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Abstract

TRADE IN TASKS

by

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Specialisation or division of labour is an important source of economic growth, but the degree of division of labour is constrained by the extent of the market. Trade in tasks represents the latest turn in a virtuous cycle of deepening specialisation, expansion of the market and productivity growth. It has attracted a lot of attention in the policy debate not for its contribution to international division of labour and productivity growth, but for its possible detrimental impact on labour markets, particularly in high income countries.

This paper analyses the task content of goods and services and sheds light on structural changes that take place following trade liberalisation. The task content of goods and services is estimated by combining information from the O*Net database on the importance of a set of 41 tasks for a large number of occupations and information on employment by occupation and industry. The study shows that tasks that can be digitised and offshored are often complementary to tasks that cannot. Therefore, the assessment of the offshorability of a job requires that one take into account all tasks being performed.

The paper finds that import penetration in services has a small, but positive effect on the share of tasks related to getting and processing information being performed in the local economy. In other words, offshoring complements rather than replaces local information processing. As distortions in the market for intermediate inputs, including offshored tasks, have a larger negative impact the more diversified and complex the economy, possible adverse effects of offshoring on the labour market should be dealt with through social and labour market policy measures, not trade restrictions. In addition, if trade restrictions are imposed, they should be levied on imported value added, not on the total import value.

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JEL classification: F16

Keywords: Trade in tasks, employment, cluster analysis

Table of contents

Tables

Figures

Boxes

Executive summary

This study contributes to the debate about offshoring and its possible impact on labour markets. It has been a concern that information and communication technologies (ICT) enables the slicing off and offshoring of activities or tasks currently performed by middle and high-skilled workers undermining their wages and job security, and contributing to the polarisation of the labour market. The empirical analysis in this study finds that firms are more likely to outsource, and possibly offshore, functions rather than individual tasks. Further, offshoring is associated with shifts in the task content of domestic production towards information intensive tasks at the expense of manual tasks, although the magnitude of the effect is relatively small. Finally, the observed polarisation of the labour market can be explained by both the proliferation of information technology *and* trade.

Specialisation or division of labour is an important source of economic growth, but the degree of division of labour is constrained by the extent of the market. These two basic truths lie at the heart of the proliferation of international value chains – expanding the size of the market through trade has allowed deepening specialisation. International fragmentation of the value chain has vastly improved consumer choice, making even high-technology products such as smart-phones available and affordable almost everywhere. Trade in tasks represents the latest turn in this virtuous cycle of deepening specialisation, expansion of the market and productivity growth.

Trade in tasks has, however, attracted a lot of attention in the policy debate not for its contribution to international division of labour and productivity growth, but for its possible detrimental impact on labour markets, particularly in high-income countries. Recent literature has estimated that between 20 and 30% of all jobs, including medium and high-skilled jobs, in a number of OECD countries can be offshored. This estimate is based on information on the importance of tasks that can be codified and provided over the internet for almost all occupations in the economy. Note, however, that the estimates are based on expected potential rather than observations of actual trade flows.

Trade and production data at the task level are not available, and it is therefore not possible to analyse trade in tasks and its impacts directly. A recent approach to get around this problem has been to assess the offshorability of tasks on the basis of how important working with computers is and how easily the activities performed in a particular occupation can be digitised. This study emphasises that tradability is not only determined by the technical feasibility of unbundling and digitisation, but also of transaction costs and the economies of scope of keeping tasks together. In a number of occupations and industries firms prefer multi-tasked workers in order to ensure that problems are solved at source as they arise as well as to facilitate incremental process and product innovation. Unbundling the offshorable tasks in such cases may undermine innovation and increase transaction costs, which may be an important reason why trade in tasks has not quite taken off yet.

In order to incorporate transaction costs and the economies of scope in the concept of offshorability, a cluster analysis of all tasks recorded in the O*Net database are performed exploring which tasks are bundled together across occupations. The cluster analysis reveals that one of the most important tasks considered offshorable in previous studies, “Getting information”, is strongly correlated with tasks that the same studies considered not offshorable. Thus, workers in occupations in which getting information is important also tend to make decisions, solve problems and establish and maintain interpersonal relationships. The fact that they constitute a cluster suggests that there are benefits from keeping them together.

The cluster analysis identified ten clusters of tasks that tend to be performed together. The next step in the analysis is to calculate the task content of output and exports based on these ten clusters in 2000 and 2008 for Members of the European Union, Switzerland and the United States, which are the countries for which the necessary disaggregated data on employment by occupation and sector are available. Three of the ten clusters account for between 60 and 70% of total task inputs in most countries, and they can be labelled “Working with others”, “Information processing tasks” and “Getting information and communicating”, based on the most important individual tasks included. We indeed live in the information society!

The task content of output is found to be fairly similar across the countries included in the study, and it has not changed much from 2000 to 2008. For instance the share of “Information processing tasks”, which contains mainly tasks that other studies have identified as offshorable, varies from 17.6% of total output in Estonia and the Slovak Republic to 23% in Luxembourg in 2008. The content of this task embodied in exports is slightly lower than that embodied in output in all countries included except Switzerland where it is slightly higher and in the Netherlands and Luxembourg where it is the same. The largest difference between the task content of output and exports for this task cluster is found in the United States (18.6% versus 17%). A higher task content of exports than output suggests comparative advantage in sectors using the task intensively. The sectors that use information processing tasks the most intensively are found to be insurance and pension funding, computer and related services and services auxiliary to financial intermediation. These are among the sectors in which Luxembourg and Switzerland feature prominently, which is reassuring as far as methodology is concerned.

Estimates of the relationship between the composition of tasks in the economy and import penetration, distinguishing between imports of goods and services, are presented for the three most important clusters. Imports of goods were found to be unrelated to all three task clusters. Imports of services, in contrast, are found to be unrelated to “Working with others”, and positively associated with “Information processing tasks” and “Getting information and communicating”, suggesting that services imports may complement information processing tasks and getting information and communicating. The effects are small, however, and must be interpreted with caution given the small sample of countries. Similar analyses were undertaken at the sector level. Again the impact of import penetration on the composition of tasks within an industry performed in the local economy is small. In some capital-intensive manufacturing industries, import penetration is associated with a shift from tasks related to operating or monitoring machinery towards information related tasks, while import penetration by and large appears to have little effect on the composition of tasks in local services sectors.

Tentative policy implications are, first, that offshorability depends on trade and communications costs as well as coordination and transaction costs within and between firms. The policy debate has mainly focussed on the trade costs, an approach that tends to exaggerate tradability of tasks. Offshoring everything that is technically offshorable is indeed possible, but it will not always make sense from a business point of view. It is recalled that Taylorism[1] gave way to "Toyotism" characterised by multi-tasked workers working in teams, because this business model was conducive to fault-less production and innovation. When transaction costs and economies of scope are taken into account, it appears that the fear of massive job losses due to a surge in offshoring is exaggerated. Second, trade in tasks has a similar impact as trade in other intermediate inputs – it improves productivity and induces shifts within firms and sectors in a similar way as technical change does – shifting resources towards high-skill, information-intensive occupations on the one hand and low-skill occupations where assisting and caring for other people are important on the other hand – and away from manual routine tasks. Recent theory developments combining the theory of the firm with trade theory provides important insights on the determinants and impacts of trade in tasks. The cluster analysis provided in this study constitutes a building block for empirical analysis within this framework and is to our knowledge the first study that does so.

1. Taylorism refers to a standard method for performing each and every job and is associated with the transformation of craft production to mass production.

1. Introduction

Division of labour has been an important source of productivity gains since the first human beings engaged in hunting and gathering. Indeed, one of the most striking trends in economic development since pre-historic times is the deepening division of labour all the way from within self-sufficient households to global value chains. The development has taken place in fits and spurts following the opening of new transport routes, innovations in transport and communications technology and innovations in management and work organisation. The most recent turn in this spiral of expanding markets and deepening division of labour is trade in tasks facilitated by the proliferation of the internet and its rapidly growing capacity for information transmission.

A task is an activity that needs to be accomplished within a defined period of time (see Box 1 for the definition of tasks and trade in tasks). Production of goods and services consists of a number of individual tasks; the more complex the good or service, the more tasks are involved. As famously observed by Adam Smith when visiting a pin factory; a single worker “not educated to his business” could at best make 20 pins per day. However, with the introduction of division of labour breaking production of pins down to 18 distinct tasks performed by 10 different workers, output per worker per day increased to 4 800 pins; a productivity gain almost beyond imagination.

Different industries under different circumstances have exploited the productivity gains from division of labour in different ways. Taylorism, for instance, has in common with the pin factory that it maximises job fragmentation in order to minimise skills requirements, allowing mass production to a mass market in an environment of skills shortages. Whereas Taylorism required that tasks were conducted in a specific sequence under a single roof, recent technical developments have eased this constraint and tasks can increasingly be performed individually across space and at different sequences.

Not all production processes can be broken down to simple tasks requiring only unskilled labour or computer processing, however. As household income increases, demand shifts from standard mass-produced goods to differentiated higher-quality goods and services where innovation and creativity are important sources of competitiveness. Fostering creativity and innovation requires a different way of organising production, taken to the extreme by information and communications technology (ICT) firms... “hiring talented, local people who share our commitment to creating search perfection and want to have a great time doing it”, as Google puts it on its web page.[2]

2. See www.google.com/jobs/lifeatgoogle

Box 1. What is a task? What is "trade in tasks"?

In dictionaries, a task is generally defined as a definite piece of work assigned or done as part of one's duty. There are two important elements in the definition of tasks:

- Tasks should be understood as units of work. A given job or occupation can be described as a set of specific tasks. Tasks are like atoms assembled together in an occupation (the occupation being the molecule).
- In addition, tasks have to be identifiable and discrete pieces of work. A task is a defined activity that has to be accomplished within a certain period of time and the list of tasks involved in a given occupation should clearly differentiate the various components of the work.

For analytical purposes, we have to work with a limited number of tasks that are common across occupations. We could be very specific and define tasks that are different for each occupation. But then we could not say much about the task content of output and trade and how it has evolved. In the rest of the document, we will therefore work with generic families of tasks rather than specific tasks.

In the context of offshore outsourcing, tasks are traded more and more. What people generally mean when talking about trade in tasks is the fact that part of activities of firms that were previously provided in-house are now outsourced, i.e. supplied by an independent firm. When this independent company is a foreign firm, there is offshoring in addition to outsourcing (offshoring relates to the relocation of the activity abroad while outsourcing corresponds to the external provision by an independent firm).

A narrow definition of trade in tasks would simply identify services that are now outsourced and traded at arm's length. These services used to be part of the non-core activities of firms (such as human resource management, marketing and sales, and other types of business process outsourcing services). But with the fragmentation of production, core activities are now subject to fine-slicing with an increase in the depth and scope of outsourcing (Contractor *et al.*, 2010).

The paradigm of trade in tasks, as defined by Grossman and Rossi-Hansberg (2008), goes beyond the increase in trade in services following new *outsourcing* strategies. Their basic idea is that instead of trade being an exchange of *goods,* it "increasingly involves bits of value being added in many different locations". Trade in tasks is therefore a theory of *offshoring* – the consequence of the separation of tasks in time and space.

Between Taylorism and the ICT campuses are producers of goods and services where the production process is broken down to bundles of tasks, some of which are essential for the firm's market position and competitiveness while others are not. Furthermore, a firm or a country may be good at performing some of the tasks required to produce a good or service, and bad at others. One of the most important gains from unbundling and outsourcing tasks is a productivity and competitiveness improvement stemming from the opportunity to specialise in what the firm does best. The biggest concern related to trade in tasks is a possible adverse effect on wages and job security.

Offshoring has attracted a lot of attention in the popular policy debate. Hitherto, the volume of tasks being offshored and traded appears to be low. Nevertheless it has been argued that offshoring of services and trade in tasks mark a major shift in international trade with a huge, largely unexploited potential, with possibly grave consequences for workers previously protected from international competition.[3]

In the public debate, advocates of open markets have focussed on the productivity gains from offshoring and trade in tasks. As firms specialise on what they do best and source non-core tasks from abroad at lower cost, productivity improves, costs come down and improved competitiveness allows expansion of output and possibly employment as well. Sceptics fear that sourcing of tasks from lower-cost countries undermines wages as

3. See Kohler (2008) for a discussion.

well as job security in the outsourcing firm and the outsourcing economy as a whole. Both are right in the sense that offshoring of tasks does improve productivity and it does lead to shifts in labour demand, to the benefit of some and the detriment of other workers. Thus, there are several forces at work, drawing in different directions. Which force dominates under which circumstances is an empirical question to which this study contributes. It aims at shedding more light on how structural shifts in the composition of tasks being performed within countries and industries are related to international trade, particularly trade in services.

The rest of the study is organised as follows: Section two summarises insights from the literature on trade in tasks and the interaction between such trade and technical development, educational attainment and structural changes in goods, services and labour markets. Section three presents a cluster analysis of data on the importance and level of a set of tasks or activities by occupation from the O*Net database, while section four provides estimates of the intensity of each task/activity in a number of sectors, and compares and contrasts the results across sectors and countries. The extent to which specialisation at the task/activity level can be related to international trade is explored in section five while section six concludes.

2. A small but rapidly growing literature presents mixed results

The make-or-buy decision: the firm, the local market and the global market

What, exactly, do workers of different occupations do when putting together a car, a T-shirt or an iPad; when underwriting a cross-border merger, writing a computer program or when preparing a meal? Do for instance machine operators perform the same tasks in US, German, Japanese and South African car manufacturing plants? To what extent can the bundle of tasks needed to produce a good or a service be unbundled? Which tasks can be automated and performed by computers or robots? Which tasks can be performed at a distance? Conversely, what holds bundles of tasks together?

These are critical questions for understanding trade in tasks. In many ways analysing trade in tasks is analogous to analysing the boundary of firms.[4] Why is production organised within firms rather than in markets? Those who remember the euphoria surrounding the IT bubble recall the vision of the global village in which self-employed people could use their talent, skills and a computer to produce directly for the market, or at least telecommute if still employed by a company.

The global village scenario has not materialised so far. The reason is that although such a scenario may be technically possible for a broad and probably broadening range of activities, there are transaction costs, tacit information and unforeseen events that require coordinated and immediate response and adjustments. These features keep bundles of tasks together and contribute to explaining the existence of firms. Even in the pin factory observed by Adam Smith, some workers did more than one task also after radical

4. A seminal paper by Coase (1937) argued that the existence of firms should be explained rather than assumed, but economics outside the fields of institutional economics and industrial organisation still largely abstracts from firms. One aspect of this question, the make-or-buy decision, was introduced into an international trade context in a series of papers by Grossman and Helpman (2002; 2003; 2005) which analysed the determinants of outsourcing and offshoring as a function of trade and transaction costs.

specialisation had taken place, since 18 tasks were performed by 10 workers. Furthermore, Taylorism gave way to "Toyotism", characterised by multi-tasked workers working in teams. Indeed, teamwork in so-called quality circles was at the heart of the success of Toyotism, and illustrates nicely the advantages of bundling tasks together.

Firms can be seen as production technologies where relative prices of inputs determine the composition of inputs given technological constraints. However, firms can also be understood as a way of organising production which aligns the incentives of individuals with the objectives of the firm. This viewpoint places people and how their skills, motivation and efforts are channelled into the production of goods and services at the centre stage. The firm is seen as a bundle of transactions and the theory of the firm is a tool for predicting which transactions will take place inside the firm and which will be sourced from outside suppliers. The key determinant of the boundary of firms is relative transaction costs, which in turn depend on the nature of the inputs, the institutional framework and transport and communication costs.

What each party brings to and takes away from a transaction is specified in contracts, and transaction costs stem from negotiating, monitoring and enforcing them. Transaction costs increase with the complexity of the contract. Above a complexity threshold, it becomes impossible to specify everything that is required by all parties under all possible contingencies. Moreover, enforcing contracts becomes difficult if the parties have incentives to renege once the contract is written and some rewards obtained. By organising production within the contractual framework of a firm, transaction costs are saved.

However, markets are considered better than firms at providing the right incentives. Furthermore, the costs of coordinating in-house activities may rise more than proportionally with the number of activities performed. The boundary of firms thus emerges as a compromise between the need for keeping transaction and coordination costs down and realigning individual incentives with the firm's objectives. For some tasks the in-house provision is preferred, while for others, sourcing from local or foreign markets is favoured.[5]

Since it is firms that outsource, insights from the theory of the firm are central to any analysis of offshoring and trade in tasks. In the same way as some tasks can be outsourced but are nevertheless kept within the boundary of the firm, some tasks that can be offshored are nevertheless sourced locally, or indeed performed in-house. An additional complication when a task crosses a border is that the parties to a contract are established under different jurisdictions. This may not matter much in cases of standardised inputs. However, when an outsourcing contract entails obligations of the parties to invest in the relationship – for instance through technology transfer on the part of the sourcing firm and customising the task on the part of the supplier – contracts can be hard to enforce across jurisdictions should disputes arise.[6]

5. Williamson (2010) provides an insightful and readable review of transaction costs economics since the seminal paper by Coase (1937) was published.

6. This is an example of what the theoretical literature calls asset-specificity. The parties to the contract incur costs in order to fulfil the terms of the contract. If it is difficult to verify whether the supplier has actually made the required investment, the supplier has incentives to invest less than agreed. If on the other hand the supplier has few alternative customers once the task or product has been customised, the sourcing firm has incentives to "hold-up" the supplier, i.e. not to compensate the supplier in full for his investment. Tasks that require such relation-specific investments are more

A possible way of benefiting from lower production costs abroad while keeping transaction costs low in circumstances where contracts are difficult to enforce is to relocate tasks or activities to subsidiaries in low-cost countries. Precise data on how important relocating of services through foreign direct investment (FDI) is relative to sourcing from unrelated foreign parties are available only for the United States, where services exports to affiliates account for about a third of exports and two fifths of imports. The sectors with the lowest intra-firm share both on the export and import side are legal services and training services, while mining services have the lowest share on the import side. In contrast, the sectors with the highest shares of intra-firm trade are management and consulting services both on the export and import side, R&D on the export side and, perhaps surprisingly, computer services on the import side (Lanz and Miroudot, 2011). It thus appears that complex activities that draw on firm-specific assets are more likely to be kept in-house.

The rapid developments in communication and information technology over the past few decades have reduced transaction and coordination costs both within firms and between firms across borders. As a result trade as a share of gross domestic product (GDP) has increased sharply and value chains have become more fragmented. However, at the same time the average firm size in major economies has increased or stayed the same, suggesting that the forces that keep tasks together are also strong. It is therefore hard to gauge the *relative costs* of in-house production, local outsourcing and offshoring. These are crucial for understanding patterns of trade in tasks and not least for predicting the future potential of trade in tasks.

How can trade in tasks be measured?

Measuring trade in tasks is easier said than done since tasks are not a well-defined statistical unit recorded in production and trade statistics. Trade in tasks, defined as the performance of activities in one country for direct use in the production process in another country, appears to have been muted so far. Nevertheless, many observers argue that the potential for trade in tasks is huge and that a wave of offshoring can be expected in the not so distant future.

Since information on trade in tasks is not readily available, trade policy analysts have looked for indirect ways of measuring such trade, and found useful information for that purpose in labour market statistics, particularly information on occupations. Occupations are characterised by a set of tasks for which certain skills are required. Labour ministries and statistical agencies in several countries have collected systematic information on the task content of occupations. The most detailed is the O*Net database for the United States. It provides a standardised list of work activities, which come close to our definition of tasks, and the importance of each activity for each occupation is scored on a scale from one to five.

The offshorability of jobs has been assessed, first, by identifying the activities recorded in the O*Net database that can be easily codified and provided electronically at a physical distance and next determine the importance of such activities for the conduct of an occupation. Matching indices of the importance of offshorable tasks by occupation with data on employment by occupation, it was found that between 20 and 29% of all jobs in major economies such as the United States, Canada and Australia could be

likely to be performed inside the firm, or by regular suppliers on long-term contracts (Baker *et al.*, 2002) offshored.[7] Furthermore, these jobs include medium to high-skilled professions that hitherto have been sheltered from international competition. These estimates caused alarm, raising fears that well-paying jobs that had previously been protected from international competition could at best face downward pressure on wages and at worst become trade-displaced. Note, however, that this measure does not quantify in any way *actual* trade in tasks.

An alternative approach to measuring trade in tasks is to extend the technique of measuring the factor content of trade[8] to measuring the tasks content of trade. This can be done through the following steps: first, translate the importance of a task into a numerical index and use it for estimating the intensity of each task for each occupation. Occupations are held by workers who provide inputs into productive sectors, which in turn produce goods and services for local and foreign markets. The next steps follow the task from the input of workers through the production process until the good or service has reached its final destination. The second step is thus to match data on employment by sector and employment by occupation. To illustrate how this works, consider the activity "interacting with computers" and the sector *construction*. Construction employs architects, engineers, carpenters, plumbers, electricians, drivers, managers and so on, each performing a set of tasks or activities. Interacting with computers is more important in some of these occupations than others. The total intensity of interacting with computers in construction is found by adding the index of its importance for each occupation, weighted by its employment share in the sector. The third step is to use the correspondence between sector classifications and goods and services classifications to establish which sector produces which goods and services and then estimate the task content of goods and services. Finally, having estimated the task content of goods and services, the task content of trade can be computed by combining the estimate of task content of goods and services in the exporting country with export values.[9] Note however that the methodology sketched here does not distinguish between tasks *embodied in* traded goods and services and tasks performed directly across borders.

In conclusion, there are two alternative empirical approaches for assessing trade in tasks, neither of which measures trade in tasks directly. However, the reason why trade in tasks has become a hot issue in the international trade policy debate is the perceived impact of trade in tasks on labour markets. Fortunately, this question, to which we turn in the next section, lends itself more easily to empirical analysis.[10]

The impact of trade in tasks on labour markets

Trade and international specialisation are two sides of the same coin. Therefore, it is inevitable that deepening international division of labour affects patterns of employment.

7. See van Welsum and Vickery (2005), Blinder (2009) and Jensen and Kletzer (2010).

8. See for instance Stone *et al*. (2011); and Trefler and Zhu (2005).

9. The task content of imports should be calculated using the task content of goods and services in the exporting country. This methodology avoids the so-called Leontief paradox, which in the case of trade in tasks arises from a false assumption that the occupational composition of employment by sector is the same across countries. Because of lack of comparable information, one is, however, forced to make the assumption that the task content of occupations is similar across countries.

10. A well established result from trade theory is that embodied factor content of traded goods and services has a similar impact on factor markets as factor mobility across borders. The same should apply to tasks.

Exactly how trade affects labour markets, is, however, quite complex and cannot easily be predicted from theory.[11] Thus, there are different forces and effects at play that pull in different directions and the net effect becomes an empirical question to which this study contributes.

It appears that hitherto trade in tasks have had little, if any, effect on total employment even at the firm level.[12] However, there is growing evidence that offshoring has had a significant effect on the composition of labour demand as well as on relative wages. Let us first take one step back and look at the main structural changes observed in OECD labour markets over the past few decades. And next investigate how these changes may be linked to trade in tasks.

At least since the late 1990s the most notable labour market development observed on both sides of the Atlantic is polarisation. In the UK there is evidence of polarisation dating as far back as to the mid 1970s (Goos and Manning, 2007). Polarisation manifests itself as an increase in the shares of employment in both high- and low-skill jobs at the expense of medium-skilled jobs. In the European Union, the share of total hours worked in the four lowest-paid occupations increased 1.58 percentage points from 1993 to 2006, the share in nine middle income occupations dropped by 7.77 percentage points and the share of the eight highest paying occupations increased by 6.19 percentage points during the same period (Goos *et al.*, 2009).

In the US employment shifted from low-skilled to high-skilled workers in a monotonous way during the 1980s; the higher the skill level, the faster the growth in employment. During the 1990s, however, the share of middle-skilled workers declined, while the share of high-skilled workers rose sharply and that of low-skilled workers rose moderately. Finally, during the 2000s, the share of medium-skilled workers continued to decline, this time mirrored by a sharp rise in the share of low-skilled services workers while the share of high-skilled workers stayed relatively flat (Autor *et al.*, 2010).

The shift towards high-skilled jobs observed during the 1980s was largely attributed to skills-biased technological progress.[13] The polarisation observed since the late 1990s, however, did not quite fit into that framework, neither could it be explained by trade-related structural changes, since it is difficult to argue that a country has comparative advantage for both low and high-skills intensive sectors at the same time. The solution to the puzzle emerges when going beyond sectors and comparing the tasks that are performed in the contracting middling jobs versus those performed at the expanding high-and low-skills ends respectively.

Middle-skilled workers tend to do manual or cognitive tasks that lend themselves to automation or codification. Examples are book-keeping, monitoring processes and processing information. Because these tasks can be substituted by machines or offshored, demand for middle-skilled workers declined and the returns to their skills likewise. At the

11. Standard theory of comparative advantage predicts that when trade is liberalised, the relative return to the most abundant factor will increase. This holds in the standard model with two sectors and two factors of production, but when complexity such as additional sectors and/or factors and trade in intermediate inputs are added, which factor(s) gain and which factor(s) lose is not determined a priori.

12. See for instance Crinò (2010) for a study of Italian firms.

13. An interesting debate in the academic literature addressed to what extent skills-biased technological change or trade was the main explanation for growing income inequalities at the time. Although consensus was not reached, the conclusion seemed to be that the major driving force was technology. See Acemoglu (2002) for a review.

high-skills end, workers tend to perform cognitive non-routine tasks that are complementary to information technology. Therefore, demand for high-skilled workers increases in tandem with investment in information technology. Finally, low-skilled non-routine tasks involve services activities such as operating vehicles and assisting and caring for others. These activities are not directly affected by trade or technology, but employment shifts into these occupations anyway for two reasons. First, as societies grow richer and greyer, demand for personal services grow in step with income. Second, productivity growth in non-routine low-skilled jobs is slow, and employment growth will be closely related to output growth in these sectors.[14] Polarisation of the labour market can in other words be explained by proliferation of information technology *and* trade and is best understood at the occupation and task level.

So what is the relationship between structural changes in the labour market and trade in tasks, then? Let us start with the finding that 20-30% of all jobs in major economies can be offshored. Even if that figure is taken at face value, it does not mean that 20-30% of all jobs will be lost to offshoring. First, offshoring has both an importing and an exporting side, and OECD countries such as Ireland and the United States are important exporters of intermediate services. Second, for some activities that in principle can be unbundled and provided at a distance, incomplete contracts can be a problem. The enforcement of services contracts for example, often relies on trust and the value of reputation, which may not travel very far.

Third, some activities that can be provided at a distance are highly complementary to activities that cannot, and firms may find it uneconomical to unbundle them. Therefore, it is not sufficient to look at the importance and level of tasks that can be provided at a distance when assessing the offshorability of jobs. Instead, one needs to look at the full range of activities that are performed by workers in a particular occupation, and assess to what extent and at what cost they can be unbundled in addition to how easily individual tasks can be offshored.

To illustrate the point, a study using the O*Net database found that offshorability increases with skill level, largely because the importance of interacting with computers increases with skill level. Nevertheless, it was also found that high-skilled occupations were the most likely to *expand* as a response to offshoring (Crinò, 2009).[15] Apparently, it is not only how much computers are used, but also how they are used and what other tasks are important for carrying out a job that matter for offshorability. For instance a scientist and a ticket booking officer both spend most of their working day in front of a computer, but the computer software may substitute the tasks that the ticket officer does, but complement and support the tasks that the scientist does.

Fourth, when a task is being offshored, it is true that the local workers who used to perform the task become idle. However, there is growing evidence that offshoring lowers

14. Structural changes in the labour market also have an interesting gender dimension observed in the United States. It appears that for women the decline in middle-skilled employment is mirrored by an increase in high-skilled employment, while men to a larger extent move from middle-skilled to low-skilled jobs, an issue that has created concern about social consequences.

15. These results come from a study that develops indices of tradability using the O*Net, derives intermediate services imports as a share of total non-energy intermediate inputs and calculates labour demand elasticities with respect to import penetration for each occupation. The study explores to what extent labour demand elasticities vary systematically with tradability. Among services occupations requiring the same level of skills, the most tradable were found to be the most likely to shed jobs in the event of offshoring.

production costs, enhances productivity and creates space for expansion and new hiring in the offshoring firm. For instance a recent study has found that offshoring intermediate services enhances innovation in Irish firms (Görg and Hanley, 2009); whereas a study of Spanish firms found a positive productivity effect of offshoring intermediate inputs (Kohler and Smolka, 2009). German multinational firms' offshoring of tasks is associated with a shift towards more non-routine and interactive tasks being performed onshore. At the same time a shift towards highly educated workers onshore was observed (Becker *et al.*, 2009). The chain of causality from offshoring to productivity gains and job creation is, however, too long to reach the news headlines, and goes largely unnoticed.

Before the great recession hit in 2008/09, the unemployment rate was historically low in the United States and a host of other OECD countries. Therefore, concerns about offshoring and jobs were as much related to developments in relative wages as total employment. The evidence of possible links between offshoring and stagnation of middle-income wages and growing income inequality is mixed. It is clear that skills are less important as a determinant of income than it used to be, as wages vary significantly across occupations for a given level of skills as measured by education and experience (Autor *et al.*, 2010). It has also been found that the return to skills that can be automated or offshored has declined, and thus that declining employment in the middle is accompanied by shrinking relative and even absolute wages in occupations dominated by medium skilled manual or cognitive routine tasks. Finally, it appears that workers who perform tasks that are complementary to offshorable tasks at both ends of the skills spectrum have seen wages rise (Autor *et al.*, 2010; Firpo *et al.*, 2011). Relative wages in other words reflect changes in relative demand and are jointly determined by technology and trade.

The gains from trade in tasks

The studies reviewed so far do not quite capture the essence of the relationship between trade in tasks and deepening division of labour in the sense observed from Adam Smith's pin factory story. Trade in tasks not only allows firms to source an increasing portion of the tasks performed in the production of goods and services more cheaply from abroad, it also allows for deeper division of labour in the sense that the production process is divided into finer and more specialised slices. For instance if a ship building firm decides to replace a small in-house design and architecture division by a contract with a specialised outside supplier, it will obtain the inputs from, say 30 highly specialised engineers instead of three in-house engineers that would have to cover a much broader field at the same cost. The opportunity to buy specialised tasks from outside suppliers is particularly important for tasks that are needed only occasionally such as testing of new products, recruitment, training and software development where in-house state-of-the-art expertise is way too costly, particularly for small and medium sized enterprises.

Gains from trade in tasks are thus related to gains from deepening division of labour. There are two aspects involved here. First, there is the process described by Adam Smith in the pin factory. We recall that breaking down the production of pins into 18 tasks increased productivity enormously, but would breaking each of these tasks into, say 5 additional even more specialised tasks yield the same productivity gain? Intuitively we would answer probably not. Second, having access to a broader spectrum of tasks makes it easier to find a good match to the other tasks being performed in a value chain. Furthermore, the thicker the market for intermediate tasks, the easier it is to mix and match standardised tasks purchased from the market into a customised product; so-called mass customisation. Since each producer will only use a subset of available inputs in the latter case, diminishing returns to specialisation will set in at a much higher level of specialisation than in the pin factory.

In any case, the productivity gain from deepening specialisation depends on how close substitutes the tasks are. The more differentiated are the tasks, the larger the gains from having more of them. However, inevitably, the larger the number of tasks, the more similar an additional task will be to at least one existing task, and the gains from adding another one diminishes as the number increases. Eventually an equilibrium is reached striking a balance between in-house provision, locally sourced and imported tasks. This balance will not last forever, but shift with changing technology, market size and transaction costs.

In order to quantify the gains from access to new intermediate inputs and tasks through trade, one needs to count the number of varieties being added. But how does one define a variety? In a trade context, a common definition is the output from a sector at the most disaggregated level possible from a particular country. For example the 8-digit product 85221000 “pick-up cartridges” produced in Korea is considered one variety. If a country imports such cartridges from 10 countries, there are 10 varieties available – 11 if such cartridges are produced locally as well. Using this definition, Feenstra and Kee (2008) found that import variety of goods to the United States has increased by 3.3% per year between 1980 and 2000 and improved productivity by 3.3% on average for the entire period, which if generalised implies that an increase in product variety of 1% per year increases productivity by 0.05% per year. Unfortunately an equally precise assessment of the gains from expanding varieties of services cannot be made since the services trade data by partner country is far too aggregated to capture any reasonable approximation to the task level. It is, however, not unreasonable to assume that the gains from expanding variety due to trade in tasks is at least of the same magnitude as for goods.

Another important result from recent research is that the gains from services trade liberalisation that lowers trade costs accelerates as trade costs come down. The effect can be illustrated by an example: Assume that when the cost of entering and operating in a new market is 100, 100 tasks are imported. Further, assume that if the costs are reduced to 80, 20 additional tasks enter the market, and if costs are further reduced to 50, 30 additional tasks will be imported. The reduction in trade costs from 100 to 80 would benefit the importers of the 100 existing tasks as well as the 20 new ones, while the cost reduction to 50 would benefit the importers of 120 existing tasks in addition to the 30 new ones and so on. (Grossman and Rossi-Hansberg, 2006, 2008; Nordås, 2010). Therefore, going the last mile of trade liberalisation has a larger marginal effect than taking the first steps when trade liberalisation draws new varieties or tasks into the market.

Dynamic gains from trade in tasks have not been much explored in the literature hitherto, but an intriguing possibility is that in the same way as there is an optimal savings and investment rate that maximizes economic growth (the golden rule), there is an optimal allocation of resources to producing intermediate goods and services that also maximises growth. After all, intermediate goods and services are similar to capital in the sense that they are not produced for immediate consumption but are used in subsequent production. The difference is mainly the time it takes to depreciate. The share of intermediate inputs in production corresponding to the golden rule depends on how easily tasks performed in-house and tasks sourced from the market can be substituted

(Jones, 2011). Furthermore, distortions that lead to deviations from the golden rule have a more detrimental impact on productivity the more flexibly firms can choose between in-house production and sourcing from external suppliers.[16] Since firms in rich and well-diversified countries probably have more flexibility in this regard than those in poorer economies, distortions in markets for intermediate inputs have a proportionally larger effect in rich countries. Thus, the dynamic gains from removing distortions to trade in tasks and intermediate inputs in general are greatest in rich and well diversified countries.

To summarise this section, trade in tasks can only be measured indirectly. The driving forces for trade in tasks should be seen in the light of the boundaries of the firm; where costs of outsourcing or offshoring are weighted against the costs of unbundling tasks and enforcing contracts with outside suppliers. Using indicators of trade in tasks, it is possible to explore the impact of such trade on labour markets with reasonable accuracy.

3. Every man's task: a calculation of the task content of occupations based on O*Net

The first papers on trade in tasks have focused on simple typologies opposing for example routine and non-routine tasks, or cognitive and manual tasks (Autor *et al.*, 2003). Studies based on a larger set of tasks, such as Blinder (2009) or Jensen and Kletzer (2010), also tend to rely on a limited number of tradable tasks. The selection of tasks and whether they are tradable or not are based on the judgement of the authors. The assumption is that offshorable tasks are the ones with little face-to-face customer contacts, high information content and a work process that is internet-enabled or "telecommutable". In the study of Blinder (2009), for example, all manufacturing activities are offshorable while educational and health care services are deemed immune to offshoring.

In this paper, our approach is different. First, we rely on a full decomposition of occupations according to 41 tasks provided by the O*Net database (see below for a description of O*Net). We keep all the tasks in the analysis and do not try to reduce them to a single linear measure based on their offshorability. We take seriously the assumption of "trade in tasks" by looking at the specialization of countries and industries along specific tasks without any *a priori* judgment on their tradability.

As previously emphasised, we do not think that whether tasks are offshorable or not is the right question. All goods are tradable and this does not imply that all goods are *actually traded*. In addition, trade in tasks should be understood beyond the simple offshoring of specific tasks that have attributes facilitating their relocation abroad. Workers in industries that are not easily offshorable are as likely affected by trade in tasks than workers with offshorable jobs. Testing the paradigm of trade in tasks implies looking at the specialisation of countries in specific tasks (rather than specific products or industries as in traditional trade analysis).

The second reason why we depart from earlier literature is that tasks may come as a bundle (and our empirical analysis supports such assumption). This could explain why in

16. This finding corresponds to the boundary of the firm theory, but seen through a different prism. If tasks provided in-house and tasks provided by the market were perfect substitutes and there were no transaction costs, all tasks would be provided by the market according to Jones' theory. By the same token, in the absence of asset specificity and transaction costs, inputs are sourced from the market according to the theory of the firm.

practice offshoring remains low. A high number of offshorable tasks could translate into a low number of offshored jobs because each job consists of a list of tasks of which some are offshorable but others less so. Complementarities between tasks could better explain the trade in tasks patterns rather than antinomies between simple categories. For example, some manual routine tasks may be bundled with important cognitive non-routine tasks so that a given occupation is not so easily offshorable. An important assumption in the trade in tasks paradigm is that tasks are separable. Empirical evidence does not fully support such separability.

Table 1. Typology of tasks

	Tasks	ID
1.	Getting Information	111
2.	Monitor Processes, Materials, or Surroundings	112
3.	Identifying Objects, Actions, and Events	121
4.	Inspecting Equipment, Structures, or Material	122
5.	Estimating the Quantifiable Characteristics of Products, Events, or Information	123
6.	Judging the Qualities of Things, Services, or People	211
7.	Processing Information	212
8.	Evaluating Information to Determine Compliance with Standards	213
9.	Analyzing Data or Information	214
10.	Making Decisions and Solving Problems	221
11.	Thinking Creatively	222
12.	Updating and Using Relevant Knowledge	223
13.	Developing Objectives and Strategies	224
14.	Scheduling Work and Activities	225
15.	Organizing, Planning, and Prioritizing Work	226
16.	Performing General Physical Activities	311
17.	Handling and Moving Objects	312
18.	Controlling Machines and Processes	313
19.	Operating Vehicles, Mechanized Devices, or Equipment	314
20.	Interacting With Computers	321
21.	Drafting, Laying Out, and Specifying Technical Devices, Parts, and Equipment	322
22.	Repairing and Maintaining Mechanical Equipment	324
23.	Repairing and Maintaining Electronic Equipment	325
24.	Documenting/Recording Information	326
25.	Interpreting the Meaning of Information for Others	411
26.	Communicating with Supervisors, Peers, or Subordinates	412
27.	Communicating with Persons Outside Organization	413
28.	Establishing and Maintaining Interpersonal Relationships	414
29.	Assisting and Caring for Others	415
30.	Selling or Influencing Others	416
31.	Resolving Conflicts and Negotiating with Others	417
32.	Performing for or Working Directly with the Public	418
33.	Coordinating the Work and Activities of Others	421
34.	Developing and Building Teams	422
35.	Training and Teaching Others	423
36.	Guiding, Directing, and Motivating Subordinates	424
37.	Coaching and Developing Others	425
38.	Provide Consultation and Advice to Others	426
39.	Performing Administrative Activities	431
40.	Staffing Organizational Units	432
41.	Monitoring and Controlling Resources	433

Source: Based on the O*Net database.

*Tasks in the O*Net database*

The dataset built for this study relies on a typology of tasks derived from the Occupational Information Network (O*Net) database. O*Net is a project on occupational information sponsored by the US Department of Labour. The latest version of the database[17] covers 855 occupations. The "O*Net content model" describes the key features of occupations with a variety of attributes and requirements classified in six categories: worker characteristics, worker requirements, experience requirements, occupational requirements, workforce characteristics and occupation-specific information. The category of interest to us is "occupational requirements". Our list of 41 tasks comes from the sub-category "generalized work activities". The list is shown in Table 1.

The 41 tasks described in Table 1 are more like generic tasks or categories of tasks. O*Net includes for each occupation a list of *specific* tasks that are different for each occupation and details the exact work to be performed under each occupation. The paradigm of trade in tasks assumes that tasks are horizontal and that the same task can be found under different occupations. If occupations were defined through tasks that are specific and could not belong to several occupations, there would be no analysis in terms of tasks.[18] "Tasks" would simply be a different way of defining occupations. Here we assume that the 41 tasks described in Table 1 are the basic building blocks of occupations. Each occupation is thus defined as a set of tasks and we can describe occupations as a matrix of tasks, telling us the proportion of each task in the occupation under consideration (see Box 3 for a formal definition).

To calculate the proportion of tasks in each occupation, we rely on two values provided with the generalised work activities in O*Net. First, there is an indication of the relative importance of each task (on a scale between 1 and 5). Second, there is a value for the level of the task (on a scale between 1 and 7). The distinction between the two is not totally clear to us, but the two measures are highly correlated.[19] Following earlier literature,[20] we calculate the task intensity as a Cobb-Douglas weighted average of the importance and the level values, where the weight of importance is 2/3 and the weight of level 1/3.

The task intensity of occupations is thus calculated on the basis of the O*Net database which is built through interviews at the workplace performed by job analysts. An open question is to what extent the task content of US occupations can be applied to occupations in other countries. Because of data availability, our dataset is limited to the European Union, Switzerland and the United States. We have no reason to believe that occupations feature different types of tasks in these countries (see Box 2 regarding the transportability of job information across countries). Similarly, we do not have variation over time as we rely on the 2010 O*Net database. As a consequence, our analysis will mainly reflect the evolution of occupations by industry rather than tasks by occupation. Despite this limitation, we obtain a large variation in the task intensities across industries.

17. We have worked with the O*Net Production database version 15.1.

18. In the category "occupation-specific information", the O*Net includes such a list of tasks that are occupation-specific.

19. The correlation coefficient is 0.91. Handel (2010) provides an assessment of the O*Net content model and notes that the two categories are largely redundant.

20. Blinder (2009), Jensen and Kletzer (2010) and Firpo *et al*. (2011).

Box 2. Trade in tasks and the transportability of job information across countries

Firms want to know how job demands differ across countries before taking decisions on outsourcing either at the job or task level. At present, the only comprehensive job database is the US Department of Labor's Occupational Information Network (O*NET), a detailed compilation of US job information across various employment sectors. A 2007 study entitled *The Transportability of Job Information Across Countries* (Taylor *et al.*, 2007) suggests that the use of O*NET for cross-border job analysis is generally sound. In other words, job descriptions may not vary all that much from country to country, despite cultural differences.

The study compared locally collected data from first-line supervisors, office clerks and computer programmers in China, Hong Kong, China and New Zealand (1,007 job incumbents, from 369 organizations) against data from the United States (O*NET). The four nations were divided into two groups: individualistic (New Zealand and the United States) and collectivistic (China and Hong Kong, China). The aims of the study were to test a set of hypotheses derived from cross-cultural theory and research, and to assess the degree of similarity (of job profiles) in the importance and level of work activities and job requirements between the United States and each of the other three countries.

The first set of hypotheses was that employees from an individualistic country would rate decision making activities, skills, and work styles associated with decision making significantly more important than those from a collectivistic country. The second set was that employees from a collectivistic country would rate inter-personal activities, skills, and work styles associated with inter-personal relations significantly more important than those from an individualistic country. The third set was that employees from an individualistic country would rate a significantly greater number of work-related activities and skills as important to their job than would employees from a collectivistic country.

In order to assess the degree in similarity of job profiles, the study used the mean country ratings associated with each job (based on the locally collected data) to compare job profiles of New Zealand, China and Hong Kong, China against those of the United States. The two aspects of job profiles explored were (a) the magnitude of mean item differences (profile level) and (b) the degree of similarity in the rank-order of work activities and job requirements (profile shape).

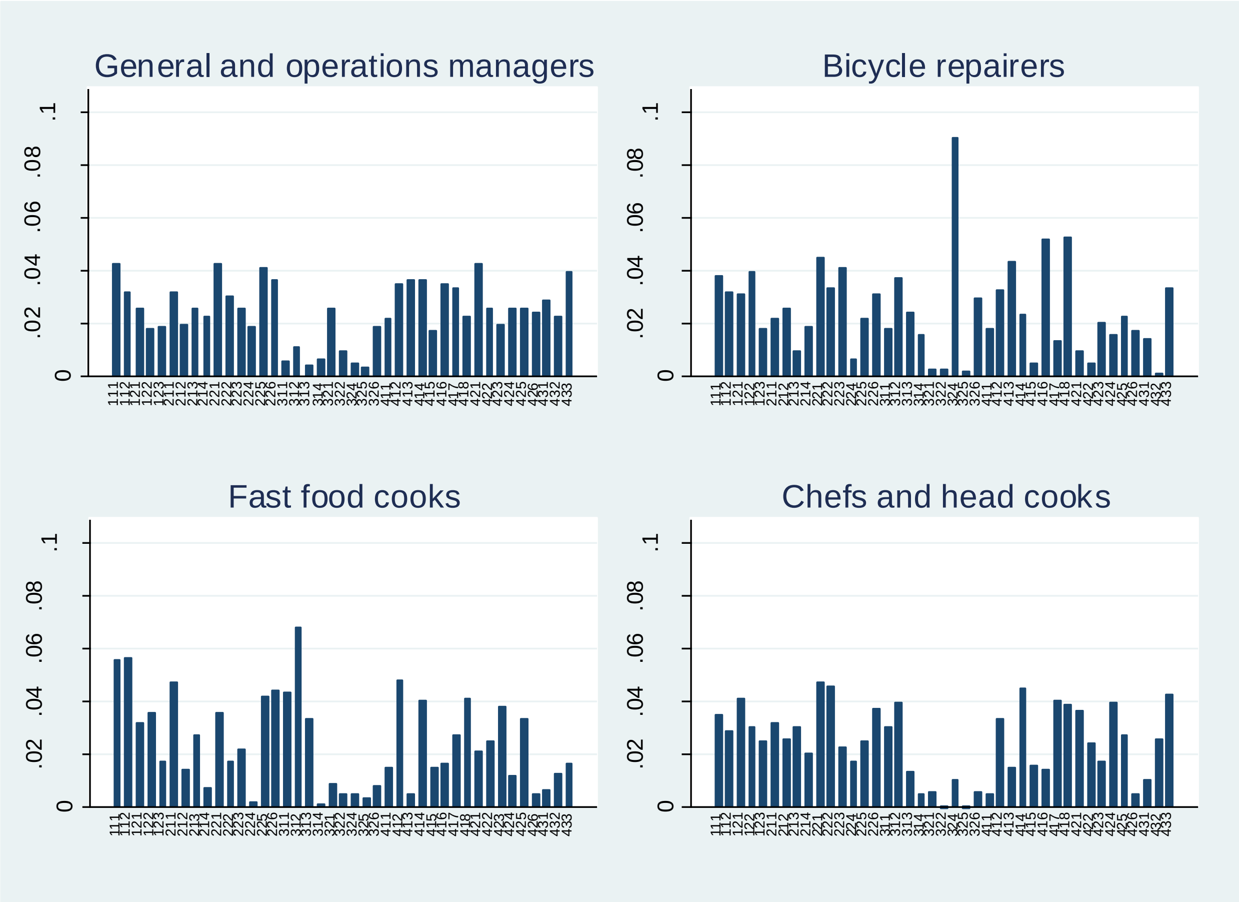
Results: The hypothesized differences, derived from cross-cultural theory, received minimal support. Regarding the similarity of job profiles, the study concluded that "differences in mean item ratings between job incumbents from the United States and the other three countries were generally small to moderate in size, and rank-orderings of the importance and level of work activities and job requirements were quite similar, suggesting that, for most applications, job information is likely to transport quite well across countries" (Taylor *et al*., 2007).

An overview of the task content of occupations

Before analysing the task intensity of industries, this section gives insights on the task content of occupations. Figure 1 illustrates the way we associate each of our 855 occupations with a given set of tasks (and a relative intensity for each task). Four occupations are represented: (i) general and operations managers; (ii) bicycle repairers; (iii) fast food cooks; and (iv) chefs and head cooks. The bars indicate the intensity of each of the 41 tasks of Table 1 in the given occupation. The tasks are identified with their ID on the horizontal axis but the purpose of the Figure is to show how bars are spread across the range of tasks (and not to read the results for specific tasks). Figure 1 highlights that with our methodology any occupation is a mix of almost all tasks. What matters is their distribution and their intensity. We thus depart from a simple association between one occupation and a limited number of tasks.

The four occupations of Figure 1 have been picked among the 855 in the dataset to show different types of tasks distributions. In the case of managers, one can see that the job of managers involves a variety of tasks: getting information, making decisions and solving problems, scheduling work and activities, organising, planning and prioritising work, coordinating the work and activities of others, monitoring and controlling resources. "General and operations managers" is only one type of managing activity in the US Standard Occupational Classification (SOC) system. There are also marketing managers, sales managers, financial managers, etc. A common characteristic is the large number of tasks with a relatively high intensity but the task content then varies across more specific types of managing activities. With 855 occupations, 41 tasks and two scales to measure the importance and level of each task, the dataset offers enough flexibility and detail to accurately characterize each type of job and the tasks involved.

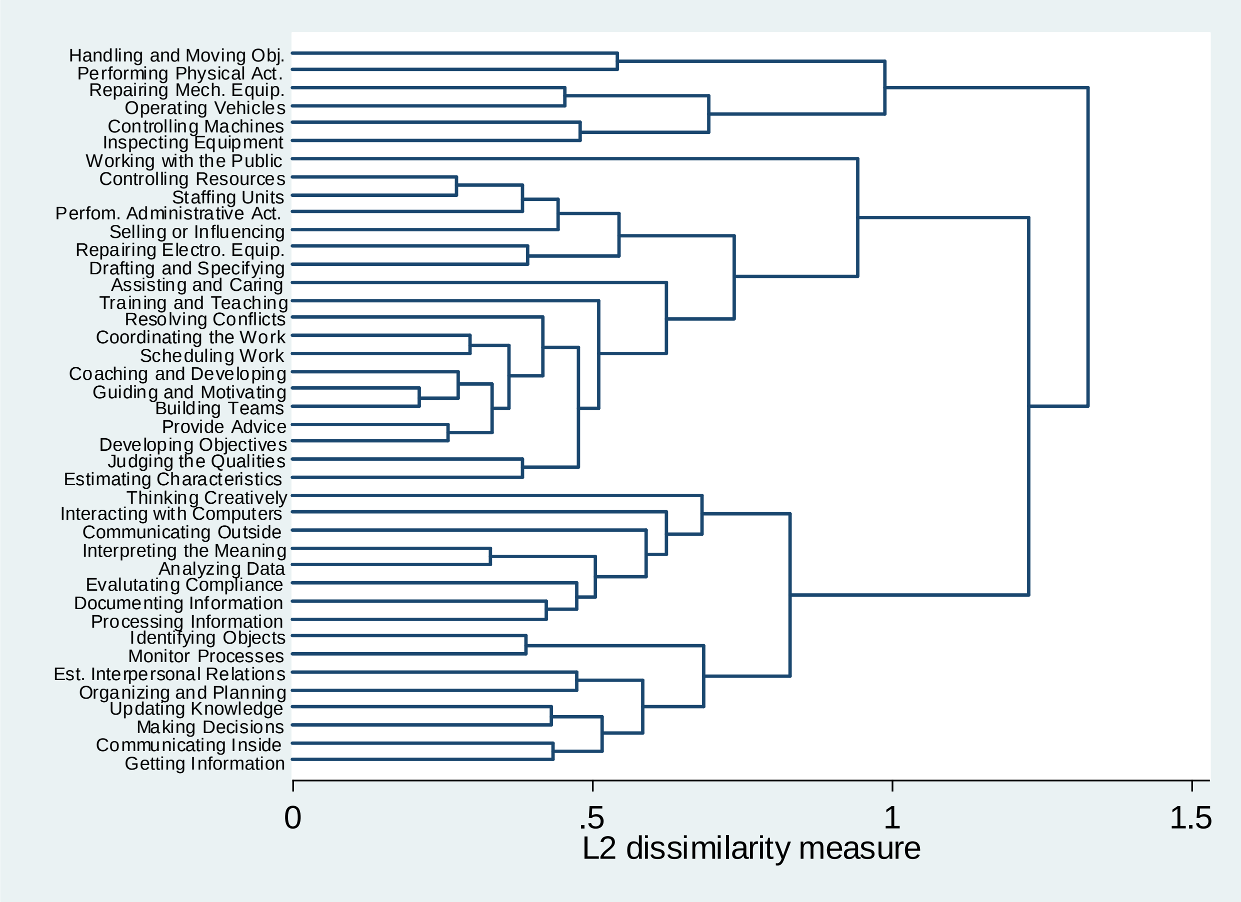
Figure 1. Distribution of tasks across four occupations



While managers are generalists in terms of tasks, the second occupation described in Figure 1 portrays the opposite case. Bicycle repairers feature a very high intensity in one type of task: repairing and maintaining mechanical equipment. This is not surprising as most of the job is precisely about mechanical repair. Nevertheless, what our approach shows is that one cannot reduce the job of bicycle repairers to this unique task. A bicycle repairer also has to make decisions and to solve problems (221), to sell and influence others (416) and to work with the public (418). The intensity calculated for some of these tasks is in some cases not very far from the ones estimated for the managers. This finding questions the relevance of typologies making a clear distinction for example between routine and non-routine tasks. By keeping all tasks in the dataset and allowing intensities to reflect the results of surveys at the workplace, we should obtain a more accurate task content and be able to capture complementarities between tasks.

The two last occupations represented in Figure 1 show that the same type of job can have contrasting task intensities. Both occupations correspond to cooks but on the left are fast food cooks and on the right are chefs and head cooks. These examples were picked to justify why we think it is useful to work at a very disaggregated level (855 occupations). Working with one category of cooks, we would miss the difference between fast food cooks and chefs. The latter deals with a wider number of tasks in their job and in particular have more than fast food cooks to make decisions, solve problems (221) and to think creatively (222). Fast food cooks have to handle and move objects (312) and to communicate with supervisors (412) more than chefs. But an important and interesting result is that fast food cooks are not limited to routine tasks, as making decisions and solving problems (221) also has a high intensity.

Figure 2. Dendrogram for the task content of occupations



Note: The dendrogram is obtained by applying hierarchical cluster analysis to the tasks by occupation dataset. Euclidian (L2) distance between clusters is calculated with the complete-linkage method.

By doing cluster analysis, we can highlight two important characteristics in the tasks by occupation dataset. Figure 2 is a "dendrogram", which is simply a tree showing how tasks are clustered together statistically. The tree shows the hierarchy in the clustering, the higher the value on the horizontal axis the more dissimilar are tasks (in the sense that the same tasks tend not to appear together in occupations). Starting from the right, the two first branches divide the list of tasks (represented on the vertical axis) into two groups.

The first group involves tasks related to “handling and moving objects” (312), “performing general physical activities” (311), “repairing and maintaining mechanical equipment” (324), “operating vehicles” (314) and “controlling machines and processes” (313). These tasks are rather manual and the cluster makes sense for all occupations involving manual work or mechanical work. All the other tasks are in a second cluster. Following the tree from the right to the left, one can see how these other tasks bundled together are further divided in sub-groups.

What the analysis reveals is first that the typology of tasks in the O*Net dataset is a good typology in the sense that the tree on Figure 2 is quite balanced. We don’t see one task opposed to all others, or clusters of too dissimilar size. It makes us confident that the typology of tasks does its job (if one may say so!). The second interesting finding coming out of Figure 2 is that some tasks we would not expect to be grouped together are indeed associated in the dataset. For example, when working with 10 clusters, “interacting with computers” (321) is in the same cluster as “communicating with persons outside the organization” (413).[21] “Interacting with computers” is also correlated with “processing information” (212) or “analyzing data” (214) as one would expect. But within the same cluster, we also find “interpreting the meaning of information for others” (411). This reveals that “working with computers” and “analysing data” -typically offshorable tasks in the literature- may be bundled with less offshorable activities involving work with others or with persons outside the organization.

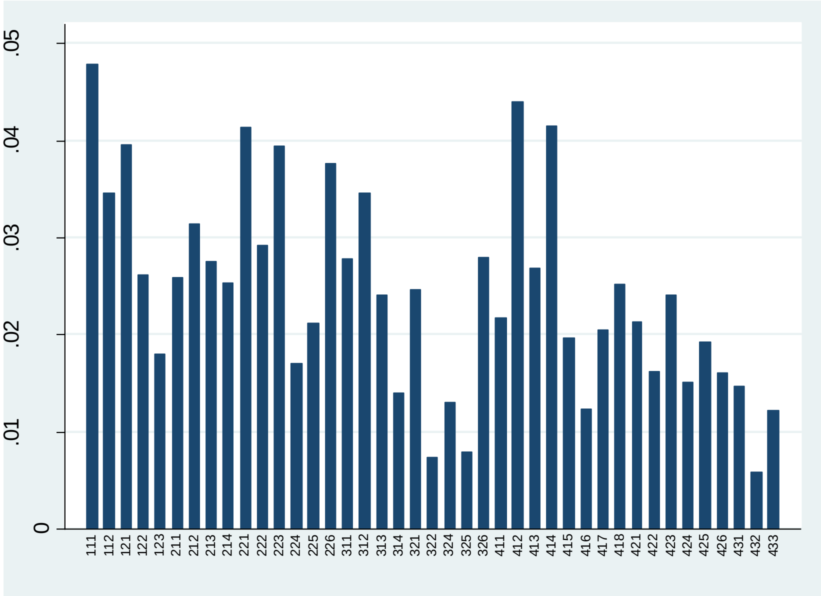
Another interesting example is “establishing and maintaining interpersonal relationships” (414). Jensen and Kletzer (2010) regard it as negatively related to offshoring because it involves face-to-face contacts. On Figure 2, it appears bundled with another group of tasks where we find “getting information” (111) which is positively related to offshorability according to Jensen and Kletzer (2010).[22] To put it in a nutshell, the clusters empirically found in the dataset do not seem to fully match the classifications used in the literature and suggest that tasks may come as a bundle. One should therefore be cautious before inferring any opportunity for offshoring.

Lastly, Figure 3 gives an indication of the average intensity of tasks in all occupations. The most common task is “getting information” (111), followed by “communicating with supervisors, peers, or subordinates” (412) and “making decisions and solving problems” (221). The least represented tasks are “staffing organizational units” (432), “drafting, laying out, and specifying technical devices, parts, and equipment” (322) and “repairing and maintaining electronic equipment” (325). This is just an average and comparing Figure 3 with Figure 1, one can see that each occupation has a very different profile in terms of the distribution of tasks, which is precisely what we are after in our analysis.

21. These 10 clusters appear when, starting from the right of the dendrogram, one stops the tree when it has 10 branches. The next section will present evidence for these 10 clusters and Table 2 provides their description.

22. Jensen and Kletzer (2010) in the same paper propose to infer offshorability on the basis of geographic concentration in the US economy. We refer here to their use of the O*Net database.

Figure 3. Average intensity of tasks in all occupations



4. Up to the task: a descriptive analysis of task intensities by industry

The previous section has described the task content of occupations. We do not stop at occupations but match the task intensities with data on occupations by industry. These data come from the Occupational Employment Statistics (OES) in the case of the United States and from the Labour Force Survey (LFS) in the case of the European Union.

While our tasks data are limited to US occupations, we introduce a country dimension in the dataset by matching the task content of occupations with country data on occupations by industry. One issue when comparing the United States and European Union economies are that their employment surveys rely on a different classification of occupations: the Standard Occupation Classification (SOC) system in the case of the United States and the International Standard Classification of Occupations (ISCO) in the case of the European Union. The structure of the two classifications is quite different; this is why we did not try to match the occupation data. We use a common industry classification (ISIC Rev. 3) for which we have a correspondence with NAICS industries (US) and NACE industries (EU) but the calculation of the task intensity of industries relies on SOC for the United States and ISCO for the European Union. We have the data for two years: 2000 and 2008. In addition to the country dimension, the tasks by industry dataset introduces a time dimension and allows us to analyse changes over years. 2008 has been picked because it was the year before the financial crisis, comparable with 2000 which was also the peak year before the economic downturn of 2001.

When comparing task intensities by industry between the European Union and the United States, we do not see large differences at the aggregate level. This can be illustrated with Figure 4. Most of the tasks are along a diagonal where the US intensity (vertical axis) is equal to the EU intensity (horizontal axis).[23] There are a few outliers. For

23. We have data for separate EU member countries but we use aggregated data for the European Union on the Figure to simplify the comparison.

example, “selling or influencing others” (416) and “performing for or work directly with the public” (418) are relatively more intensive in US industries. “Updating and using relevant knowledge” (223) and “organizing, planning and prioritizing work” (226) are relatively more intensive in EU industries. But overall there is a good correlation at the aggregate level, making us confident that the United States and European Union data can be compared.

For specific industries and countries, we have more variation across task intensities. This is where the analysis becomes interesting. Linking the task content of industries to output and exports (as is done in the next section) further differentiates the results. Before doing such analysis the rest of this section looks at specific industries to characterise their task content.

Figure 4. Average task intensity by industry - US/EU comparison

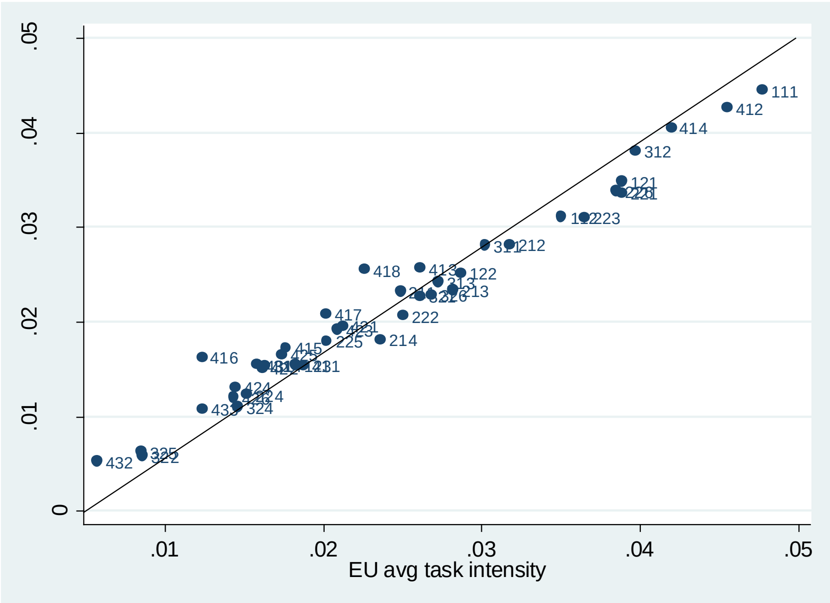


Table 2 below gives an overview of how industries are associated with a higher intensity for specific tasks. We have grouped the 41 tasks of Table 1 into 10 clusters (following the cluster analysis represented in Figure 2). For each cluster, the Table indicates the three industries that are the most intensive in this group of tasks. We have separated the United States and European Union data and kept them in their original industry classification (NACE for the European Union and NAICS for the United States). The US industries are more disaggregated. The purpose of the table is not to compare the two lists (as the average intensity by industry is similar in the United States and the European Union) but to have an illustration of industry intensities in tasks at two levels of disaggregation.

Table 2. Task intensities by industry: top-3 industries for each cluster of tasks (European Union and United States)

Cluster	Tasks involved	Top 3 EU industries (NACE 2-digit)	Top 3 US industries (NAICS 4-digit)
1 - Physical tasks	Performing General Physical Activities Handling and Moving Objects	Tanning and dressing of leather Activities of households as employers of domestic staff Manufacture of wood and of products of wood (except furniture)	Seafood Product Preparation and Packaging Animal Slaughtering and Processing Postal Service
2 - Tasks related to mechanical equipment	Operating Vehicles, Mechanized Devices, or Equipment Repairing and Maintaining Mechanical Equipment	Mining of coal and lignite; extraction of peat Other mining and quarrying Land transport; transport via pipelines	School and Employee Bus Transportation Waste Collection Coal Mining
3 - Tasks related to machines	Inspecting Equipment, Structures, or Material Controlling Machines and Processes	Manufacture of wood and of products of wood (except furniture) Mining of coal and lignite; extraction of peat Tanning and dressing of leather	Footwear Manufacturing Apparel Knitting Mills Machine Shops; Turned Product; Screw and Bolt Manufacturing
4 - Working with the public	Performing for or Working Directly with the Public	Retail trade Other service activities Hotels and restaurants	Gasoline Stations Beer, Wine, and Liquor Stores Personal Care Services
5 - Selling and controlling	Drafting and Specifying Technical Devices, Parts, and Equipment Repairing and Maintaining Electronic Equipment Selling or Influencing Others Performing Administrative Activities Staffing Organizational Units Monitoring and Controlling Resources	Retail trade Activities auxiliary to financial intermediation Sale, maintenance and repair of motor vehicles	Jewelry, Luggage, and Leather Goods Stores Shoe Stores Clothing Stores
6 - Working with others	Estimating the Quantifiable Characteristics of Products Judging the Qualities of Things, Services, or People Developing Objectives and Strategies Scheduling Work and Activities Assisting and Caring for Others Resolving Conflicts and Negotiating with Others Coordinating the Work and Activities of Others Developing and Building Teams Training and Teaching Others Guiding, Directing, and Motivating Subordinates Coaching and Developing Others Provide Consultation and Advice to Others	Education Health and social work Other service activities	Child Day Care Services Limited-Service Eating Places Other Residential Care Facilities
7 - Thinking creatively	Thinking Creatively	Education Computer and related activities Recreational, cultural and sporting activities	Personal Care Services Independent Artists, Writers, and Performers Performing Arts Companies
8 - Information processing tasks	Processing Information Evaluating Information to Determine Compliance with Standards Analyzing Data or Information Interacting With Computers Documenting/Recording Information Interpreting the Meaning of Information for Others Communicating with Persons Outside Organization	Insurance and pension funding Computer and related activities Activities auxiliary to financial intermediation	Legal Services Accounting, Tax Preparation, Bookkeeping, and Payroll Services Depository Credit Intermediation
9 - Identifying and monitoring	Monitor Processes, Materials, or Surroundings Identifying Objects, Actions, and Events	Activities of households as employers of domestic staff Land transport; transport via pipelines Manufacture of food products and beverages	School and Employee Bus Transportation Other Pipeline Transportation Inland Water Transportation
10 - Getting information and communicating	Getting Information Making Decisions and Solving Problems Updating and Using Relevant Knowledge Organizing, Planning, and Prioritizing Work Communicating with Supervisors, Peers, or Subordinates Establishing and Maintaining Interpersonal Relationships	Activities auxiliary to financial intermediation Insurance and pension funding Financial intermediation	Legal Services Agents and Managers for Artists and Other Public Figures Accounting, Tax Preparation, Bookkeeping, and Payroll Services

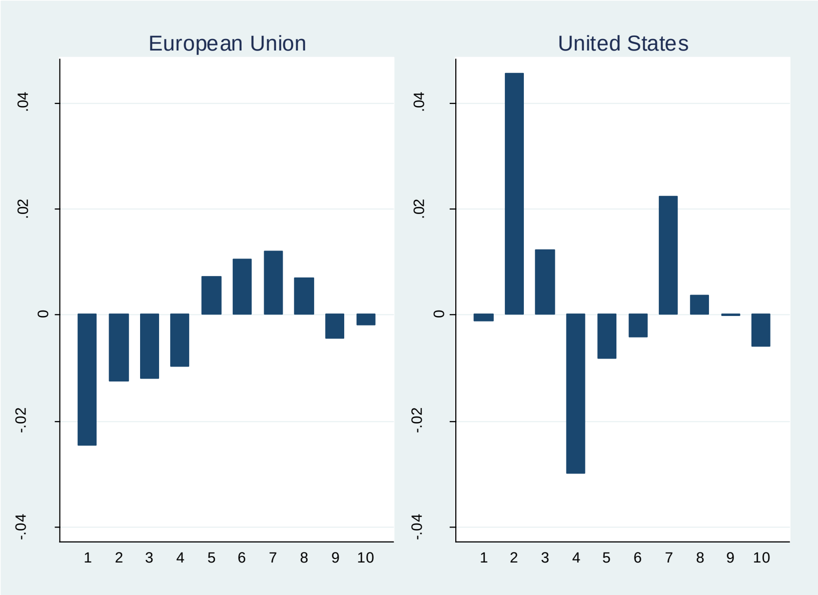
Industries that are intensive in physical tasks (cluster 1) are not surprisingly manufacturing activities, such as leather tanning and dressing or manufacture of wood products. But there are also services that can rely on physical tasks, such as postal services or the work done by domestic staff employed by households. Cluster 2 deals with the use of vehicles and mechanical equipment and we find land transportation or school bus transportation as industries intensive in such tasks. Mining activities also appear in this category. Cluster 3 encompasses tasks related to machines that are intensive in specific manufacturing industries. Tasks involving work with the public (cluster 4) are, on the contrary, in services industries, such as retail trade, personal care services or hotels and restaurants. In cluster 5 associated with selling, we find retail trade at the 2-digit level and more specific types of stores at the 4-digit level.

Cluster 6 is a broad category of tasks that have in common working with others. This is, therefore, the category of education, health and other service activities. Thinking creatively is a cluster by itself where education, recreational and cultural services are found. At a more disaggregated level, the industry of artists and performers make an intensive use of such tasks. Cluster 8 will be analysed in more detail in the next section of the paper as it includes information processing tasks (that are often regarded as highly offshorable). Industries intensive in such tasks are insurance, financial intermediation and computer and related activities. Identifying and monitoring (cluster 9) is interesting because it appears more cross-cutting in terms of the industries involved. Most of them are related to transportation but the manufacturing of food products and beverages is also an industry where monitoring processes are important. Lastly, cluster 10 (that will also be analysed in the next section) concerns tasks aimed at getting information and communicating with others. Insurance and financial intermediation are the industries intensive in such tasks, as well as professional services (legal services and accounting) when looking at a more disaggregated level.

An interesting question is how the task intensities of industries have changed over time. In our dataset, we can compare two years: 2000 and 2008. Figure 5 shows the average change in the European Union and the United States for the 10 clusters of Table 2. In the case of the European Union, there is a decrease in the intensity of tasks related to physical activities, use and maintenance of mechanical equipment, use and control of machines. We do not see the same decline for US industries. Tasks related to mechanical equipment is even the category with the highest increase (+4%).

Cluster 4 (working with others) sees a relative decline both in the European Union and the United States. This is interesting to note as one would expect this type of tasks to be on the rise. Because of the face-to-face contact implied by such tasks, they are regarded as less offshorable and are, nonetheless, decreasing. Clusters 5 and 6 (selling & controlling and working with others) have a relatively higher intensity in the European Union and decrease in the United States, but the change is modest (less than 1%). “Thinking creatively” is the second cluster with the highest positive change in the United States (+2%) and although smaller there is also an increase in Europe. There is little variation in the intensity of clusters 8, 9 and 10, both in the United States and the European Union. Clusters 8 and 10 are the ones that would be regarded as the most offshorable and there is no dramatic change to report. Overall, the task content of industries has not been significantly altered between 2000 and 2008. The highest change reported on Figure 5 is a little above 4% (for cluster 2 in the United States).

Figure 5. Average change in the task intensity of industries (2000/2008): European Union and the United States



But Figure 5 is an average over industries and does not tell us anything about the link between the observed change and international trade. The relationship between changes in the task content of production and trade openness is investigated in the next Section.

5. How are changes in task content of production related to international trade?

As noted, trade in tasks can only be measured indirectly. Trade is, however, most important for its impact on employment, income and structural changes. This section analyses first, the extent to which the task content of a country's production differs from the task content of its net exports. At the moment it is only possible to do so for a limited number of countries because of paucity of data, particularly on employment by occupation. Next, the extent to which the task content of local production varies systematically with import penetration is explored.

The task content of a sector is calculated by combining the index of the importance of a particular activity by occupation as provided by the O*Net database and the employment share of that occupation in the sector as explained in Box 3. Since we only have comparable tasks indices for one year, variation over time is due to changes in the structure of employment by occupation within and across industries.

Box 3. Estimating the task content of output and exports

The O*Net database provides information on the relative importance of each task or work activity by occupation. These are transformed into indices based on the score and importance of tasks using the formula: $TC_{hj} = \sum_{k=1}^{A_h} I_{jk}^{2/3} L_{jk}^{1/3}$

A_h is the number of work activities or tasks under category h, I_{jk} and L_{jk} represent the importance and level of task *k* in occupation *j*; weighted by two thirds and a third respectively.

An estimate of the intensity of a task or activity for each sector, *s* at time *t* is made as follows:

$$TI_{ths} = \begin{bmatrix} TC_{11} & TC_{1j} \\ & \\ TC_{h1} & TC_{hj} \end{bmatrix} \text{x} \begin{bmatrix} \lambda_{t11} & \lambda_{t1s} \\ & \\ \lambda_{tj1} & \lambda_{tjs} \end{bmatrix}$$

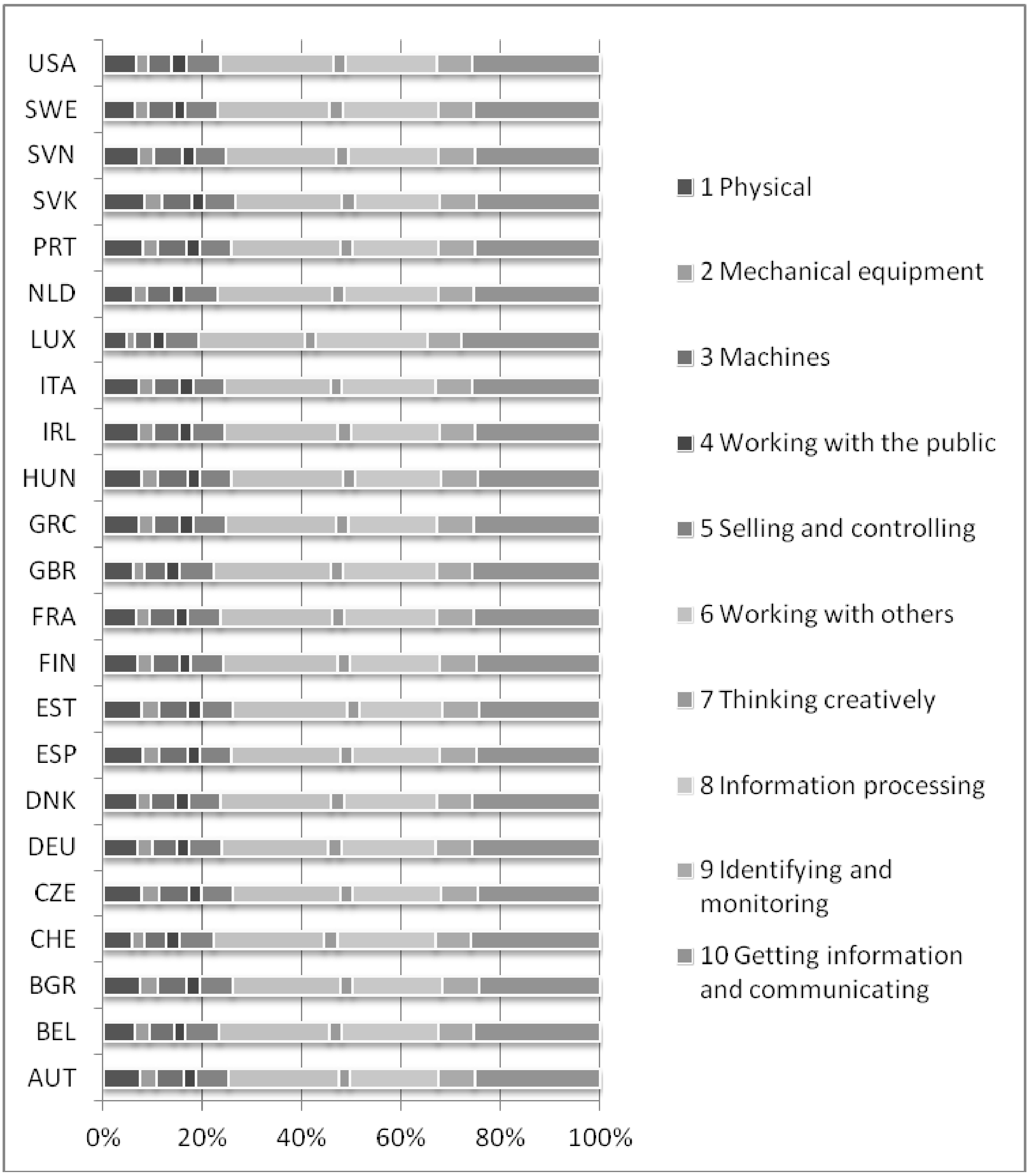
The first matrix is an *h* x *j* matrix where the intensity of task *h* in occupation *j* is depicted. The second matrix is a *j* x *s* matrix containing the share of occupation *j* in total employment in sector *s*. Multiplying the two matrices yields an employment-weighted average index of the intensity of task *h* in sector *s*. The estimated task intensity of each sector will vary over time, but the variation is entirely driven by changes in the composition of employment by occupation within sectors. TI_{ths} is a *h* x *s* matrix where $\sum_h TI_{ths} = 1$. It can be multiplied by a column vector representing output by sector, which yields the contribution of each task to the entire economy ($\mathrm{T}_{\mathrm{th}}^{\mathrm{y}}$). In order to estimate the task content of total exports ($\mathrm{T}_{\mathrm{th}}^{\mathrm{e}}$), the task intensity matrix is multiplied by the vector of exports by sector.

$$\mathrm{T}_{\mathrm{th}}^{\mathrm{y}} = \begin{bmatrix} \mathrm{TI}_{\mathrm{t11}} & \mathrm{TI}_{\mathrm{t1s}} \\ & \\ \mathrm{TI}_{\mathrm{th1}} & \mathrm{TI}_{\mathrm{ths}} \end{bmatrix} \text{x} \begin{bmatrix} \mathrm{Y}_{\mathrm{t1}} \\ \\ \mathrm{Y}_{\mathrm{ts}} \end{bmatrix} \text{ and } \mathrm{T}_{\mathrm{th}}^{\mathrm{e}} = \begin{bmatrix} \mathrm{TI}_{\mathrm{t11}} & \mathrm{TI}_{\mathrm{t1s}} \\ & \\ \mathrm{TI}_{\mathrm{th1}} & \mathrm{TI}_{\mathrm{ths}} \end{bmatrix} \text{x} \begin{bmatrix} \mathrm{X}_{\mathrm{t1}} \\ \\ \mathrm{X}_{\mathrm{ts}} \end{bmatrix}$$

This yields an *h* x 1 matrix presenting the intensity of each task in total output and exports respectively. The task content of imports can be estimated for country *i*: $T_{th,i}^{m} = \sum_j \alpha_{tij} T_{th,j}^{e}$ where α_{tij} is the share of country country j's total exports at time t destined for country *i*.

Figure 6 shows the contribution to total output by cluster of tasks and country in 2000. The clusters that account for the largest contribution in all countries are the "getting information and communicating"(cluster 10), "information processing tasks"(cluster 8) and "working with others"(cluster 6). It is recalled that cluster 10 contains "getting information", which other studies have considered one of the most tradable tasks, but also "establishing and maintaining interpersonal relationships" and "making decisions and solving problems", two tasks that are considered among the least tradable by other studies. Cluster 8 contains a number of information processing and handling tasks considered to be highly tradable by other studies, while cluster 6 contains many of the least tradable tasks.

Figure 6. Task content of output (2000)



Given the relative importance of clusters 10, 8, and 6, it is useful to focus on these three in the following. Table 3 reports the respective task contents of output and of exports of countries for the years 2000 and 2008. As noted in the previous section, there are only small changes in task content of output from 2000 to 2008. It is also notable that the task content of exports is quite similar to the task content of production. For instance the share of "information processing tasks" varies from 17.6% of the total in Estonia and the Slovak Republic to 23% in Luxembourg in 2008. The content of this task embodied in exports is slightly lower than that embodied in output in all countries included except

Switzerland where it is slightly higher and the Netherlands and Luxembourg where it is the same. The largest difference between the task content of output and exports for this task is found in the United States (18.6% versus 17%).

Table 3. Relative shares of three selected task clusters in output and exports (%)

	6. Working with others				*8. Information processing*				*10. Getting information and communicating*			
	2000		2008		2000		2008		2000		2008	
Country	output	exports	output	exports	output	exports	output	exports	output	exports	output	exports
Austria	22.1	21.3	22.0	21.5	17.6	16.8	18.5	17.5	25.3	24.6	25.6	24.8
Belgium	22.1	21.7	22.4	21.8	19.4	18.7	19.6	19.3	25.5	23.9	26.0	25.2
Bulgaria	21.8	24.9	n/a	n/a	17.9	12.6	n/a	n/a	24.4	24.6	n/a	n/a
Switzerland	22.3	21.6	21.9	21.0	19.7	20.1	19.9	20.2	26.0	25.8	26.2	25.8
Czech Republic	21.8	21.3	21.8	21.0	17.7	16.6	18.4	17.5	24.5	23.8	24.8	24.0
Germany	21.6	21.0	21.7	21.2	19.1	18.2	19.3	18.6	25.8	24.6	25.8	24.7
Denmark	22.3	21.6	22.5	21.7	18.6	17.6	19.0	18.5	25.6	24.6	25.7	25.0
Spain	22.0	21.5	n/a	n/a	17.4	16.1	n/a	n/a	25.0	24.4	n/a	n/a
Estonia	23.0	22.5	23.1	22.8	16.8	15.6	17.6	16.4	24.3	23.7	24.6	23.6
Finland	22.8	22.0	23.1	22.4	18.1	17.9	18.3	18.5	24.9	24.2	24.9	24.3
France	22.5	21.5	22.7	21.8	18.6	18.1	18.9	18.7	25.4	24.5	25.4	24.5
United Kingdom	23.6	22.8	n/a	n/a	18.9	18.8	n/a	n/a	25.8	25.2	n/a	n/a
Greece	22.2	22.3	22.4	21.9	17.9	16.2	18.0	17.0	25.5	24.9	25.5	25.1
Hungary	22.3	21.5	22.5	21.6	17.3	15.7	17.8	16.6	24.6	23.7	24.8	23.8
Ireland	22.7	21.8	n/a	n/a	17.9	18.6	n/a	n/a	25.1	24.8	n/a	n/a
Italy	21.2	20.8	21.6	20.9	18.7	17.2	18.6	17.6	25.7	24.6	25.5	24.4
Luxembourg	21.3	21.2	21.7	21.5	22.4	22.5	23.0	23.0	28.0	27.9	28.0	27.9
Netherlands	23.1	22.5	23.3	22.6	18.9	18.2	19.2	19.2	25.4	24.4	25.4	24.7
Portugal	22.0	21.7	n/a	n/a	17.4	15.5	n/a	n/a	25.1	24.1	n/a	n/a
Slovak Republic	21.5	21.1	21.7	20.9	17.1	16.5	17.6	16.5	24.9	23.6	24.6	23.6
Slovenia	22.2	21.5	22.2	21.5	18.1	16.6	18.3	17.1	25.1	24.0	25.2	24.1
Sweden	22.5	21.3	n/a	n/a	19.1	18.5	n/a	n/a	25.5	24.6	n/a	n/a
USA	22.8	22.5	22.7	22.2	18.3	16.7	18.6	17.0	25.9	24.5	25.7	24.4
Sample average	22.2	21.8	22.3	21.7	18.4	17.4	18.9	18.2	25.4	24.6	25.5	24.7

Note: The task contents of output and exports are calculated as explained in Box 3.

A higher task content of exports than output suggests comparative advantage in sectors using the task intensively. The sectors that use information processing tasks the most intensively are insurance and pension funding, computer and related services and services auxiliary to financial intermediation (see Table 2 above). These are among the sectors in which Luxembourg and Switzerland feature the most prominently, and the finding is reassuring as far as methodology is concerned.

Can anything be said about the relationship between the relative intensity of these three tasks clusters and exposure to international trade? To explore this question, the shares were regressed on import penetration of goods and services respectively, controlling for market size (represented by the natural logarithm of country output) and economic development (represented by the natural logarithm of country output per worker). Table 4 shows the regressions results for the three clusters "working with others", "information processing", "getting information and communicating". As the sample size is small, results should be interpreted with a large amount of caution. Annex

A outlines in more detail the methodology and data used in the econometric analysis and also shows results for other clusters.

Table 4. Regression analysis: relationship between the output share of task clusters at the country level and import penetration

	6. Working with others	8. Information processing tasks	10. Getting information and communicating
Import penetration: goods	0.013	0.003	-0.011
	(0.017)	(0.018)	(0.011)
Import penetration: services	-0.034	0.119***	0.083***
	(0.024)	(0.024)	(0.015)
Output	0	0.001	0.001*
	(0.001)	(0.001)	(0.001)
Output per worker	0.003	0.009***	0.004**
	(0.003)	(0.003)	(0.002)
Year dummy: 2008	-0.002	-0.004	-0.003*
	(0.003)	(0.003)	(0.002)
Constant	0.196***	0.045	0.178***
	(0.028)	(0.028)	(0.018)
R-squared	0.075	0.793	0.789
Number of observations	38	38	38

Notes: The dependent variables in the system of 9 equations are the shares of each task cluster in country output. The variables output and output per worker are measured in logs. ***, ** and * indicate significance at the 1%, 5% and 10% level respectively.

Table 4 shows that none of the three clusters is significantly correlated with import penetration of goods. On the other hand, the shares of the clusters "information processing" and "getting information and communicating" are both significantly and positively correlated to import penetration of services. These two clusters are key for financial services and computer services and results indicate that tasks related to getting and processing information are complementary to services imports. Interestingly, variation in the share of cluster six "working with others" across countries appears not to be affected by any of the variables included in the analysis and the explanatory power of the regression is quite low. The variation across countries is also quite small in our sample, suggesting that "working with others", which is most important in sectors such as health and education is unaffected by trade. The shift in the task composition towards cluster ten is not surprising, since other studies have also found that import competition has this effect in some of the countries included in our sample. Also the shift towards cluster eight is in line with a recent study from the United States (Crinò, 2010), but it is nevertheless surprising that import competition from services *increases* the share of information processing tasks in the economy.

Table A.1 in Annex A furthermore shows that six out of nine output shares of task clusters are significantly correlated with services import penetration (four negative, two positive) while only two task clusters are significantly correlated with goods import penetration (one positive, one negative). Hence, results suggest that exposure to services trade can better explain the allocation of tasks within a country than exposure to goods trade can.

Regression analyses carried out at the industry level indicate that import penetration tends to have only a limited and small impact on the allocation of tasks within an industry (Table A.2 in Annex A). A noteworthy finding is that increases in imports of goods in the capital-intensive industries "chemicals and chemical products", "other non-metallic mineral products" and "basic metal products", go along with a shift from activities directly related to production ("tasks related to mechanical equipment" and "tasks related to machines") to more information-based activities ("information processing" and "getting information and communicating") within the respective sectors. Finally, import penetration is in most cases not significantly related to the composition of tasks in services industries.

6. Trade in tasks and structural changes: concluding remarks

This study has emphasized the importance of taking into account both the forces that contribute to unbundling and codification of tasks and the forces that keep tasks together when analysing the potential for trade in tasks. The trade-off between these forces is best understood at the firm level. A useful analytical framework is therefore one that embeds the transaction cost theory of the firm into trade policy analysis.

The productivity gains from fragmenting production into simple tasks were understood already centuries ago, famously described in Adam Smith's pin factory and developed to perfection in the scientific management or Taylorism theory which was implemented for instance in Ford's car manufacturing plants, allowing mass production of affordable cars. However, when moving away from mass production of standard products to more sophisticated and differentiated products, Taylorism gave way to Toyotism, which was characterised by multi-tasked, multi-skilled workers working in teams. This way of organising production was considered better suited for an environment in which innovation and problem solving at source are important. Essentially, this study asks whether and to what extent the pendulum is swinging back towards Taylorism with the opening up to the possibility of trade in tasks.

Our cluster analysis suggests that there are still important economies of scope and synergies in keeping tasks together – and transaction and coordination costs in unbundling them. Production and trade data are not available at the tasks level, and the econometric analysis had to be conducted at the sector level, exploring to what extent the predicted consequences of trade in tasks can be observed. Econometric results suggest that the tasks embodied in services imports are complementary to tasks related to information gathering and processing performed in the home economy. Thus, trade in services is associated with shifts in the task content of domestic production towards information intensive tasks at the expense of manual tasks, although the magnitude of the effect is relatively small.

A possible explanation of the apparent complementarity between imported services and information-intensive tasks in OECD countries is that bundles of tasks or entire functions rather than individual tasks are outsourced and offshored. Functions that are typically outsourced are computer software development and maintenance, human resources, accounting, office cleaning and many more. But as more and more firms outsource these, a market is created for specialised suppliers of these services. What are non-core functions for some companies becomes the core of other companies and the latter may innovate and transform it into a new industry. Computer services are one example, but even office cleaning has followed this path. In the past most firms employed their own cleaning personnel who cleaned offices with water, soap, a mop and a vacuum cleaner. Specialised office cleaning firms, in contrast, enter the offices with an arsenal of specialised tools, machines and chemicals, providing cleaning and environmental services – and employment opportunities for a broad range of occupations, including engineers and managers. Deepening division of labour is perhaps at least as much about the splitting off of functions that develops in due course into industries of their own, as trade in individual tasks.

An important finding in the literature on trade in tasks is that the offshoring of tasks produced with a particular factor is equivalent to technological progress that augments the productivity of that factor (Grossman and Rossi-Hansberg, 2008). This result may seem counter-intuitive but, in practice, lowering offshoring costs for low-skill tasks may lead to an increase in the productivity of low-skilled workers and hence an improvement in their wages. Governments should, therefore, refrain from adopting policies that discourage offshoring or tend to increase offshoring costs. Such policies have been discussed in the context of the responses to the financial crisis, where tax breaks or public support would be denied to companies moving jobs overseas. The impact of such policies could be to lower the productivity of workers in these industries with further pressure on their wages. Under the pressure of declining demand, firms are already trying to reduce costs and to lower salaries. If firms are deprived of the reduction of costs through offshoring and better efficiency, salaries of low-skilled workers become the only variable of adjustment.

To conclude, trade in tasks is likely to have a similar impact as trade in other intermediate inputs – it improves productivity and induces shifts within firms and sectors in a similar way as technical change does. The magnitude of such shifts has been difficult to assess, but the fear of massive job losses due to a surge in offshoring of individual tasks is probably overblown. More detailed analysis is necessary before any firm conclusions and policy implications can be drawn. Nevertheless a tentative policy implication is that distortions to trade appear to have a larger impact on productivity when affecting intermediate inputs than when imposed on trade in final goods. Furthermore, the negative impact on productivity could be larger the more diversified the economy. The first best policy environment is free trade, but if trade taxes are imposed, they should be designed in such a way that they are levied on traded *value added*, not the total import value.

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Annex A

Regression analysis

To assess the relationship between task intensity and exposure to international trade, a system of nine equations is estimated that explains the allocation of country output and industry employment in terms of task clusters. Since task clusters are measured as intensities, i.e. shares at either the country or industry level, a reduction in the intensity of one task cluster will be reflected in a respective increase in the intensity(-ies) of another task cluster. To account for this interdependence, task clusters are estimated simultaneously instead of using cluster by cluster OLS regressions. To make identification of the system of equations possible, one task cluster is omitted in the system so that equations for nine task clusters are estimated simultaneously at either the country level or the industry level:

System of equations at the country level:

$$T^{y}_{cth} = \alpha + \beta_1 IPG_{ct} + \beta_2 IPS_{ct} + \beta_3 \text{output}_{ct} + \beta_4 \text{output p.w.}_{ct} + D08_t + e_{cth}$$

System of equations at the industry level:

$$TI_{cths} = \alpha + \beta_1 IPG_{cts} + \beta_2 IPS_{cts} + \beta_3 \text{output}_{cts} + \beta_4 \text{output p.w.}_{cts} + \beta_4 \text{labourcost p.w.}_{cts} + D08_t + e_{cts}$$

The dependent variables T_{cth} and TI_{cths} are described in detail in Box 3 in Section 5. T_{cth} indicates the intensity of task cluster *h* in total output of country *c* in year *t*. TI_{cths} indicates the employment-weighted intensity of task cluster *h* in sector *s* in year *t*. IPG_{ct} and IPS_{ct} indicate import penetration of goods and services respectively and are defined as the share of goods or services imports in expenditure of country c. While goods trade data are from the OECD ITCS database and services trade data from the OECD TISP database, expenditure is calculated using output data from the OECD STAN database and trade data, e.g. IPG_{ct}=(goods imports)/(output-exports+imports). Import penetration measures at the industry level are calculated analogously, but while services trade data still come from the OECD ITCS database, goods trade data are directly sourced from OECD STAN. Data for output ($Output_{\mathrm{ct(s)}}$), output per worker ($output\ p.w._{ct(s)}$) at the sector and country level and labour cost per worker ($labourcostp.w._{cts}$) at the sector level are from OECD STAN and are measured in natural logarithms. $D08_t$ is a dummy variable for the year 2008 and captures year specific shifts in the intensity of task clusters. The residual e_{cth} captures random shocks to task intensities.

Table A.1 shows the regression results of the system of equations explaining the intensities of task clusters in country output. Since regressions are based on 22 countries and two years, i.e. 2000 and 2008, coefficients are estimated on few observations and results should be interpreted cautiously. The coefficients indicate how the explanatory variables are related to the allocation of tasks in a country, or, in other words, how these variables shift task intensities within a country. Results suggest that import penetration of services is more important for the allocation of tasks within a country than import penetration of goods. While import penetration of goods is significantly correlated with only two task clusters, i.e. negatively with "working with the public" and positively with "selling and controlling", import penetration of services significantly shifts the intensity of six out of nine task clusters. In particular, services import penetration is complementary to the two information tasks "information processing" and "getting information and communicating", while it is negatively correlated to the task intensities of "thinking creatively", "identifying and monitoring" and the two more hands-on clusters "tasks related to mechanical equipment" and "tasks related to machines".

Table A.1. Simultaneous equation regressions explaining the output share of task clusters at the country level

	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6	Cluster 7	Cluster 8	Cluster 9	Cluster 10
	Tasks related to mechanical equipment	Tasks related to machines	Working with the public	Selling and controlling	Working with others	Thinking creatively	Information processing	Identifying and monitoring	Getting information and communicating
Import penetration: goods	0.002	0.004	-0.013**	0.012***	0.013	0.001	0.003	-0.003	-0.011
	(0.006)	(0.011)	(0.005)	(0.005)	(0.017)	(0.003)	(0.018)	(0.003)	(0.011)
Import penetration: services	-0.037***	-0.059***	0.008	0.006	-0.034	-0.010***	0.119***	-0.019***	0.083***
	(0.009)	(0.015)	(0.007)	(0.006)	(0.024)	(0.004)	(0.024)	(0.005)	(0.015)
Output	-0.001**	-0.001	0	0.001**	0	-0.000***	0.001	-0.000*	0.001*
	(0.000)	(0.001)	(0.000)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)	(0.001)
Output per worker	-0.004***	-0.005***	-0.001	0.002***	0.003	0.001***	0.009***	-0.001*	0.004**
	(0.001)	(0.002)	(0.001)	(0.001)	(0.003)	(0.000)	(0.003)	(0.001)	(0.002)
Year dummy: 2008	0.003***	0.003*	0.001	-0.002***	-0.002	-0.001	-0.004	0.001*	-0.003*
	(0.001)	(0.002)	(0.001)	(0.001)	(0.003)	(0.000)	(0.003)	(0.001)	(0.002)
Constant	0.091***	0.134***	0.036***	0.022***	0.196***	0.021***	0.045	0.096***	0.178***
	(0.010)	(0.017)	(0.009)	(0.007)	(0.028)	(0.004)	(0.028)	(0.006)	(0.018)
R-squared	0.801	0.747	0.228	0.556	0.075	0.249	0.793	0.679	0.789
Number of observations	38	38	38	38	38	38	38	38	38

Notes: The dependent variables in the system of 9 equations are the shares of each task cluster in country output. The variables output and output per worker are measured in logs. ***, ** and * indicate significance at the 1%, 5% and 10% level respectively.

Table A.2 shows some regression results for the task intensity at the industry level. In particular, only the coefficients for import penetration are reported, as the relationship between task intensity and exposure to trade is of main interest. For each industry a system of nine equations has been estimated where the equations vary only in terms of the dependent variable, i.e. the intensity of the respective task cluster. Results should be analysed by industry to see how import penetration shifts task-intensities within that industry. Since regressions are estimated using few observations, i.e. 22 to 37 depending on the industry, results should however be interpreted with caution.

Generally, import penetration seems to have only a limited and small impact on the allocation of tasks within an industry. In many cases the relation between import penetration and task intensity is not significant and the sizes of the coefficients are typically smaller than 0.01 indicating that a one percentage point change in import penetration shifts task intensity by less than 0.01 percentage points. Nevertheless, one noteworthy result is that in the capital-intensive industries "chemicals and chemical products", "other non-metallic mineral products" and "basic metal products", import penetration is significantly and positively correlated with the task clusters "information processing" and "getting information and communicating", while it is negatively correlated with "tasks related to mechanical equipment" and "tasks related to machines". This suggests that an increase in goods imports in these sectors go along with a shift from activities directly related to production to more information-based activities within the respective sectors.

Table A.2. Regression analysis: relationship between the intensity of task clusters and import penetration at the industry level

Industry (ISIC Rev. 3)	Number of obser-vations	Cluster 2 Tasks related to mechanical equipment	Cluster 3 Tasks related to machines	Cluster 4 Working with the public	Cluster 5 Selling and controlling	Cluster 6 Working with others	Cluster 7 Thinking creatively	Cluster 8 Information processing	Cluster 9 Identifying and monitoring	Cluster 10 Getting information and comm-unicating
1014 Mining and quarrying	35	-0.020***	-0.021***	0	0.005	0.024***	0.002*	0.018*	-0.007***	0.015**
1500 Food products and beverages	26	-0.002	-0.011	0.008	0.017***	0.004	0.005***	0.016	-0.007*	0.001
1600 Tobacco products	22	-0.012	-0.004	-0.001	-0.003	-0.007	0	0.014	0.001	0.008
1700 Textiles	30	-0.004	-0.016***	0.002	0.005*	0.002	0.005**	0.003	-0.003***	0.007**
1800 Wearing apparel, dressing and dyeing of fur	30	-0.002	-0.003	0.001	0.003*	0.002**	0.002	0.001	-0.001	0.001
1900 Leather, leather products and footwear	33	0	0	0	0.000***	-0.001**	0.000***	0	0	0
2000 Wood and products of wood and cork	36	-0.004	-0.006	0.005*	0.007	-0.022*	-0.002	0.006	0.007	0.001
2100 Pulp, paper and paper products	30	0.002	0.001	0	0.005	-0.002	0	0.003	0.001	-0.006*
2200 Printing and publishing	30	0.006	0.021	-0.014	0.005	-0.053*	-0.021**	0.007	0.01	-0.004
2300 Coke, refined petroleum products and nuclear fuel	32	-0.001	-0.002	-0.002	0.010*	0.018***	0.001	-0.004	-0.006	-0.011*
2400 Chemicals and chemical products	36	-0.003**	-0.009**	0.001	0.003**	0.002	0.001	0.009**	-0.002**	0.006**
2500 Rubber and plastics products	36	-0.005**	-0.021***	0.004***	0.008***	0.017***	0.001	0.010*	-0.003*	0.003
2600 Other non-metallic mineral products	37	-0.034***	-0.050***	0.002	0.032***	0.035***	0.002	0.056***	-0.012**	0.022**
2700 Basic metals	30	-0.008***	-0.014***	0.002	0.006***	0.009**	0.003***	0.010***	-0.003*	0.006**
2800 Fabricated metal products, exc. machinery and equipm	30	-0.002	-0.041***	0.008***	0.023***	0.024**	0.003	0.001	-0.003	-0.001
2900 Machinery and equipment, n.e.c.	36	-0.002	-0.003	0	0.001	0.002	0	0.003	0	0
3000 Office, accounting and computing machinery	28	0	0	0	0	0	0	0	0	0
3100 Electrical machinery and apparatus, n.e.c.	26	-0.002	-0.003	0.001	0.002	0.013***	0	0.001	-0.001	-0.001
3200 Radio, television and communication equipment	26	0	0	0.002**	-0.001	0	-0.002***	-0.002	-0.001	0
3300 Medical, precision and optical instruments	28	0	-0.001	0.001	0.001	0	0	0	0	0.001
3400 Motor vehicles, trailers and semi-trailers	28	0.010***	0.003	0.001	0.004	0.004	-0.001*	-0.014***	-0.002	-0.015***
3500 Other transport equipment	28	0.006	-0.006	0.001	0.005***	-0.008**	0	0.009	-0.003	0.002
4041 Electricity, gas and water supply	37	-0.072***	-0.05	-0.026	0.013	0.147***	0.032***	0.039	-0.039***	0.014
4500 Construction	34	-0.026	0.003	0.009	-0.055**	-0.056	-0.011	-0.02	0.012	0.086*
5052 Wholesale and retail trade - repairs	32	0.019*	0.02	-0.003	-0.012	0.013	-0.013	-0.029	0.01	-0.03
5500 Hotels and restaurants	36	-0.000*	-0.001**	0.001**	0	0.001	0	0	-0.000**	0
6063 Transport and storage	32	0.006	0.004	-0.002	-0.002	-0.013	-0.002	0.007	0.003	-0.003
6400 Post and telecommunications	31	0.009	0.011	-0.003	0.008	-0.034*	0.001	-0.006	0.004	-0.002
7074 Real estate, renting and business activities	35	-0.003	-0.011	-0.002	0.004	0.054**	0.007	-0.007	-0.007	-0.021
7599 Community, social and personal services	35	0.025**	0.046**	0.026	-0.014	-0.149***	-0.009	-0.078*	-0.007	0.056**

Notes: The dependent variable in each regression is the employment-weigthed intensity of task cluster *h* in sector *s*. The table shows an excerpt of the regression results, i.e. the regression coefficients of the import penetration variable obtained from estimating a system of 9 equations for each industry. ***, ** and * indicate significance at the 1%, 5% and 10% level respectively.