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Offshoring Medium-Skilled Jobs and Wage Inequality in Task-Based Approach – From Practical to Theoretical Perspectives

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Abstract

The last two decades has seen job polarization and the rapid increase in wage inequality emerging as a trend in many developed countries. Among hypotheses about the influence of globalization, task offshoring has been receiving high attention from several researchers. Employing the descriptive and critical review as a research method, the paper provides summary, classification and evaluation of both theoretical and empirical literature on offshoring medium-skilled job tasks and wage inequality in the task-based approach. The paper also identifies patterns and trends in the literature as well as lessons drawn from previous studies and provides implications for future research.

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1 INTRODUCTION

Job polarization and the rapid increase in wage inequality have emerged as a trend in many developed countries in the last two decades. Empirical research has shown a reduction of employment share in middle-wage occupations but a growth in high-wage and low-wage ones in the USA, Canada, and many high-wage countries in Europe. At the same time, a pattern of wage distribution is also discerned, namely, the wage at a top and the bottom of the distribution increases faster than in the middle section. Thus, this phenomenon has become a great interest for researchers in labor economics field.

Moreover, in the international economy, countries exchange with each other based on their comparative advantages to improve their productivity and welfare. Beside trading of tangible resources and goods, skill endowment is also believed to be a resource that can be traded. Against the background of new industrial revolution, most previous research has looked into the trade in job tasks but not in skills. Particularly, "a task is a unit of work activity that produces output (goods and services). In contrast, a skill is a worker's endowment of capabilities for performing various tasks" [1]. Workers or machines can perform occupational tasks. Skill is acquired through education or enriched via lifetime experience. Thus, workers apply their skills to the production of tasks in exchange for a wage return. Meanwhile, tasks are employed to produce final goods. Due to the impact of globalization, there is the movement of jobs or tasks from developed countries to the developing ones in oder to reduce production and labor costs irrespective of whether the offshoring is done by the same or different companies. This recent phenomenon is so-called offshoring in job tasks. For example, the United States has offshored their medium-skilled job tasks to developing countries when Apple decides to move all their factories to Vietnam and China. Thus, it is believed to be an important factor contributing to wage inequality in developed countries.

This paper aims to investigate how offshoring medium-skilled job tasks can explain the wage inequality from both theoretical and empirical point of views. To answer this question, the following sections first summarize and categorize the existing theoretical research based on different academic disciplines as well as analyze some specific theoretical methods of the task assignment in explaining the impact of offshoring. Furthermore, the paper identifies challenges and lessons to bring the task-based approach to the data by reviewing and evaluating the empirical literature, then briefly points out new directions for further research.

2 REVIEW OF THE TASK-BASED APPROACH

In theoretical terms, the task-based approach is believed to be a powerful framework for explaining the new trend of wage inequality, job polarization as well as demand for labor. The task model allows economists to clearly examine the effects of not only offshoring opportunities and technology innovation but also immigration. This paper reviews research on offshoring with a focus on offshoring medium-skilled job task.

Firstly, here is the inevitability of establishment of the task-based approach. From the pioneering work of Tinbergen [21], the economy acknowledges skill endowment as one of the input factors directly producing a final good. Particularly, the labor market is characterized by two types of labor, namely, skilled labor with college graduates and unskilled labor with secondary or high school ones. The wage of each type of labor, so-called the return to skill, is determined by relative supply and demand of each respective type of skills. Therefore, there exists a race between education, representing for the supply of skills, and skill-biased technology improvement, linking to the demand for skills. Particularly, the development of skill-biased technology leads to higher demand for more skilled workers, and hence greater demand for college education. In constrast, Acemoglu [6] has proved that not all technologies can substitute skill factors. In the late twentieth century, new technologies appeared to be skill-complementary for either skilled or unskilled labor. For instance, with a computer, unskilled workers can now work in inventory control in supermarkets or restaurants, which formerly employs skilled labor only. In this case, technologies now take a form of factor-augmenting. In addition, the canonical production function framework of Tinbergen is hard to use to explain the new shift of task and wage distribution in industrialized countries in recent decades. Thus, the more suitable theoretical explanation for this polarization has received increasing attention from many researchers.

During the last two decades, there has been a large body of theoretical research in to change of wage inequality and employment patterns in the light of new globalization trend and technological innovation. Accordingly, the literature is categorized into groupings of research fields as followed:

In labor economics

The idea of the task-based approach is introduced in the works by Autor et al.[2]. This new framework employs two types of labor corresponding to routine and non-routine tasks, but not two kinds of skills, to produce the final output. A task is defined as routine if its cognitive and manual activities are limited, well-defined and follow specific steps which can be described as a computer code. Thus, the computer can be substituted the labor of routine tasks in some fields, for example, bookkeepers, cashiers, manufacturing workers and other handlers of repetitive information processing sectors. In contrast, a non-routine task cannot be replaced but complemented by computers because of its creativity, flexibility, and complexity. David's model also applied a Cobb-Douglas (CD) production function, instead of a constant elasticity of substitution (CES) aggregate function in the canonical model, which allows expressing the substitution between computer capital and routine task but the complementation between computer capital and non-routine tasks. This model shows that a decrease in the price of computer capital due to technological improvement increases the demand for both routine and non-routine tasks but decreases labor supply to routine tasks. Analogously, occupations with larger investments in computer capital experience a large increase in labor input of non-routine tasks but a decline in routine tasks.

Autor et al. [3] further improve the previous framework, with a three-task technology of production, namely abstract, routine and manual task, and the self-selection hypothesis. Particularly, based on the different degree of complementary of computers, the non-routine tasks are divided into (i) abstract tasks, engaging in problem-solving, organization or management activities, are more complementary with computers; (ii) manual tasks in respect to jobs, that requires manual duties such as truck drivers, security guards or cleaners, are not as complementary to computers as non-routine abstract tasks. Moreover, the workers with college education in-elastically supply to abstract tasks while workers with high school certificates can choose to supply to either manual tasks or routine tasks. As a result, a decline in computer capital's price leads to a decrease in the wage of routine labor, while a rise in the wage of abstract labor and an ambiguous effect on manual labor's wage. Associating with a reduction in the wage of routine jobs, the model also implies the movement of high school workers, such that middle-skilled tasks decrease, whereas lower skilled employment composition augments and high-skilled jobs remain stable. These two theoretical frameworks are believed to explain the recent phenomenon of task and wage polarization in developed countries [10]. Adopting these frameworks, several studies further investigate the impacts of technology on the labor market. However, some researchers argue that technology is not the only factor to explain the recent trend of polarization since most early literature only examines the model in a closed economy.

In trading

Many economists start to apply the task-based approach to consider the relationship between the international trade and labor market. In the past, the link between trade and relative wage was primarily explained by using the Stolper-Samuelson theorem of the Heckscher-Ohlin model of trade. More precisely, in the world economy with two goods, two factors, and two countries, development of trade leads to a rise in the returns of the country's abundant factor but a drop in the returns of its scarce factor. Over the past decade, there exist a lot of emerging literature which focuses on trade in job tasks rather than in physical goods [19]. Among them, the model developed by Grossman and Rossi-Hansberg [15] which is recently drawn heavily by researchers in trading research. This model highlights that tasks are needed to produce output and firms are motivated to offshore tasks by the factor cost savings in an open economy. Their model considers a continuum of L-tasks performed by workers having relatively little skill, and a continuum of H-tasks carried out by workers having a greater education. The difference in technology improvement between countries causes the rise of the offshoring. The main finding of this model is the three effects of trading in tasks on wage distribution in the domestic country. First, the relative price effect of offshoring in L-tasks induces a downward movement in low-skilled wage via the mechanism similar to Stolper-Samuelson model. Second, labor supply effect implies a reabsorption of workers who formerly performed the offshoring tasks in the domestic economy. It may lead to further pressure on their wage. The final effect has the same result of the increase in productivity of low-skilled labor; thus, it is called the productivity effect of offshoring. Particularly, the cost saving actions of firms from utilizing the cheaper cost of performing L-tasks may increase the demand for low-skilled labor which consequently inflates their wages. However, this model neither mentions aggregate effect of these three effects nor employs the matching between different skill groups and various job tasks [15, 22, 8]. Another popular contribution to the theory of international trade is the framework of Costinot and Vogel [9]. This model considers the allocation of a continuum of workers with skill distributions to a continuum of intermediated tasks to produce one final good with the CES aggregator. In the world economy, offshoring leads to skill downgrading in both countries and an extensive increase in wage inequality within and across countries.

Linking the idea of trading in tasks and the direction of new technologies

Acemoglu and Autor [1] generalize an explicit framework of task assignment. This approach is particularly introduced in the paper as a basic task-based model since it has huge contribution to the literature on the theoretical determinants of change in job polarization and wage inequality. The model assumes three types of skills, namely low, medium and high skill, allocated across continuum tasks which together produce a unique final output under CD function. The central role of this approach is the Ricardian comparative advantage differing across types of workers in performing tasks. An optimal choice of allocation of skills to tasks and an optimal wage structure are uniquely derived in equilibrium. In a closed economy, the comparative static of technology change is exercised in two different directions. First, the skill bias technical change directs towards skilled workers. Second, technological innovation directly displaces workers in performing routine tasks. In terms of an open economy, the offshoring of tasks to abroad is assumed as an exogenous parameter appearing from the technological difference across countries. Thus, the effects of offshoring parallel the effects of technology replacing tasks in the way of contracting the medium-skilled tasks but expanding the low and high-skilled tasks, hence decreasing the relative wage of medium-skilled labor. This basic model has been not only applied many times for the empirical analysis but has also been further modified and improved in a lot of extended conceptual explanations. Among them, the latest theoretical framework of Valizadeh, et al. [22] is the extended version of task assignment model. In contrast with the hypothesis of Grossman and Rossi-Hansberg [15], this extended model allows for matching between continuum tasks and three specific skills which implies the task competition among skill groups through a relative comparative advantage in productivity. However, this model considers offshoring as an endogenous process decided by the domestic firm, instead of exogenous offshoring in the framework of Acemoglu and Autor [1]. In doing so, the extended approach can address the important hypothesis of polarization and productivity effect in a more explicit model, consisting of task skill heterogeneity, endogenous offshoring and spillover effects induced by job tasks mobility.

3 THE TASK ASSIGNMENT FRAMEWORK

Task assignment model provides a natural mechanism for interpreting patterns related to occupations in the labor market as well as wage structure among different skill groups. The model makes an explicit distinction between tasks and skills. Skills do not directly produce output, but rather tasks which are performed by different skill-level workers do. In general technology, each skill level has a comparative advantage in performing different tasks. This model is further developed based on the framework of Acemoglu and Autor [1], Autor [4] and Oldenski [19].

Framework setting

A static environment is applied in a closed economy with a unique final good. The unique final good is produced by a combination of a continuum of tasks (i) represented by the unit interval [0,1]. With the application of the Cobb-Douglas technology combining the service of tasks y(i), the output (Y) of a final good is defined as follows:

$$Y = exp\left[\int_{0}^{1} lny\left(i\right)di\right] \tag{1}$$

It is proposed that there be three types of labor: low-(L), medium-(M), and high-skilled workers (H), of which there is a fixed, inelastic supply among them. Besides labor factors, capital or technology factor (k) is also required to produce an available task. The production function of task (i) is as follows:

$$\begin{aligned} y\left(i\right) = {} & A_L.\alpha_L\left(i\right).l\left(i\right) \\ & + A_M.\alpha_M\left(i\right).m\left(i\right) \\ & + A_H.\alpha_H\left(i\right).h\left(i\right) \\ & + A_k.\alpha_k\left(i\right).k\left(i\right) \end{aligned} \tag{2}$$

where (A) denotes a factor-augmenting technology; (α) is the productivity of workers at a specific skill level in the performance of a task (i); and (l,m,h) and (k) are index representing the number of low-, medium-, high-skilled workers and capital factor allocated to task (i).

The comparative advantage of skill groups differs across tasks

The assumption of comparative advantage of skill groups, captured by the (α) parameter, is a central difference of task assignment model. Based on (2), any tasks (i) can be produced by workers of any skill level. In other words, medium-skilled workers can produce either the very simple tasks which might require only low-skilled workers or the very complex tasks which are better performed by high-skilled workers and vice versa. However, in the sense of comparative advantage of skill groups, high-skilled workers will be better than the medium-skilled worker in performing higher numbered tasks. Similarly, medium-skilled workers will have a higher comparative advantage than low-skilled workers in producing medium level tasks. The simple structure of comparative advantage is formally expressed as $\alpha_L(i)/\alpha_M(i)$ and $\alpha_M(i)/\alpha_H(i)$ which are possibly different and strictly decreasing.

The sets of tasks

Following the structure of the comparative advantage difference, the economy includes three convex sets of tasks in which one set is producedy only low-skilled workers, one by only medium-skilled workers, and the other by only high-skilled workers only. The two cut-off points of the task partition represent as I_L and I_H such that $0 < I_L < I_H < 1$. In particular, any tasks $0 \leq i \leq I_L$ are the least complex tasks produced by low-skilled workers while $\mathrm{m}(\mathrm{i}) = \mathrm{h}(\mathrm{i}) = 0$. Any task $I_H \leq i \leq 1$ are the most complex tasks performed by the high-skilled workers but $\mathrm{l}(\mathrm{i}) = \mathrm{m}(\mathrm{i}) = 0$. The interval $[I_L, I_H]$ is called intermediate task produced by medium-skilled workers while $\mathrm{l}(\mathrm{i}) = \mathrm{h}(\mathrm{i}) = 0$. Crucially, the optimal allocation of tasks, I_L^* and I_H^*, and the relative wages across skill groups will be endogenously determined in the model.

Equilibrium without machines

A usual manner of the economy in the equilibrium is that the producer wants to maximize their profits subject to labor market clearing condition. For now, the model assumes no labor supply decision on the part of the workers, and no machine which can substitute workers to produce the specific tasks $(\alpha_K(i) \equiv 0)$. Thus, given the supply of different types of labor in the market, firms will optimize the allocation of skills to tasks, then derive the price of the task as well as the wage of different skill-level workers in the equilibrium.

Equilibrium conditions

The optimal threshold tasks I_L^* and I_H^* must jointly satisfy a set of conditions, namely, the law of one price, the no-arbitrage condition and the market clearing requirements.

Factor market clearing condition

The assumption of the different comparative advantage of skill groups across tasks ensures a simple and tight requirement of equilibrium in this economy, particularly the factor market clearing. The whole labor supply of each low-, medium- and high-skilled workers, as L, M and H respectively, are used in the production of corresponding tasks.

$$\int_0^1 l(i).di \leq L;$$
$$\int_0^1 m(i).di \leq M;$$
$$\int_0^1 h(i).di \leq H \tag{3}$$

Law of one price

Because of competitive labor markets, the law of one price for the skill must hold in any competitive equilibrium. For example, this law implies that all tasks employing low-skilled labor have to pay an equal wage, ω_L. In equilibrium, wages are defined as marginal products of different types of skills. Within the threshold task I_L and I_H, the value of ω_L must be identical for any $i < I_L$. As a consequence, ω_M is identical for any $I_L < i < I_H$ and ω_H is also identical for any $i > I_H$.

No-arbitrage across skills

The condition of no-arbitrage across skills claims that the unit cost of producing task I_L must be identical in equilibrium whether using low- or medium-skilled workers. Similarly, for the marginal task located at I_H. , the producing cost using either the medium-skilled or the high-skilled workers must equalize. Formal expressions are as follow [a] :

$$\frac{\omega_L}{A_L.\alpha_L(I_L)} = \frac{\omega_M}{A_M.\alpha_M(I_L)} \quad (4a)$$

$$\frac{\omega_M}{A_M.\alpha_M(I_H)} = \frac{\omega_M}{A_H.\alpha_H(I_H)} \quad (4b)$$

Optimal solutions

Following the equilibrium conditions, the basic model can determine the optimal threshold tasks, I_L^* and I_H^*. Then the relative wage structure between skill groups, as well as the price of tasks performed by different skill groups can be solved in a straightforward manner. Before obtaining the expression of I_L^* and I_H^*, it is efficient to determine the price of tasks and wage level as a function of the threshold tasks.

Price of tasks

The variable $p(i)$ denotes the price of production of task i. By assuming the price of the final good equal to 1, $p(i)$ can derive from the following equation:

$$exp\left[\int_0^1 lnp(i)\,di\right] = 1 \quad (5)$$

The price $p(i)$ may be varied among the tasks, even these tasks are produced by the same skill-level workers. By the law of one price, the difference of prices must exactly offset with productivity variation among different skill groups. Thus, the identical price index of tasks produced by the low-, medium-, and high-skilled workers are defined as follow:

$$P_L = p(i).\alpha_L(i) = p(i').\alpha_L(i'), \forall i, i' \in [0, I_L] \quad (6a)$$

$$P_M = p(i).\alpha_M(i) = p(i').\alpha_M(i'), \forall i, i' \in (I_L, I_H) \quad (6b)$$

$$P_H = p(i).\alpha_H(i) = p(i').\alpha_H(i'), \forall i, i' \in [I_H, 1] \quad (6c)$$

From (5) and (6) the last equilibrium condition can be characterized, so-called the price normalization:

$$\int_0^{I_L} [lnP_L - ln\alpha_L(i)]\,di + \int_{I_L}^{I_H} [lnP_M - ln\alpha_M(i)]\,di + \int_{I_H}^{1} [lnP_H - ln\alpha_H(i)]\,di = 0 \quad (7)$$

Moreover, due to the Cobb-Douglas technology in the production of final

[a] The original equations in the paper of Acemoglu and Autor [1] are wrong. Equations (4) are corrected by the author.

goods, the expenditure across all tasks should be equalized and also equal to the value of total output. It can be expressed as:

$$p(i).y(i) \equiv Y, \forall i \in [0,1] \quad (8)$$

By using the convenient implication of CD productivity structure and combining with the market clearing condition, the number of each type of labor allocated to the task are defined as:

$$l(i) = \frac{L}{I_L}, \forall i \in [0, I_L] \quad (9a)$$

$$m(i) = \frac{M}{I_H - I_L}, \forall i \in [I_L, I_H] \quad (9b)$$

$$h(i) = \frac{H}{1 - I_H}, \forall i \in [I_H, 1] \quad (9c)$$

In addition, it is important to compare two tasks produced by different types of employees. By using (6), (8) and (9), the relative price of task performed by medium and low-skilled workers as well as the relative price of tasks produced by high and medium-skilled workers can be obtained as follow:

$$\frac{P_M}{P_L} = \left(\frac{A_M.M}{I_H - I_L}\right)^{-1}\left(\frac{A_L.L}{I_L}\right) \quad (10a)$$

$$\frac{P_H}{P_M} = \left(\frac{A_H.H}{1 - I_H}\right)^{-1}\left(\frac{A_M.M}{I_H - I_L}\right) \quad (10b)$$

As seen in the above equations, the relative price of different tasks depends on factor augmenting technology A, the total number of each worker in the economy and the two cut-off points of sets of tasks. With the given value of M, L, H and A, the price of tasks can be determined once the unique optimal I_L^* and I_H^* are solved.

Wages of skill groups

Wage levels are simply defined as marginal products of different types of skills and must be identical among workers in the same skill level. From (2), (6) and (8), the wage levels of low-, medium-, and high-skilled worker are determined respectively as follow:

$$\begin{aligned}\omega_L &= p(i).A_L.\alpha_L(i)\\ &= P_L.A_L, \forall i \in [0, I_L] \quad (11a)\\ \omega_M &= p(i).A_M.\alpha_M(i)\\ &= P_M.A_M, \forall i \in [I_L, I_H] \quad (11b)\\ \omega_H &= p(i).A_H.\alpha_H(i)\\ &= P_H.A_H, \forall i \in [I_H, 1] \quad (11c)\end{aligned}$$

From these above expressions, it is simple to derive the relative earning across skill groups. These following ratios play a major role in the interpretation of the wage structure and inequality in the task model. The relative wage functions depend on relative supplies between respective skill groups and the equilibrium task assignment I_L and I_H.

Thus, wage inequality is uniquely determined since the task assignment function are uniquely defined in equilibrium.

$$\frac{\omega_H}{\omega_M} = \left(\frac{H}{M}\right)^{-1}.\left(\frac{1 - I_H}{I_H - I_L}\right) \quad (12a)$$

$$\frac{\omega_M}{\omega_L} = \left(\frac{M}{L}\right)^{-1}.\left(\frac{I_H - I_L}{I_L}\right) \quad (12b)$$

The optimal task assignment

To derive the optimal function of I_L^* and I_H^*, the model finally employs the no-arbitrage conditions. Recall that (4a) implies that there is no different cost to produce task I_L whether employing low-skilled or medium-skilled workers. Combining this equation and (12b), the no-arbitrage function of task allocation between low- and medium-skilled groups can be derived as:

$$\frac{A_L.\alpha_L\left(I_L\right).L}{I_L} = \frac{A_M.\alpha_M\left(I_L\right).M}{I_H - I_L} \quad (13)$$

Analogously, the so-called no-arbitrage function of task allocation between high- and medium-skilled workers is obtained from (4b) and (12a):

$$\frac{A_M.\alpha_M\left(I_L\right).M}{I_H - I_L} = \frac{A_H.\alpha_H\left(I_H\right).H}{1 - I_H} \quad (14)$$

Again, since the labor supplies of each skill levels, the factor-augmenting technologies, and the task productivity schedules are known, the unique equilibrium I_L^* and I_H^* can be determined from (13) and (14) respectively. Thus, given these, the value of the price index of task and wage levels of all skill groups also are uniquely determined.

Interpretation of Equilibrium

In the I_L-I_H scale (Fig. 2), the equilibrium task margins can be determined at the intersection between these two no-arbitrage curves which both have an upward slope. However, the no-arbitrage curve between medium- and high-skilled labors has a steeper slope than the no-arbitrage curve between low- and medium-skilled labors. Moreover, it is necessary to illustrate the allocation of tasks as the equilibrium between the supply and demand of different types of skill groups. To do that, (13) and (14) are rearranged as follow[b]:

$$\frac{1 - I_H}{I_H - I_L}.\frac{\alpha_M\left(I_H\right)}{\alpha_H\left(I_H\right)} = \frac{A_M.H}{A_M.M} \quad (15a)$$

$$\frac{I_H - I_L}{I_L}.\frac{\alpha_L\left(I_L\right)}{\alpha_M\left(I_L\right)} = \frac{A_M.M}{A_L.L} \quad (15b)$$

In other words, the right-hand side of these expressions represents the relative effective supply while the left-hand side corresponds to the relative effective demand between each two skill groups. The intersection between the demand curve and supply curve of (15a) and (15b) depicts the allocation of task I_L^* and I_H^* respectively. Furthermore, from the above expressions, the relative supply curves, independent of the task margins, are shown as horizontal lines. However, the relative demand curves have a downward slope since the relative task-productivity is strictly decreased in task margins as the assumption. Nevertheless, Fig. 2 clearly visualizes the equilibrium with the partition between three types of skilled labor.

Offshoring of medium-skilled workers-Comparative static

So far, the model only considers a closed economy. In the global economy where countries trade resources with each other, the task equilibrium and wage structure are supposed to be different. Moreover, instead of trading finished goods and services, trading in tasks has now become an emerging trend of the international economy. In particular, some specific tasks are moved to other countries with a lower average income. In return, the task-export countries can still trade in the

[b] There is another mistake in the original paper of Acemoglu and Autor [1]. Equation (15b) is corrected with $\alpha\left(I_L\right)$ instead of $\alpha\left(I_H\right)$

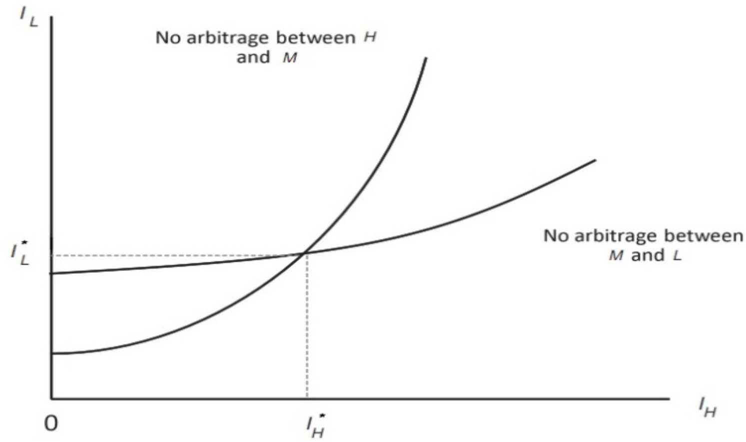

Fig. 1 Determination of Equilibrium task margins [1]

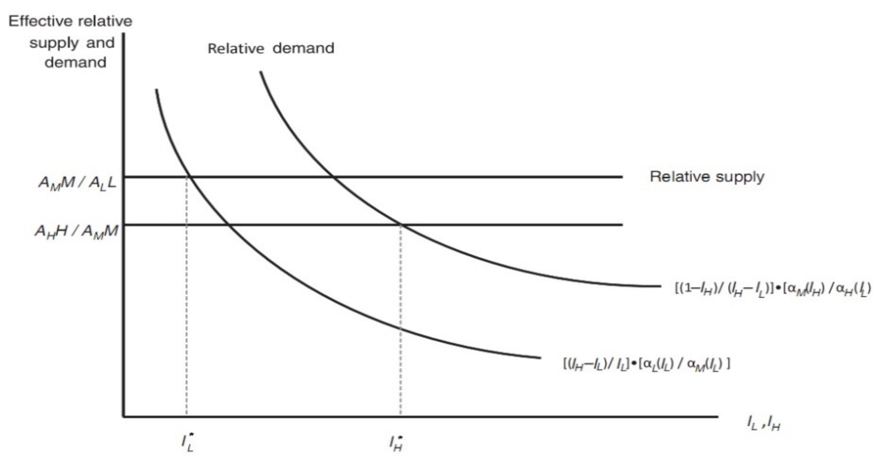

Fig. 2 Equilibrium allocation of skills to tasks [1]

final good to ensure trade balance and minimize their production costs. Based on the observation that medium-skilled tasks are more likely to be offshored than low and high-skilled tasks, the next section illustrates how offshoring of medium-skilled tasks can affect the equilibrium.

An exogenous offshoring

First, assume that there now exists a range of tasks, denoted as

$$[I',\ I''] \subset [I_L, I_H]$$

to be offshored to foreign countries and the size of this interval is denoted as ε. In a closed economy, $\varepsilon = 0$ and the equilibrium are showed as in the previous section. In open-to-trade consideration, ε increases positively which leads to a change in the size of medium-skilled task interval, i.e. $(I_H - I_L - \varepsilon)$. As a

[c] In the original paper, there is no detailed explanation for the effects of offshoring on task margins and wage structure. According to Acemoglu and Autor [1]; however, these effects are equivalent

consequence, there will be a reallocation of tasks, then a change in wage structure in the economy[c]

In this case, the new equilibrium task margins are $\widehat{I_L}$ and $\widehat{I_H}$ which can be determined by the following no-arbitrage equations in log form:

$$lnA_M - lnA_H + \beta_H(I_H) + lnM - lnH - \ln(I_H - I_L - \varepsilon) + \ln(1 - I_H) = 0 \quad (16a)$$

$$lnA_L - lnA_M + \beta_L(I_L) + lnL - lnM + \ln(I_H - I_L - \varepsilon) + \ln(1 - I_H) = 0 \quad (16b)$$

Recall that $\beta(.)$ is a log form of the two comparative advantage of skill groups across tasks, namely $\beta_H(I) \equiv \ln\alpha_M(I) - \ln\alpha_H(I)$ and $\beta_L(I) \equiv \ln\alpha_L(I) - \ln\alpha_M(I)$. As observed in the initial assumptions, these two terms are also continuously differentiable and strictly decreasing.

Task reallocation

Conveniently, the comparative statics also can be exercised by using these equations (16). The starting points are equilibrium I_L^* and I_H^* with $\varepsilon = 0$, and then ε increases to value $\varepsilon' > 0$ Mathematically, these equations are totally differentiated with respect to I_L, I_H and ε, then solve the matrix of the obtained equation system. Therefore, the result is:

$$\frac{dI_H}{d\varepsilon} > 0; \frac{dI_L}{d\varepsilon} < 0 \text{ and } \frac{d(I_H - I_L)}{d\varepsilon} > 0$$

In other words, a positive offshoring shock in medium-skilled tasks increases the task margin $\widehat{I_H} > I_H^*$, but decreases the task margin $\widehat{I_L} < I_L^*$. This effect implies that some medium-skilled workers are now starting to produce either $\left|\frac{dI_H}{d\varepsilon}\right|$ tasks which were previously performed by high-skilled workers or $\left|\frac{dI_L}{d\varepsilon}\right|$ tasks which were previously performed by low-skilled workers. A consequence of offshoring in medium-skill task is an increase in the supply of low- and high-skilled tasks, and hence expansion of these tasks.

Wage distribution

Following the result of tasks reallocation, the impacts are characterized as:

(i) ω_H/ω_M increase;

(ii) ω_M/ω_L decrease;

(iii) ω_H/ω_L depends on whether $|\beta'_L(I_L).I_L|$ is smaller or higher than $|\beta'_H(I_H).(1 - I_H)|$.

The first two characteristics (i) and (ii) are intuitive. Since some medium-skilled tasks are offshored to foreign countries, the relative wages of the medium-skilled workers both compared to low and high-skilled workers will diminish. It is because medium-skilled workers have to be reallocated to the tasks in which they have no comparative advantage. Furthermore, to reduce production cost, medium-skilled tasks can be offshored further. Hence, the wages of this skill group are reduced compared to those of the other two skill groups. The last characteristic implies an interesting general effect on the wage of high-skilled groups relative to low-skilled groups. The nature of comparative advantage claims that medium-skilled employees can encroach on the

to the impacts of task replacing technologies which are discussed more precisely. Therefore, the paper uses all interpretations of the latter as the explanation of the former.

other two skill groups, but the question is which of the encroachment on L or H has a higher degree. The result depends on the comparative advantage of skill groups expressed by terms of β, as well as the size of task sets I_L and $(1 - I_H)$.

In particular, the inequality $|\beta'_L(I_L)| < |\beta'_H(I_H)|$ implies that the high-skilled labor has a stronger comparative advantage relative to medium-skilled ones around I_H, and the low-skilled labor have a weaker comparative advantage relative to medium-skilled ones around I_L. In this case, medium-skilled employees will be likely to be reallocated to become low-skilled workers rather than high-skilled workers. In this case, the relative wage of high-hand low-skilled labor will increase. On the other hand, the change of relative wage can be explained by the inequality $I_L > (1 - I_H)$. Since the set of low-skilled tasks is larger than that of high-skilled tasks, any reallocation of medium-skilled workers has a smaller effect on low-skilled workers' wages and a higher effect on wages of high-skilled groups. In this case, the relative wag e of high and low-skilled group will decrease.

4 HOW TO PUT THE TASK INTO THE TEST-THE CRITICAL REVIEW OF EMPIRICAL LITERATURE

With the growing body of literature on offshoring tasks, the researchers focus on the employment effect and wage effect of offshoring and report mixed results for the developed countries. According to Autor [4], although the task asignment model has some potential value, it is challenging to test this model empirically. Particularly, it is difficult to measure and identify the economic mapping between tasks and skills as well as distinguishing returns-to-task and returns-to-skill regressions. By evaluating previous empirical research, this section raises three issues of measurement that need to be considered and draws some useful lessons for the economists.

Challenge in task measurement

Different from the canonical setting, in which skill proxies are broadly collected such as education and experience, the task approach requires suitable proxies for job tasks but not for skills. These proxies have to be able to represent the allocation of skill across tasks as well as the change of this allocation over time. Unfortunately, most of the primary research datasets used for estimating earning provides little information about job tasks. This results in substantial measurement challenge. As a natural appeal, occupations are employed as proxies for job tasks since they can easily be conceptualized as bundles of tasks. However, the occupational categorization contains hundreds of various occupations which are very difficult to represent as task measures in their raw form. Therefore, how to reduce a huge set of occupation codes to a lower dimensional object becomes problematic. The relevant literature shows at least three approaches used to solve this problem [4, 5].

At the industrial level, a first method is to aggregate many distinct occupations into a few broad classifications such as production, service, professional, etc. For instance, data from the Bureau of Economic Analysis (BEA) has been used by Oldenski [19]. The BEA surveys consist of data on U.S multinational companies operating 112 manufacturing and service industries. These industries are sorted according to BEA version of 4-digit North American Industrial Classification System codes. Although this is a typical and straightforward method, this method is considered to obscure the overlaps of task contents among occupation [5]. In particular, accountants in offices and machine operators in factories belong to different industrial categories but they both perform similar tasks, i.e. routine tasks. Furthermore, similar to company directors, university lecturers also make extensive use of high-skilled tasks. Thus, researchers using this method have to apply additional subjective judgments.

Alternatively, the occupation- level task measures have been widely used in empirical works in order to reduce the limitation of similarities. This approach manually groups occupations based on a set of standardized job descriptors to each occupation. A key advantage of this method is its main inputs, including detailed occupation and objective dimensions of task contents, can be evaluated by the statistical agencies that supply them. Two major data sources are the US Labor Department's Dictionary of Occupational Titles (DOT) first issued in 1939 and its successor, the Occupational Information Network (O*NET) introduced in 1998 [4]. DOT task measures originally follow the congregation of Autor et.al [2] and [3]. For example, occupations requiring direction, control and planning activities and quantitative reasoning belong to non-routine abstract tasks. Other jobs involving only Eye-Hand-Foot coordination are measured as non-routine manual tasks while routine tasks correspond to occupations requesting Set limits, Tolerances or Standards, and Finger Dexterity Acemoglu and Autor [1]. With O*NET data, however, some occupations have a long list of characteristics which are unwieldy in a regression setting due to collinearity [16]. Furthermore, according to Autor [4], using job task descriptors to assign tasks to the occupations has two major limitations. Fundamentally, occupational level measurements dismiss all heterogeneity in job tasks among workers within an occupation since personal skills and actual tasks differ among workers. Moreover, tasks also tend to be reallocated when the relative sizes of occupations have changed. Thus, this method could systematically understate the extensive margin of this reallocation unless the databases are regularly refreshed, but this is done at extremely high cost. Besides these two intrinsic limitations, this approach has to face practical difficulties in designing the job content descriptors from data sources. Both U.S data sources mentioned above are preceded the task assignment model. Thus, most of the objective and subjective job scales of these sources are still unclear, monotonous and confusing in terms of task measurement.

A final approach is using the direct survey at the individual level. Job task information can be collected for testing specific hypotheses without restrictions on the variability of tasks both within and across occupation. The survey respondents answer the sets of questions about demographics, employment, wage data as well as job-activity descriptions. Currently, this method is believed to be a successful task measurement that could minimize the above mentioned problems. One of the significant examples is the IAB/BIBB[d] . It is a detailed self-reported data on primary activities of workers which are measured from the job activities questions. However, the IAB/BIBB data are not purposely conducted for either economy-

wide lever or over-time changes in job tasks. Moreover, Handel [5] introduces the survey of the Princeton Data Improvement Initiative (PDII) which collects new data on job activities of American workers performing different cognitive, interpersonal and physical tasks. Although this survey does not provide the time-series component, it allows researchers to test the variation of job tasks within occupations. Another example is the British Skills Survey of Francis Green and collaborators. The survey provides a consistent measurement of skills used in the workplace in term of job performances, technical uses, training requirements and so on.

A lesson from these initiatives and from many other recent surveys is how to design the questionnaires which can successfully measures routine tasks from different perspectives. For example, mopping floors is a mundane repetitive task from the perspective of human labor but is not a routine task from the perspective of machine automation. In fact, as a characteristic of current computer technology, visual recognition and environmental adaptability needed to produce this task is a technical challenge for computer science. Therefore, to classify different types of tasks, it is more practical to ask workers more detailed about which tasks they usually produce and to apply outside expertise later on for the reliable information.

Conceptual challenges and regression of wage on task

In the Ricardian model of task-based approach, workers are systematically allocated to various job tasks based on the schedule of comparative advantage among skill groups. In the equilibrium of the basic model, despite being assigned to different tasks, workers of the same skill level will receive the same wage due to "law of one price". This practice poses a first conceptual challenge which concerns the intrinsic difficulty of recognizing credible counterfactuals in task framework. In reality, each worker could produce any available job tasks in the economy, then could receive a different wage within each task segment. Furthermore, if there is a significant proportion of labor to be reallocated to other task categories, the aggregate wage of each skill group would be altered. Therefore, there are some of the task assignment literature

[d] The West German Qualification and career survey conducted in 1979, 1984/84, 1991/92, 19998/99 and 2005/06 by the Federal Institute for Vocational Training (BIBB) and the Institute for Labor Market Research (IAB). The survey has less than 300.000 respondents who belong to German employed population from 16 to 65 year-old labor force data first introduced by DiNardo and Pischke [11].

in support of Roy [20] model where the returns to a variety of skills can be occupation-specific. For instance, Firpo et al. [12] goes one step further than the basic model of Acemoglu and Autor [1] by allowing wages to be varied across job tasks in the setting of an empirical test as in Roy model of wage setting. However, Autor [4] argues that these reallocations becomes relevant to reality in the case of offshoring of middle-skilled labor. In this case, there exist some degree of misallocation at any given moment due to a set of plausible frictions in the economy. The displacement of middle-skilled labor and the full effects on wage structure depends on how productive middle-skilled labor is in alternative uses. In short, comparative advantage shapes the effect of offshoring on the task assignment, productivity and wage of all factors. Thus, it poses another challenge for empirical analysis in obtaining the schedule of the comparative advantage because the productivity of workers in producing tasks to which they are not assigned is difficult to estimate.

These conceptual challenges are particularly relevant for the estimation of wage return to tasks in the empirical implementation of task assignment model. In the task-based approach, tasks are conceptually different from skills, and then the wage returns to jobs tasks are also different from that of skills. The key prediction of the theory with the constant comparative advantage is that: "If the relative market price of the tasks in which a skill group holds comparative advantage declines, the relative wage of that skill group should also decline. Even if the group reallocates its labor to a different set of tasks (i.e., due to the change in its comparative advantage)". In short, the changes in market value of tasks should exert an impact on the change of wages by skill groups. The question is how to bring this insight into data and to obtain the clarified wage regression. Critically, the distinction between task return and skill return is meaningful in regressing wage since the assignment of skills to tasks is endogenous. This endogenous variable is defined based on the stock of human capital of workers and the contemporaneous productivity of the task. The model indicates that task allocations are themselves dependent on the current wage distribution and hence the regression of wage on job tasks will generate potentially misleading results. Therefore, Autor [4] suggests that the regressing wages be paid on skills with the Mincerian approach are more informative about wage inequality than the regressing wages paid on tasks with an alternative method. Taking the empirical approach of Baumgarten et al. [7] as an example, the Mincer wage equation of workers is as follows:

$$\ln WAGE_{ijkt} = \alpha + \beta DEMOG_{it} + \gamma WORK_{it} + \delta TASK_k + \lambda OS_{jt} + \vartheta OS_{jt} \times TASK_k \theta IND_{jt} + \rho R\&D/Y_{jt} + \tau_j + \mu_t + \iota_i + \epsilon_{ijkt},$$

where the $\ln WAGE_{ijkt}$ measured variable denotes the hourly wage of individual i at time t in industry j and occupation k. It depends on offshoring OS_{jt}; task intensity $TASK_k$ ranging from 0 to 1, where 1 implies the greatest sum of non-routine and interactive tasks. The control variables are demographic status $DEMOG_{it}$, workplace-related characteristic $WORK_{it}$, industrial characteristic IND_{jt} and the research and development intensity of industry $R\&D/Y_{jt}$. The error term of industry, time and individual fixed effects, as well as the remaining error term, are respectively denoted as $\tau_j, \mu_t, \iota_i\ and\ \epsilon_{ijkt}$. This empirical analysis concludes that the workers are prevented from the negative wage effect if the task consists of a higher degree of interactivity and non-routine content.

Challenge in offshoring measurement

According to Hummels et al. [16], the offshoring measurement must exactly match all three core elements of offshoring. The first one is the intermediated inputs used for production but not for consumption. The second element is the import inputs procuded abroad but not domestically. Finally, it is the inputs that could have been produced internally by the same firm. The second element is easy to measure using data while the two others pose the challenge to offshoring measurement.

The national trade statistics and input-output tables

The popular approach that expresses input-user element employs the national trade data combining with input-output (IO) tables[e] , World-Input-Output-Database used in Foster et al. [13], OECD Input-Output Database used in Hummels et al. [17]. While the trade data informs the level of imports and exports, the IO tables answer the question of whether the imports are final goods or intermediated inputs, by which sector and in which proportion the inputs are used. The main problem is that there is a limited number of countries reporting the source country for the inputs in IO tables as well as the industry which the inputs are used in trade data. To tackle this problem, a solutions is suggested by Feenstra and Hanson [14] with a ”proportionality assumption”. That is, imports as a share of total sales for the input are assumed to be distributed equally across sectors. Moreover, this paper also distinguishes between ”narrow offshoring” and ”broad offshoring” in term of offshoring measurement. While the latter measures the most comprehensive set of inputs purchased by the firm, the former restricts to the inputs which are purchased from the same two-digit industry as that of producing firm. The narrow offshoring is believed to be closer to the essence of fragmentation, which necessarily takes place within the industry. The proportionality assumption, however, lies behind the widely used suggestion of Hummels et al. [17], so-called a measure of vertical specialization. This concept involves the use of imported inputs in producing a country exported goods and allows the measure to be easier taken to the data. National data is publicly available and can be achieved for a large number of countries. The main weakness of this approach, however, is to specify which products are intermediate inputs based on who the user is.

[e] For examples: IO table is constructed from the Census of Manufactures data in Feenstra and Hanson [20]

The firm-level data

To solve the weakness of using trade data, many researchers employ the firm-level data for the offshoring measurement. The purpose of using the report of trade activities of a specific firm to see which firms are engaged in offshoring with regard to intermediate inputs in production. Besides, using the firms industry classifications enables research to account for compositional differences within industrial. For instance, Hummels et al. [18] employ firm data of the Firm Statistics Register (FirmStat)[f] supplemented with additional data from other firm registers in statistic in Denmark. The offshoring is measured by the total value of merchandise imported by manufacturing firms. Furthermore, the distinction between broad and narrow offshoring depends on the output and input mix of an individual firm, rather than an industry. This approach is thought of as the "golden standard" for accuracy; however, the firm data is not available for all countries and not accessible to many researchers. Furthermore, the firm-level datasets might lose cross-country variation.

5 CONCLUSION AND DIRECTIONS FOR FUTURE RESEARCH

The recent job polarization and wage inequality, stimulated by empirical literature over the last two decades, are successfully explained with the task assignment framework. In task-based approach, a task, not a skill, will be directly participate in the production of the final good. The classification of tasks associated with complementarity and substitutability of technologies and skill factors. A medium-skilled task can be substituted while a low-skilled and high-skilled task are complemented by technology. Due to globalization, job tasks can be moved from one country to another and this is labelled as offshoring. The wave of offshoring has recently grown and been mostly applied to the medium-skilled tasks.

In the theoretical terms, this paper has reviewed several studies in different academic disciplines, then discussed an explicit model with an aim to offer insights into the interaction among skills, tasks, technology and offshoring in the labor market. Regarding empirical analysis, a task assignment model is also applied to the vast literature on wage inequality of developed countries, which obtain the similar results to the models predictions, namely a decrease in demand and wage of medium-skilled groups. By critical reviewing empirical research, this paper also identifies some major challenges in task measurement, calculation of offshoring and wage regression. Besides, it also discusses the advantages and disadvantages of different methods and propose solutions to overcome these problems.

For future research, the effect of offshoring on the employment rate could be examined. Since in most recent studies, the task assignment model is placed in a full-employment setting. It is interesting to propose the task-based framework setting in the economy with a positive unemployment rate for which

[f] The data covers most of Danish firm in the private sector from 1995 to 2006.

not only real wage but also the social welfare need to be fully examined. Moreover, most empirical studies focus on offshoring in high-skilled labor in industrialized countries while this research matter in developing countries tends to be overlooked by international researchers. Therefore, future studies should develop a full theoretical model to analyze the offshoring on all three sets of tasks and test the effect of offshoring on developing countries empirically, especially the countries whose both offshored and offshoring take place. Also, there should be more studies to compare the impact of bilateral cooperation on both partner countries regarding offshoring. By so doing, policy recommendations could be made not only for a single economy but also for the global economy so that workers from different industries are protected from losing their wages in both short and long term.

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