-purpose set of task indices to be used for labour market analysis. Differently from existing studies which rely on a rather piecemeal approach to task classification, our framework coherently and systematically organises all relevant dimensions of work around two conceptually different axes: one which would refer to the content of tasks (*what* people do at work), and the other which would refer to the methods and tools used at work (*how* work is organised and done), where the fundamental dimension of routine is to be found. We briefly introduce an application of our model with real data for European countries, whose main objective is methodological and illustrative. We show how the nested structure of our proposed task framework, where aggregate indices can be decomposed into lower level ones, allow for a richer breakdown of results. This includes the identification of a detailed "tasks profile" for virtually any existing job in the economy, making it potentially useful for the design of skills policies.

2. The task approach

According to the main proponent of the tasks approach in labour economics, tasks can be simply defined as units of work activity that produce output (Autor, 2013). The point of departure of this approach is a strictly technical view of production, seen as a mechanical process of transforming inputs into outputs. Work is an input in this process, and tasks are more or less discrete units of work. Depending on the complexity of the production process, it may require the combination of more or less different types of tasks, in the same way as it may require different types of raw materials.

An important thing to note is the absence of any reference to human agency in the definition of tasks. This is intentional: one of the aims of the approach is to understand better the substitution of human workers by machines for the performance of some types of tasks. Work is therefore understood as any kind of active input into the production process, which can be performed by human beings or machines (or animals, we could perhaps add). Which factor will perform the task in a particular production process will depend on the principle of comparative advantage: "comparative advantage in production means that the factor with the lowest economic cost of performing a task is assigned to that task. Economic cost in turn reflects both a factor's technological capability and its opportunity cost" (Autor 2013, page 5). In other words, depending on what is technologically feasible, a task will be performed by the cheapest factor.

But even in this model, human labour has a certain primacy over machine input in the production process. Because it is intrinsically flexible and adaptable, human labour has historically preceded machine input in the performance of most types of tasks (Autor 2013, page 4). The typical historical sequence of automation would be one in which human workers first perfect and codify the performance of a particular task, which can then be taken up by machines once technology allows for it. This does not necessarily mean that all tasks will end up being carried out by machines: again, that will depend on the comparative advantage of capital over labour in each particular case.

From this perspective, skills are defined as the stock of (innate or acquired) human capabilities that allow human beings to perform tasks (Autor 2013, page 4). Different types of tasks require different types of skills, in quantitative and qualitative terms: some tasks require simple skills, some tasks require complex ones; some tasks require very specific and some tasks only generic skills. Human beings have the capacity to learn and acquire many different types of skills, and depending on the complexity of associated tasks, this may require a significant amount of time and effort. This results in specialization, because it is simply more efficient that different workers specialize in different tasks so that they can benefit from increased competence in such tasks over time.

As we already discussed in the introduction, this approach provides the basis for a more nuanced understanding of the nature of labour demand than the traditional unidimensional concept of skills. It has clear foundations at the micro level of production and it seems particularly useful for understanding the process of automation of some types of jobs, and in more general structural developments of labour demand. However, it has some problems too. To begin with, it strangely blurs the boundaries between the concepts of capital and labour by stating that work (and tasks) can be equally performed by both, depending on technology and relative costs. In a literal sense, we agree that machines can perform certain types of tasks. But a crucial difference is that machines have no real “agency” as human workers do (at least, until a proper artificial intelligence comes into existence), and therefore there must always be human labour behind (for instance, designing, controlling or maintaining the machines). This is why even the most advanced industrial robots can be understood as very sophisticated tools: their main effect is to increase the productivity of the remaining industrial workers.

But perhaps the biggest limitation of this approach is that it largely neglects the social aspect of the production process, without which it cannot be properly understood. A notable exception is Deaming (2015) where the role of social skills within production is emphasized. While technology has a specific role in requiring certain work tasks to be carried out, social factors are an important determinants too, especially when one moves away from the immediate work task (Rose et al., 1986). As previously mentioned, what makes human labour a flexible and adaptable source of task input is the fact that workers have real agency. It also means that their input to the production process requires their cooperation. Ensuring such cooperation has historically been achieved by different means, including coercion and consent: the important point is that those means are themselves an important aspect of production, in at least two ways.

First, ensuring cooperation requires some labour input on its own, and therefore it generates some specific tasks (such as supervisory, managerial and control tasks). Those tasks are not necessary for production in a technical sense, and therefore cannot be explained with a technical framework such as the tasks approach we are discussing: they are necessary in a *social* sense, to ensure the cooperation of workers. A similar conceptualization of skills as socially-determined, and not only productive and expandable, can be also found in Green (2013).

Second, the need to secure cooperation will also (re)shape the contents and methods of labour input in production, in ways that cannot be explained with a strictly technical framework either. For instance, the level of routine involved in a job can be as much the result of social as technical constraints. Taylorism used standardization and routinization of work as a tool for increasing the degree of managerial control over the labour process (Braverman,1974).

Furthermore, tasks cannot exist in isolation, but have to be coherently bundled into jobs. We may think about tasks as units of labour input from the perspective of production, but jobs are the unit of labour demand from the perspective of firms and workers. And jobs are not only bundles of tasks, but also positions within the social structure of productive organizations, giving access to differential social power, resources and life chances. A tasks approach that does not take these issues into account cannot advance our understanding of trends in work and labour demand, neither at the micro nor at the macro level.

Finally, tasks are also socially embedded because the structures of production of any economy necessarily reflect the structures of consumption of society. The change in the contents and types of tasks in production will ultimately reflect how societies change in their tastes and preferences, in their institutions and organizational forms. This is why there can be, even within similarly developed capitalist economies, significant differences in the prevalence of different types of tasks in their productive structures (and the associated occupational categories). Social-Democratic models, for instance, have tended to expand the public provision of social services and to reduce the weight of low-paid manual service occupations, while Market-Oriented models often moved in the opposite direction (Esping-Andersen, 1999). This, which is associated to different patterns of structural change in employment (job polarization in the latter, structural upgrading in the former), can be also reflected in a smaller weight of non-routine manual tasks in Social-Democratic countries relative to Market-Oriented economies (Oesch, 2015). This would be again a development driven by social rather than technical mechanisms, and therefore cannot be fully understood with a strictly technical framework.

So a crucial building block for the proposed new framework is that the structure and types of tasks in an economy do not only reflect the technical nature of the production process and the structure of demand, but also its social organization. But before presenting in detail our proposal, the following section identifies some of the classifications used in previous studies.

3. A review of existing classification of tasks

In their seminal paper, Autor, Levy and Murnane (2003), identify four broad categories of workplace tasks which are classified along two main axes: routine (as opposed to non-routine) and cognitive (as opposed to manual). Routine tasks, which can be more easily automated, can be therefore either cognitive (such as record keeping or repetitive customer service) or manual (for instance repetitive assembly).

Several influential papers defending the RBTC hypothesis and investigating job polarization draw on the Autor, Levy and Murnane model (see for instance Goos and Manning 2007; Autor, Katz and Kearney 2006; Spitz-Oener 2006; Goos, Manning and Salomons 2010; Autor and Handel 2013). However, only two of the above cited studies follow the original taxonomy (i.e. Goos and Manning 2007 and Spitz-Oener 2006), while the others consider instead a three-fold classification of tasks by bringing together the two routine categories in one. More precisely, Autor, Katz and Kearney (2006) and Autor and Handel (2013) classify tasks into abstract, routine and manual, where the latter category refers to tasks that require physical effort and dexterity, with low cognitive demand but adaptability and flexibility. Goos, Manning and Salomons (2009, 2010) use instead the concept of service tasks, alongside abstract and routine, denoting those that involve social interaction with clients. Both manual and service tasks tend to be in the non-cognitive (low-skilled) and non-routine quadrant, and therefore would grow in relative terms with computerization.

The cognitive (abstract) axis is directly linked to the traditional concept of skills, since it refers to tasks that require intellectual effort (and therefore are complementary to information technologies) and are often associated to formal educational requirements. The definition of what constitutes cognitive tasks is not very precise in the papers reviewed, which sometimes can lead to somewhat contradictory measures. In the original formulation of Autor, Levy and Murnane, they further differentiated between analytical (information processing) and interactive (managerial) cognitive tasks: in our view, the introduction of managerial responsibilities in the measurement of this task dimension implies adding a dimension of organizational power that does not seem warranted by the underlying theoretical framework.

On the other hand, the routine axis is the main focus of the model of RBTC, and has been heavily studied in the recent literature. In the original formulation of Autor, Levy and Murnane, routine tasks are defined as those that "require methodical repetition of an unwavering procedure" (Autor, Levy and Murnane 2003, page 1283). More recently, it has been more precisely defined as "sufficiently well understood [tasks] that can be fully specified as a series of instructions to be executed by a machine" (Acemoglu and Autor 2011, page 1076). The problem with this concept is that it appears to conflate a very subjective meaning with a very technical one: whereas in human terms routine means *boring*, the literature of RBTC refers to repetitive, standardized and codifiable tasks which can be carried out by machines. Most repetitive, standard and codifiable tasks are likely to be felt as boring by human agents, but not all tasks that are boring are necessarily repetitive, standard and codifiable. A further problem is that the level of routine associated with a task depends on how that task is organized rather than on the content of the task itself. The routinization of particular types of work is the historical result of processes of division of labour and reorganization of production under particular social conditions: for instance, the routinization of manufacturing carried out by Taylor and Ford was explicitly aimed at reducing the degree of control the work process by craft workers (Braverman 1974). In any case, the model of RBTC would argue that information technologies are substitutive of labour input in routine tasks and therefore it tends to depress labour demand in those tasks.

Finally, at a more general level, a relevant conceptual problem in the RBCT theory is the considerable amount of overlap (in reverse) between the concepts of routine and cognitive tasks. Almost by definition, a task which is routine can be performed with little cognitive effort, and vice versa: non-routine tasks will necessarily involve more active cognitive input (for a discussion, see Fernández-Macías and Hurley, 2016).

In addition to the above mentioned strand of the literature which mainly focuses on the effect of technological change on labor demand, other related studies on international trade identify what types of tasks are easier to offshore. These are not only those which require codifiable rather than tacit information (Leamer and Storper, 2001) or be can be summarized in deductive rules (Levy and Murnane, 2004) but also those which do not require face-to-face personal communication and/or contact with end users (Blinder, 2009). Social interaction is therefore emphasised in these studies as a key aspect of jobs to understand their likelihood to be relocated abroad.

Finally, the literature on organisational change sheds lights on important dimensions to include in our framework. Decentralisation of authority, delegation of responsibility and greater workers' autonomy are among recent trends in work organisation (see Caroli, 2001 and OECD, 1999 for a review). Indeed trends in work organisation have been marked by a shift from mass production, "Tayloristic" forms of organisations - characterised by centralised and bureaucratic control - towards "Just-in-Time", flexible and less hierarchical ones. It is recognised that modern organisational practices lead to increasing interaction, cooperation and exchange of information among workers; increasing workers autonomy and responsibility, and decreasing specialisation while increasing multitasking.

4. A framework for measuring tasks across jobs

A review of the specialized literature allowed us to identify a number of task categories that are relevant to characterise the nature of work activity and to understand recent developments of labour demand and structural change. The technological strand of the literature primarily focused on cognitive and routine tasks as the main dimensions, although adding other secondary task categories such as interactive (managerial), service and manual (as opposed to cognitive). The literature on the effects of trade on labour demand also gave a significant role to the routine dimension, although giving even more emphasis to social interaction. And the organizational literature, finally, emphasised the increasing importance of autonomy, communication and cooperation, and multitasking. Can we classify each of those task dimensions identified in the literature within a more or less comprehensive conceptual framework?

In our view, all of the above mentioned categories can be classified in two axes that are conceptually different: one which would refer to the **content** of tasks and the other which would refer to the **methods and tools** used. The axis of contents would refer to the object of work activity, understanding work as a transformative process which is applied on things, ideas or social relations. The axis of methods would refer to the ways work is organized and to the physical objects used for aiding the production process. The concepts previously reviewed of cognitive, manual and service tasks, for instance, would be classified within the axis of task contents. The concepts of routine or autonomy, on the other hand, would be classified within the axis of task methods.

In very simple terms, we can think about those two axes as the *what* and the *how* of work activity. The task content is mostly dependent on what is being produced (or rather, transformed in the production process), and therefore also on the structure of demand and needs that are satisfied by economic activity. The type of task content will tend to be associated, therefore, to the economic sector to which the work activity belongs: interpersonal and service tasks are more frequent in service sectors, while manual tasks are more frequent in goods-producing sectors such as agriculture and manufacturing. However, the complexity of contemporary production processes means that the link between the actual tasks performed by workers in each sector and the final output of the overall production process is significantly blurred: there are many intermediate and meta-tasks whose relation with the actual output is only indirect.

The methods and tools of work, on the other hand, are less dependent on what is being produced and more on the technology and social organization of production. Therefore, they are more historically and institutionally contingent. For the production of the same goods or services, different societies or organizations can use significantly different methods and tools at different points in time.

Table 1 below presents the full classification of tasks according to our proposal. All of the key categories reviewed in the literature have been included in this framework, and we have also added some categories to fill the gaps that in our view are implicit in the structure proposed. The first broad category of our framework, *physical tasks*, would encompass the types of activities that the literature sometimes refers to as “manual”. We split it into two categories. The first one, strength, refers to the pure exertion of muscular power, and it is probably the category of labour input that has been most significantly reduced by technical change since the origins of civilization (even before machines, the domestication of animals enabled a very significant reduction of this kind of task input). Still, it remains a significant component of some types of work activity, so we include it in our framework. The second category of physical tasks is (manual) dexterity, which corresponds most directly with the concept of manual tasks. As in the previous case, technical change has reduced significantly the amount of labour input in this kind of task for centuries: but it still represents a significant category of labour, even if it is in secular decline.

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

Table 1: A classification of tasks according to their contents and methods

The domain of *intellectual tasks* refers to information processing and problem solving, and is similar to the concept of cognitive tasks found in the literature. Until relatively recently, intellectual tasks expanded as technical change reduced the amount of human labour necessary to carry out physical tasks: but particularly in the case of information processing, advances in computing have allowed for a large-scale substitution of intellectual human input by machines in recent decades. Following the framework of OECD's Programme for the International Assessment of Adult Competencies (PIAAC), we split information processing tasks into literacy and numeracy, referring respectively to the processing of verbal and numeric information. The richness of the PIAAC's Survey of Adult Skills allows us to further differentiate literacy into the processing of business, technical and humanities verbal information, and numeracy into accounting and analytic mathematical tasks. The third category of PIAAC's framework (problem-solving in technology-rich environments) is considered as a separate category of intellectual tasks, and we keep it at a higher level of generality by eliminating the direct reference to a technological environment. Problem-solving is further divided into the gathering and evaluation of information on the one hand, and the creativity required for finding and implementing a solution on the other.

The third broad dimension of the task content classification in our framework refers to *social tasks*, aimed at the interaction with other people. As in the previous case, the amount of labour performing this type of task content has grown as technical progress reduced the amount of physical task input: but unlike information processing, even the most advanced machines are still incapable of replacing humans in human interaction, so labour is likely to continue growing in this category in the foreseeable future. Although it is obviously linked to the service sector of the economy, it is important to note that they are by no means synonymous: our focus is on the content of work as a transformative process, and some types of services are actually aimed at the transformation of the physical environment (for instance, cleaning services) or the processing of information (such as business or legal services). In our framework, the category of social tasks refers to work activity that is *directly* aimed at social interaction. We have not found in the literature a finer breakdown of social interaction tasks that could fit our framework, so on the basis of our own inspection of detailed occupational codes and a review of the areas covered by the different sources with task information (more on this in the following section), we have differentiated the following four sub-categories: serving/attending, teaching/training/coaching, selling/influencing and managing/coordinating. We would have wanted to include two extra categories of social tasks for which we could unfortunately find no specific sources: caring and entertaining. Our measure of serving/attending incorporates only to some extent the dimension of caring, as we shall see later.

The category of "methods" essentially refers to forms of work organization, and we have broken it down into three categories following the main dimensions identified in the specialized literature: autonomy, which refers to the degree of latitude of workers in their tasks; teamwork, which refers to whether they work in direct collaboration with small groups of co-workers; and routine, referring to the degree of repetitiveness and standardization of the work processes. The inclusion of routine in this domain of our framework may seem surprising, since in previous papers it is sometimes considered as a type of task content (rather than a method), with a similar status as cognitive tasks. In our view the degree of routine involved in a task is not an aspect of task content as such, but an aspect of how tasks are organized in a particular work process. The same type of task content (in terms of the object of the transformative process of work, as classified in the first half of our framework) can be carried out with a low or a high degree of routine: in this respect, the routinization of a task should be understood in itself as part of the process of organizational change, rather than as something given by the material nature of the production process.[1]

Finally, in our model we have included two variables measuring the use of tools, one referring to (non-ICT) machines and the other to Information and Communication Technologies (which is further subdivided into office applications and programming).

It is important to note that in this context, the concept of tasks is only an analytical tool to understand better the structure and change of labour demand. Occupations (or jobs), and not tasks, are ultimately the unit of analysis. In quantitative approaches to labour market analysis, we never directly observe, measure or classify tasks as such. A strictly defined analysis and classification of tasks would require a very different approach, probably similar to what F.W. Taylor proposed nearly a century ago, which involved studying in detail each particular work process in order to break it down into its smallest possible units (Taylor, 1911). There is no statistical source at present that measures and classifies tasks in that way, and it is quite likely that there will never be. So a tasks approach, in this sense, is just a framework for analyzing occupations or jobs focusing on the different types of labour input into the production process that are typically involve.

5. An application of our proposal to EU-level occupational analysis

In this section we will present a specific application of our proposal for Europe, building a set of indices at the "job" level, i.e. combinations of occupation and sector at the 2-digit level, that match the classification of tasks presented in the previous section. For more details on this approach, see chapter 2 of Fernández Macías et al. (2012).

Sources

There are two main options for measuring the task content of occupations: aggregating the answers of individual workers to surveys on skills and working conditions, or drawing from occupational databases. At present, there is no international source of neither of those categories that can be used for constructing the full set of task indices that we have set out in table 1. Therefore, we opted for combining information from different sources:

a. *Workers' surveys:* the data contained in these sources are generally measured at the level of individual workers, and contain their replies to questions about what they do at work among other issues. In this case, we have used two different international sources that fit in this category: the European Working Conditions Survey (EWCS) and the OECD Survey of Adult Skills (PIAAC). Using workers' surveys to infer the task content of jobs and occupations has advantages and disadvantages. On the one hand, it allows studying the variability in task content within each occupation or job type. On the other hand, gathering information on tasks from workers introduces a potential bias in measurement, since the workers´ answers may be subjectively biased or just wrong (dissatisfied workers may exaggerate the amount of routine in their jobs, or new recruits may not be able to answer). Furthermore, there can be inconsistencies in the classification of workers across occupational levels and sectors.

b. *Occupational databases:* these datasets, which are produced drawing information both from job incumbents and occupational analysts, contain information on a range of variables measuring task content, skill requirements, job characteristics, etc. There are two main sources in this category that we know of, both from the US: the Dictionary of Occupational Titles (DOT) and its successor the Occupational Information Network dataset (O*NET). Both datasets are widely used in the existing literature for the US (see for instance Autor, Levy and Murnane, 2003; Autor, Katz and Kearney 2006; Acemoglu and Autor, 2011) but also Europe (e.g. Goos, Manning and Salomons, 2009). These sources are generally quite detailed in their measure of task content, and their conceptual framework is closer to our own than the workers' surveys previously discussed. However, they have important problems for our purposes as well, which make it necessary to use them just as a complementary source, despite their more exhaustive coverage of our task model. First, they are only available for the US. Although the task content of occupations should in principle be roughly similar across similarly developed economies, there are institutional and socioeconomic factors that differ across countries and could have an impact even at the level of task content. A second problem of this source is that it does not allow studying the variation of task content and methods that may exist within each occupation. And finally, although the conceptual framework of

O*NET is closer to ours than that of other sources, it is obviously not identical and therefore it is still useful to triangulate its information with other sources.

Table 2 below shows the sources used for the construction of indices for each category of task in our framework. As can be seen in the table, O*NET is the source that can provide a more exhaustive coverage of all the elements. O*NET has a modular structure, with different datasets providing information on job attributes from different perspectives: we have taken elements from three of those datasets (work activities, abilities and skills), in some cases providing information on the same element from a different angle. In practice, we used those different modules of O*NET as if they were different sources. For a list of the variables used for the construction of each index, we refer to Table 4 of the appendix and to Fernández-Macías, Bisello, Sarkar and Torrejón (2016).

Table 2 also shows that the different sources are stronger in particular areas. For instance, EWCS is very detailed in terms of work organization, whereas PIAAC has an excellent coverage of intellectual tasks, and O*NET has a good coverage of all the task content categories. As shown in the last column of table 2, there are some elements which are only covered in one of the sources, but in most cases the indices have been constructed by combining information from at least two. Since most of the variables we use are just proxies of our concepts, this redundancy increases the consistency and robustness of our measure. Having different measures of the same concept is also useful for testing the validity of measurement, as we will see later.

It is important to highlight that although the three sources refer to the employed population, they cover different geographic areas. O*NET bases its measurement on US workers, while the EWCS is a European Survey and PIAAC covers different OECD countries (many of them in Europe, but not all). To keep a certain degree of consistency, we have restricted the EWCS sample to EU15 and the PIAAC sample to the available EU15 countries plus the US (O*NET obviously remains restricted to the US). This way, our set of task measures refers to advanced Western economies, a group of countries with broadly similar levels of economic development and comparable socio-economic structures.

The construction of the indices

The procedure we followed for constructing the indices can be summarised in a number of steps, which have been separately applied to each of the sources shown in table 2:

1. Identification of variables: we first identified the variables that could match the elements in our model, a mapping exercise similar to the one shown in table 1 (but much more detailed).
2. Inspection of results: before any further manipulation of the variables, we inspected some basic descriptive statistics of the variables identified in the previous step, to further evaluate if they fitted our framework.
3. Normalisation of variables to a 0-1 scale: in the original sources, the individual variables use different scales which are not directly comparable. Therefore, they had to be normalised before they could be aggregated. We opted for a normative rescaling to 0-1, with 0 representing the lowest possible intensity of performance of the task in question and 1 the highest possible intensity.
4. Correlation and factor analysis: once the variables related to an individual element in our model were normalised, we proceeded to analyse the correlations between them. In principle, different variables measuring the same underlying concept should be

highly correlated, although there are situations in which they may legitimately not be (for instance, when two variables measure two compensating aspects of the same underlying factor). Beside standard pairwise correlations, we used Cronbach's Alpha to test the overall correlation of all the items used for computing a particular index and a Principal Components Factor Analysis to evaluate the consistency of the variables, and identify variables that did not fit our concept well.

5. Once we selected the variables to be combined into a single index (linked to a particular element in our model), we proceeded to combine them, by simply averaging. Unless we had a particular reason to do otherwise, all the variables used for a particular index received the same weight.
6. Finally, once all the indices from each source were constructed, we proceeded to compute their average scores for all the occupation-by-sector combinations at the two digit level. When the data source included the information at the individual worker level, we computed also the standard deviation and number of workers in the sample, for later analysis.

As shown in Table 1, our tasks framework has a nested structure, and the construction of the indices from each source reflects that structure. So generally, the aggregation of individual variables for each index was carried out at the most detailed level (indicated in italics in table 1), and the construction of indices at higher levels was carried out by averaging the indices below as indicated by the nested structure. This ensures that the values of the indices at higher levels are consistent with the lower levels, and will allow later to break down any high-level score into its lower level component in order to understand it better.

Once we generated from each source the set of possible indices shown in Table 1, we proceeded to merge and compare them. The procedure was as follows:

1. All the indices from the different sources were combined into a single dataset, in which the units are *jobs* (2-digit occupation by 2-digit sector combinations, or 3-digit sector occupations) and the variables scores for individual elements in our model from the different sources.
2. Data from the European Labour Force Survey on the level of employment in each job was added to the dataset holding the task indices. These employment figures were later used for weighting the indices.
3. Then, we performed correlation and factor analysis of the scores computed by different sources for the same elements in our model, to evaluate their consistency and identify possible problems. Once we were satisfied, we combined the scores of the different sources by simple averaging. Employment-weighted percentile indices were also computed as an alternative parameterisation.

	EWCS	PIAAC	ONET				Available in x sources
			Work activities	Abilities	Skills	Context	
In terms of the object of work/task:							
1. Physical: manipulation and transformation of things	x			x			[2]
a. Strength	x			x			2
b. Dexterity				x			1
2. Intellectual: manipulation and transformation of ideas	x	x		x			[3]
a. Information processing: processing of codified information		x		x			[2]
i. Literacy: processing of verbal information		x		x			2
-Business		x					1
-Technical		x					1
-Humanities		x					1
ii. Numeracy: processing of numerical information		x		x			2
-Accounting		x					1
-Analytic		x					1
b. Problem solving: finding solutions to complex/new issues	x	x		x			[3]
i. Information gathering and evaluation	x	x		x			3
ii. Creativity: finding a solution	x			x			2
3. Social: interacting with other people		x	x		x		[2]
a. Serving/attending			x				1
b. Selling/persuading		x	x		x		2
c. Teaching/coaching		x	x		x		2
d. Managing/coordinating		x	x				2
In terms of the methods and tools used in the work/task							
1. Work organization							
a. Autonomy: self-direction and latitude	x	x				x	3
b. Teamwork: working in small groups	x					x	2
c. Routine: Repetitiveness and standardization of the task	x						2
i. Repetitiveness	x						1
ii. Standardization	x						1
2. Technology							
a. Operation of mechanical machinery and tools (non-ICT)	x		x		x		3
b. Operation of ICT	x	x	x				3
-Basic ICT		x					1
-Programming		x			x		2

Table 2: Mapping of sources to the elements in our task model using 2010 EWCS, Round 1 of the Survey of Adult Skills (PIAAC), and O*NET version 17.

The consistency across sources and variables

In order to evaluate the consistency of our indicators, an indicator of inter-item covariance and scale reliability (Cronbach's Alpha) was computed for all the original variables used for each of the main components of our framework (i.e. physical, intellectual, social, work organisation and technology), across the different sources. With the exception of work organization, for which the Cronbach's Alpha is 0.4, the other values are reassuringly high (between 0.8 and 0.9). The low value of work organization was to be expected, since contrary to other components of our framework, it is formed by subcomponents which measure entirely different things (for this reason, it does not make sense to compute an overall "work organization" index; the same happens with the "technology" component).

Furthermore, we conducted a separate Principal Components Analysis (PCA) of all the original variables used for the construction of our indices. After extracting as variables the first 7 factors identified by the principal components analysis (all the factors with an eigenvalue higher than 1, accounting for more than 82% of the total variance for all the original indicators included in the analysis), we correlated them with each of the components and subcomponents of our index, to compare the results of our normative aggregation with the statistical aggregation performed by the principal components analysis (which is entirely based in the observed correlations in the task intensity across occupations and sectors). The results, not presented here for brevity but available in Eurofound (2016), shows that the internal structure of the data is highly consistent with our framework (the factors identified by PCA are generally similar to the elements of our framework).

The distribution of task content and methods across occupations in Europe

To test the validity of our proposal and measurement, it is useful to visually inspect the task scores of some key occupations. Figure 1 below shows the extent to which the 9 largest European "jobs" (or occupation-by-sector combinations) involve each of the categories of tasks measured in our framework. In broad terms, the results seem consistent with prior expectations, while at the same time providing a comprehensive profile of the tasks contents and methods of different jobs: for instance, office and building cleaners carry out more physical than intellectual or social tasks, with a high degree of repetitiveness (though not so much standardization) and limited use of machines or ICT; whereas public administration clerks carry out mostly business-related information processing tasks, with some problem-solving and a significant use of basic ICT. Being able to inspect the whole range of task categories for such a varied collection of jobs reveals some interesting patterns. Some task categories are relatively high in all occupations (problem-solving), while others are generally low (use of machinery, or analytic numeracy), and some are *polarized* (high in some cases and low in others, for instance physical tasks and information processing). Physical and intellectual tasks are not necessarily inversely correlated: for instance, doctors and nurses show both high values of physical and intellectual tasks; and a job as physical as building trades involves relatively high levels of some types of intellectual tasks (such as technical literacy information processing or problem-solving). Social tasks are rather widespread in the 9 jobs shown in figure 1 (all jobs involve some degree of social interaction), but they also clearly differentiate categories of workers (selling and serving discriminate jobs which involve less or more direct contact with customers, for instance).

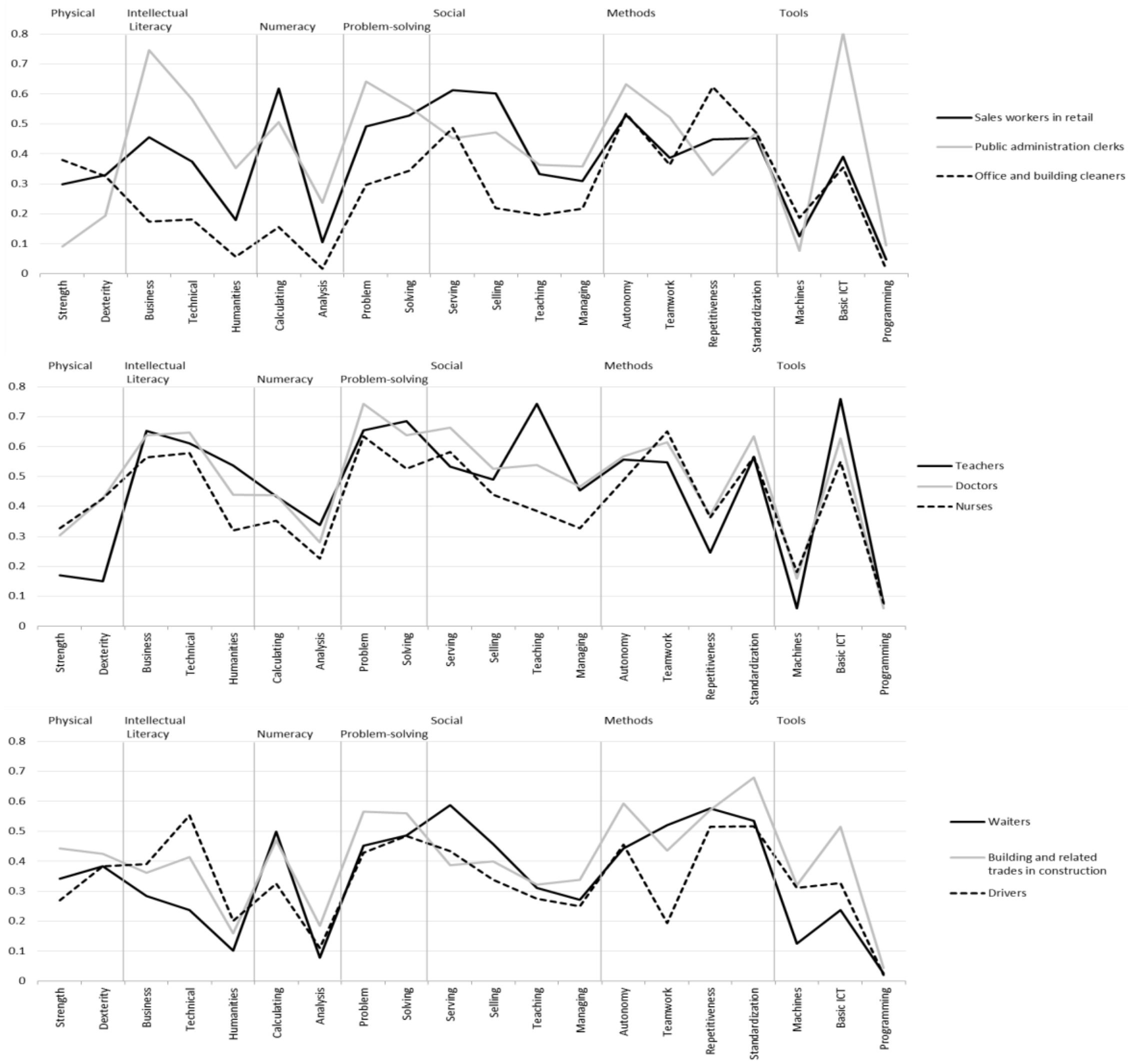

Figure 1: Task profile of 9 significant jobs (EU15)

We can generalize some of these points by reviewing the general distribution of task contents and methods for the whole EU15 workforce (figure 2). This can be understood as the task profile of the average European worker, across all occupations and sectors. Thus, the average European job would involve a high level of intellectual tasks (particularly the processing of business-administrative information and problem-solving), a mid-high level of social tasks (particularly serving and selling), and a low level of physical tasks. In terms of the task methods and tools, it would involve relatively high levels of autonomy, some degree of routine (particularly in terms of standardization), and more ICT (basic office applications) than machinery use. The most widespread task categories are problem-solving, serving and selling, autonomy and routine. All of these indices have relatively high average scores and a low dispersion: in other words, most types of jobs involve these tasks to some degree. On the other hand, business-related task content (business information processing, accounting and basic ICT) have high average values but also a high dispersion, which means that their distribution is more polarized: some jobs involve very high levels in these categories but some others very low. And finally, strength-related physical tasks, humanities literacy tasks, analytic numeracy tasks, machinery use and programming have low average values with a high dispersion (which means that the majority of jobs involve very little of these types of task, with only a small minority of jobs doing them).

Task indices	Summary statistics		
In terms of the object of work/task:	**Mean**	**Std dev**	**CV**
1. Physical	0.28	0.11	0.39
a. Strength	0.25	0.13	0.52
b. Dexterity	0.32	0.10	0.33
2. Intellectual	0.49	0.11	0.22
a. Information processing	0.40	0.12	0.30
i. Literacy	0.47	0.12	0.26
-Business	0.55	0.24	0.44
-Technical	0.47	0.16	0.35
-Humanities	0.27	0.15	0.56
ii. Numeracy	0.34	0.13	0.39
-Accounting	0.48	0.23	0.47
-Analytic	0.21	0.16	0.74
b. Problem solving	0.57	0.11	0.20
i. Information gathering & evaluation	0.57	0.12	0.22
ii. Creativity	0.56	0.11	0.19
3. Social	0.40	0.10	0.26
-Serving/attending	0.46	0.12	0.26
-Selling/persuading	0.44	0.14	0.32
-Teaching	0.37	0.13	0.36
-Managing	0.34	0.11	0.33
In terms of the methods and tools used in the work/task			
1. Work organization			
a. Autonomy	0.58	0.12	0.21
b. Teamwork	0.48	0.20	0.41
c. Routine	0.49	0.13	0.25
i. Repetitiveness	0.41	0.16	0.39
ii. Standardization	0.58	0.17	0.30
2. Technology			
a. Machines	0.19	0.14	0.71
b. ICT	0.39	0.22	0.55
-Basic ICT	0.59	0.24	0.41
-Programming	0.08	0.10	1.20

Distribution (percentiles 5, 25, 75, 95).
(lines link average values)

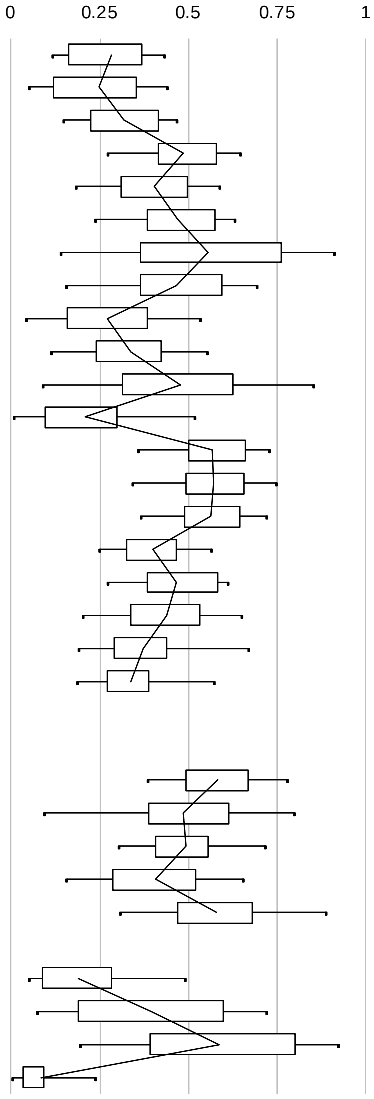

Figure 2: Average task scores for EU15, 2014 (EU-LFS weights)

6. Conclusions

To our knowledge the expanding literature on the task approach to labour markets still lacks a comprehensive framework of task measures which can be used for a detailed characterization of the nature of work activity across different jobs. In this paper, we have presented a new encompassing and general-purpose set of indices for measuring of the task contents (what people do at work) and methods (how work is organised and done) across occupation-sector combinations. Unlike the majority of existing studies, our framework tries to cover all of the relevant aspects of work, placing a particular emphasis on the social aspect of the production process. It also allows an in depth understanding of specific task attributes, as well as their distribution and interactions.

For illustrative purposes, we presented an application of our model for European countries using existing international data sources and we highlighted its usefulness for labour market analysis. The hierarchical structure of our framework is a novelty compared to previous approaches. This allows breaking down any significant finding into finer and finer levels of detail, allowing for a richer understanding of overall trends and patterns. For instance, we were able to characterize what people do at work and how by drawing a very detailed "task profile" for each job in Europe, subject to data availability of course.

Measuring task dimensions and indicators as continuous variables, and with separate and potentially overlapping scores, allows for a more nuanced analysis of the distribution of tasks across jobs, including the combination and clustering of tasks in particular task bundles. This contrasts with a significant number of papers that use a tasks approach only to classify occupations into a few categories (routine manual occupations, etc.).

Some of our initial findings can already suggest potential contributions to the literature: for instance, that some task dimensions are highly specific to a few occupations (such as physical or some of the more technical intellectual tasks) whereas others are present in a majority of jobs (such as problem-solving and to some degree social interaction). While the aim of this paper was to present our proposal rather than evaluating any specific hypothesis, we hope our framework can be put to that use in the future and contribute to advancing this area.[2]

Acknowledgments

This article derives from previous work carried out within Eurofound's European Jobs Monitor. The views expressed in this article are those of the authors and do not necessarily reflect those of the European Foundation.

Endnotes

[1] Taylorism provides a good example: it was explicitly aimed at reducing work tasks to repetitive and standardized procedures in order to increase productivity, to gain a better control of the production process and to replace high by low-skilled labour input (Braverman, 1974). Of course, such a routinization of work facilitated a later automation, but that is a different issue. For a discussion of routine-biased technical change, see Fernández-Macías and Hurley (2017).

[2] The full dataset of task indicators based on our framework, computed for all detailed ISCO and NACE combined codes, can be freely downloaded at the following link https://www.eurofound.europa.eu/observatories/emcc/european-jobs-monitor, as well as the Stata routines necessary to generate them from the original (publicly available) data sources (see Fernández-Macías et al. 2016 for more details)

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Annex

	EWCS	PIAAC	ONET			
			Work activities	Abilities	Skills	Context
In terms of the object of work/task:						
1. Physical: manipulation and transformation of things						
a. Strength	q24a,b,c,d			1.A.3.a.1,3,4		
b. Dexterity		F_Q06c		1.A.2.a.1,2,3		
2. Intellectual: manipulation and transformation of ideas						
a. Information processing: processing of codified information						
i. Literacy: processing of verbal information				1.A.1.a.1,2,3,4		
-Business		G_Q01b,g,G_Q02a				
-Technical		G_Q01a,f,h,G_Q02c,d				
-Humanities		G_Q01c,d,e,G_Q02b				
ii. Numeracy: processing of numerical information				1.A.1.c.1,2		
-Accounting		G_Q03b,c,d				
-Analytic		G_Q03f,g,h				
b. Problem solving: finding solutions to complex/new issues						
i. Information gathering and evaluation	q49e,f	D_Q13a,b,c		1.A.1.b.4,5,6		
ii. Creativity: finding a solution	q49c,q51i			1.A.1.b.2		
3. Social: interacting with other people						
a. Serving/attending			4.A.4.a.8			
b. Selling/persuading		F_Q02d,F_Q03b, F_Q04a,b	4.A.4.a.6,7		2.B.1.c, d	
c. Teaching/coaching		F_Q02b,c	4.A.4.b.3,5		2.B.1.e	
d. Managing/coordinating		D_Q07a,b,D_Q08a,b	4.A.4.b.1, 4			

In terms of the methods and tools used in the work/task						
1. Work organization						
a. Autonomy: self-direction and latitude	q39,q46,q50a,b,c, q51f,q43	D_Q11a,b,c,d, F_Q03a,c,				4.C.3.a.4, 4.C.3.b.8
b. Teamwork: working in small groups	q56,q57a,b,c					4.C.1.b.1.e
c. Routine: Repetitiveness and standardization of the task						
i. Repetitiveness	q24e,q44a,b,q49d					
ii. Standardization	q46c,q49a					
2. Technology						
a. Operation of mechanical machinery and tools (non-ICT)	q23a,q46d		4.A.3.a.3,4, 4.A.3.b.4,5		2.B.3.g,j,l	
b. Operation of ICT	q24h,i	G_Q05a,c,d,f, g G_Q06	4.A.3.b.1			
-Basic ICT		G_Q05a,c,e,f				
-Programming		G_Q05f			2.B.3.e	

Table 3: Variables used for the construction of the indices using 2010 EWCS, Round 1 of the Survey of Adult Skills (PIAAC), and O*NET version