Skill Differences and Wage-Effort Relationship: Who Are More Exploited, High-Skilled or Low-Skilled Workers?

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Abstract

Who are more exploited, high-skilled or low-skilled workers? We address this question using the efficiency wage model with skill differentials incorporated. We perform simulations to find the Nash equilibrium numerically, and our central results are the following. First, higher-skilled workers are offered higher wages but exert less effort, and in particular the skill-wage relationship matches the observed data on wage inequality of the U.S. Second, we employ two measures of the degree of exploitation. On the one hand, the ratio between effort and wage the higher-skilled workers experience is lower than that of lower-skilled workers. This is due to their higher fallback positions which provide them with stronger negotiation power vis-á-vis their employers. On the other hand, in terms of the effort-wage ratio adjusted by skill, it is higher for higher-skilled workers when the range of skill is from zero to around 80th percentile but the ratio falls precipitously as skill increases. The workers with the highest level of skill experience zero degree of exploitation in terms of both measures.

Keywords: Exploitation, efficiency wage model, skill, effort

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1 Introduction

In explaining economic inequality, income inequality is as important as wealth inequality. As evidenced in Piketty (2014), in the U.S. the rise of income inequality since the 1970s is largely due to the rise of wage inequality. In addition, it is a widely-agreed consensus, and well-documented, that the wage inequality in the U.S. and the other advanced countries has been growing (see, e.g. (Kuhn et al., 2020; Nolan et al., 2019)) and, furthermore, as shown in figure 1, the wage dispersion within the top wage group is much greater than the one in any of the rest of the wage distribution. While this literature uses wages, or income, as a central factor for welfare, we may broaden the perspective and examine not simply wages alone but wages relative to efforts workers exert to earn the wages, and consider the wage-effort ratio as an alternative key factor for welfare.[1] Then, an important question that emerges is on the distribution of the wage-effort ratio against skill levels.[2] In this paper, we address this question by employing the concept of exploitation and ask, who are more exploited between high-skilled high-wage workers or low-skilled low-wage workers?

In fact, exploitation has seldom been an object of research in economics in general. However, it is not impossible to conceptualize it. Consider neoclassical marginalist theory, according to which a worker's wage in perfect competition equals her marginal productivity. In this view, exploitation can be theorized as taking place due to whatever that makes the market imperfect, such as agency problem, asymmetry information, or incomplete contract, etc., thereby allowing an employer to pay her workers unfair wages, i.e. less than their marginal productivity.

On the other hand, according to Marxian theory, which is the most important source for the theory of exploitation, workers are exploited in the sense that they receive only a part of the value they created and this is the case regardless of market structures, and therefore exploitation is a defining feature of the capitalist economy. Furthermore, as demonstrated in Roemer (1982), there is a correspondence between class and exploitation, i.e. those who hire others are exploiters and those who are hired by others are the exploited. In this view, since exploitation depends on agents' class position, as long as one is a member of the working class, her wages being high or low does not change the fact that she is exploited. However, we may still compare the degree of exploitation among them, which will be more pertinent

[1] In the main discussion below, we employ the effort-wage ratio, rather than its inverse, the wage-effort ratio.

[2] For instance, Foley (2016, 2018) and Cogliano (2023) suggest that in the long-run the effort-wage ratios will be equalized across workers.

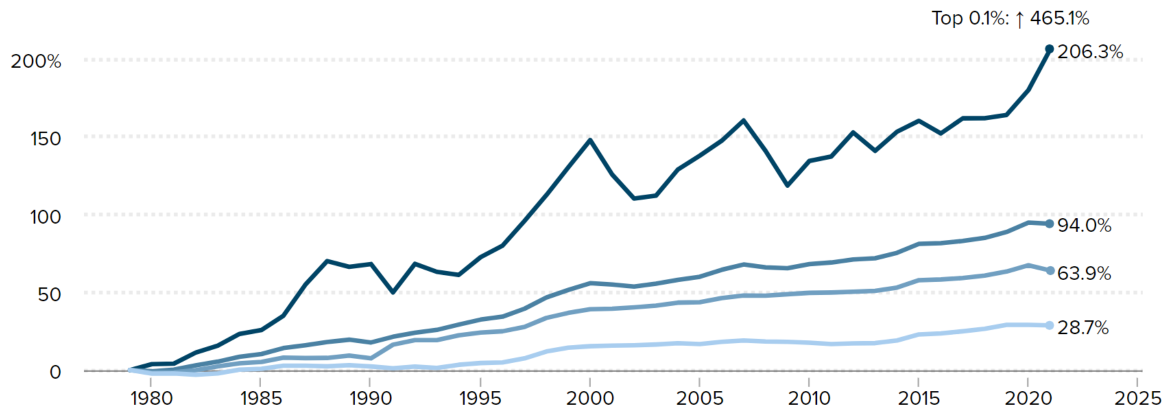


Figure 1: Cumulative percent change in real annual wages, by wage group, the U.S. 1979–2021

Sources: Economic Policy Institute website.

especially when the wage inequality is on such a significant level.

To address these issues, we present a multi-industry efficiency wage model, where each industry hires one specific type of labor skill, and each type of skill has a different value-creating, productive power. Acquiring higher skills are more costly due to the greater costs of education, training, and time etc. and consequently, only the workers with greater wealth are able to obtain more advanced skills.[3] When unemployed, the workers have to eat into their remaining wealth, and therefore the workers with greater wealth, and hence equipped with more advanced skills, will enjoy greater per-period consumption during unemployment. It makes their fallback position stronger than workers with less wealth and hence equipped with less advanced skills. The labor contract is incomplete in the sense that the employers purchase the labor power but how much labor can be extracted cannot be specified in the contract. Therefore, in each industry the workers and the employers are engaged in a Stackelberg game of labor extraction with the latter moving first.

We perform simulation exercises to find the Nash equilibrium numerically, and the result suggests that higher-skilled workers are offered higher wages but exert less labor efforts compared to lower-skilled workers. In particular, our result on the wages, which are critically higher for the top 20 percentile of the skill group and above, well matches the U.S. data on the wage inequality. Note that while the same amount of effort will give the same amount of hardship and exhaustiveness, or disutility, to both higher-skilled and lower-skilled workers as a human species, it will produce a different amount of output depending on the worker's skill. Hence, here we employ two measures of degree of exploitation to compare between workers

[3] As we will explain below more in detail, all agents in the model are endowed with some wealth, but only those with some sufficient amount of wealth become a capitalist and the rest become a worker.

with different skills. The first is the ratio between the effort and wage, which measures the hardship, exhaustiveness, or disutility a worker experiences per wage regardless of skill level. The second measure is constructed by multiplying skill to the ratio between the effort and wage. It is based on an idea that higher-skills make greater contribution to production than lower-skills do and we call it the skill-adjusted effort-wage ratio. It measures value-creating capacity, or productive power, per wage.

According to our numerical simulation results, the effort-wage ratio, on the one hand, is lower for the higher-skilled workers. The reason is because they have stronger fallback positions, which provide them with a stronger bargaining power vis-á-vis the employers than the case of lower-skilled workers. On the other hand, the result on the skill-adjusted effort-wage ratio is more complicated. In the skill range of zero to around the 80th percentile, an increase in skill leads to an increase in the skill-adjusted effort-wage ratio, but in the skill group of top quintile, an increase in skill leads to a decline in the ratio. More interestingly, our result suggests that the workers with the highest skill level experience zero degree of exploitation both in terms of the two measures of the degree of exploitation.

Our paper is related to the following strands of literature. The efficiency wage models similar to the one in this paper can be found in Bowles and Gintis (1988), Bowles (2004), and Gintis and Ishikawa (1987), etc. Krueger and Summers (1988) examines wage differentials for equally skilled workers, focusing on the role of job characteristics as a determinant of wages. Rebitzer (1995) empirically tests one of the predictions of the efficiency wage model, i.e. that there would be a negative correlation between wages and supervision without considering skill differentials.

In comparison to these papers, where workers are homogeneous, our model incorporates labor heterogeneity by introducing skill differentials. Yoshihara (1998) combines the labor discipline model to Roemer (1982)'s general theory of exploitation and class, and in that model workers are heterogeneous in terms of differential wealth endowments. In our model, it is the same that workers have different wealth, but in addition to that the wealth differentials generate skill differentials since the workers use their wealth for education and training to acquire skills, which are costly. Veneziani and Yoshihara (2015) and Cogliano et al. (2019) incorporate skills to Roemer (1982)'s general theory of exploitation and class, but the labor contract therein is costlessly enforceable and hence is complete, which is different from our labor discipline model based on incomplete contract framework.

Our model is also related to the skill-biased technological change literature such as Card and Dinardo (2002) who connects skill differential to income inequality. A power-biased technological change in Skott and Guy (2007) develops upon the skill-biased technological change model by incorporating the labor discipline framework. More specifically, our result on the wage inequality and skill premium well corresponds to the empirical evidences documented for the U.S. economy. The main explanation in the literature is an increase in the relative demand for skills driven by the skill-biased technical change such as computer and information revolution; see, e.g. Levy and Murnane (1992), Acemoglu (2002), etc. In comparison, the skill premium in our model is due to the wealth the skilled workers have, which allowed them to acquire costly skills in the first place and which also provides them with funds for consumption during unemployment and hence are the basis of their strong fallback position and bargaining power.

The rest of the paper is organized as follows. Section 2 presents a efficiency wage model with skill differentials along with the simulation exercise to numerically find the Nash equilibrium. Section 3 conduct simulation exercises to examine the degree of exploitation of higher-skilled and lower-skilled workers. Section 4 concludes the paper.

2 The model

The labor market described in this section extends the labor discipline model in Bowles (2004). The labor discipline model builds upon the idea that labor contract is incomplete in the sense that labor effort cannot be contracted as it is not verifiable and, when it is verifiable, it is not costlessly enforceable. In a principal-agent setup, employers and workers engage in a Stackelberg game with the employers the first mover and the workers the second mover. The incomplete contract and the sequential move give rise to a structure where the employers wield power over the workers to induce them to exert more labor effort. While workers are homogeneous in Bowles (2004)'s model, or most of the models in the literature, our model incorporates skill differentials and the workers with a certain skill level are employed in a certain industry.

2.1 The basic setup of the model

Consider an economy with a sufficiently large number of agents. Different groups of agents are endowed with different amounts of wealth, denoted by ω. There is the minimum required level of wealth, $\overline{\omega}$, to organize a capitalist production, and those whose wealth is greater than the threshold become an employer and hire workers, while those whose wealth is less become a worker.

The workers use their wealth in acquiring a skill as it incurs costs for education, training, etc. A more advanced skill is more costly to acquire than a less advanced skill is. With τ denoting the costs of education, training, etc. for acquiring a skill, it is expressed as $\tau = \tau(s)$ with $d\tau/ds > 0$. Workers do not spend all their endowments in acquiring a skill but leave some as rainy day funds for unemployment. Denoting the rainy day funds by $\widetilde{\omega}$, we get $\widetilde{\omega} = \omega - \tau$. Other than that, there is no saving as workers spend all their wages, and therefore the rainy day funds will not change unless the worker is unemploymed, when it will start to gradually decrease until she is employed again. $\widetilde{\omega}$ is the source of consumption during unemployment. We adopt the following assumption.

Assumption 1 *Let $\mathcal{W}$ be the set of all workers. For any $x, y \in \mathcal{W}$ such that $x \neq y$, if $\omega_x > \omega_y$, then (i) $s_x > s_y$ and (ii) $\widetilde{\omega}_x > \widetilde{\omega}_y$ hold.*

It means that the workers with greater wealth (i) acquire more advanced skills and (ii) have more rainy day funds and hence are still wealthier even after the expenditure for acquiring skills. In particular, assumption 1, (i) is motivated by the recent finding in Chetty et al. (2023) that in highly selective private colleges the share of students from high-income families is much greater than those from low-income families.

The rest of the agents with wealth greater than $\overline{\omega}$ become employers. Suppose a certain group of the employers is assigned to a certain industry, which employs workers with a certain skill level $s \in [0, 1]$. Consider a representative employer in a certain industry employing workers with skill level s. Each of her workers exerts per hour effort, $\varepsilon \in [0, 1]$, in response to the per hour wage rate, denoted by w, offered in the contract and the worker's fallback position is denoted by z. As will be examined more in detail below, z is an increasing function of s, i.e. a higher-skilled worker enjoys greater fallback position, hence $z = z(s)$ with $dz/ds > 0$. The contract is renewed every period with a certain probability. If not renewed, the worker becomes unemployed, which is her fallback position, and is replaced by an identical worker from the unemployment pool. The worker selects ε so as to maximize the present value of her expected lifetime utility of being employed.

The workers' best-effort response, $\varepsilon(w, z)$, is known to employers. The employer considers t percentage of their workers as shirking and terminate their contract. The probability of a worker's contract being terminated is assumed to be a negative function of her effort. That is, the harder you work, the less likely it is to be considered as shirking and get laid off; hence, $t(\varepsilon) \in [0, 1]$ where $dt/d\varepsilon < 0$. At the beginning of each period, the employer, to maximize profits, selects and announces w and t.

In sum, given a skill level s and hence the fallback position $z(s)$, both wage rate w and labor effort ε will be determined by the class relation between the workers and employers. The per-period utility function of a worker is expressed as

$$u = u(w(s, z(s)), \varepsilon(s, z(s))) \tag{1}$$

with $u_w > 0$, $u_\varepsilon < 0$, $u_{ww} \leqslant 0$, $u_{\varepsilon\varepsilon} \leqslant 0$. A simple version of the termination schedule is adopted as follows.

$$t = 1 - \varepsilon \tag{2}$$

2.2 Workers

With the worker's per-period utility function as in equation (1), and given a time preference rate r, the present value of expected lifetime utility of the worker is defined as

$$\begin{aligned} v &= \frac{u(w, \varepsilon) + (1 - t(\varepsilon))v + t(\varepsilon)z}{1 + r} \\ &= \frac{u(w, \varepsilon) - rz}{r + t(\varepsilon)} + z \end{aligned} \tag{3}$$

where the second equation uses the stationarity assumption. Note that $v - z = \frac{u(w,\varepsilon) - rz}{r + t(\varepsilon)}$ is the employment rent an employer has to grant workers in order to induce them to work at the desired level of labor intensity. The worker chooses ε that maximizes v. The first-order condition, $v_\varepsilon = 0$, yields

$$u_\varepsilon = t_\varepsilon(v - z) \tag{4}$$

Now let us examine fallback position. First of all, we can consider that there are some values of $\underline{\varepsilon}$ and $\underline{w}$ which yield $v(\underline{\varepsilon}, \underline{w}) = z$. That is, at this pair of labor effort and wage, the worker is indifferent between the job and her fallback position. The worker's fallback position is the present value of her lifetime utility of unemployment. As mentioned earlier, the unemployed have no income and they have to eat into their remaining wealth, which is their rainy day funds. Hence, the worker's per-period utility when unemployed is $u(b, 0)$ recalling that b is the per-period consumption during unemployment.

At the end of each period, an unemployed worker is hired back with probability λ, which we take as constant for now. Later, the endogenous determination of the the equilibrium level of λ will be discussed and incorporated into the model. Similarly to the definition of v in equation (3), z is defined as

$$\begin{aligned} z &= \frac{u(b, 0) + \lambda v + (1 - \lambda)z}{1 + r} \\ &= \frac{u(b, 0) + \lambda v}{r + \lambda}. \end{aligned} \tag{5}$$

As mentioned earlier, the source of b is the worker's rainy day funds, $\tilde{\omega}$, which is the wealth leftover after the expenditure for acquiring skill. Each worker has to decide the level of b and we assume that they all decide b in the following way.

$$u(b, 0) = su(w, \varepsilon) \tag{6}$$

That is, the worker with skill level s plans to consume b per period during unemployment such that her per-period utility during unemployment is identical to $s \times 100\%$ of her per-period utility during employment. As long as the per-period utility during employment is greater for a higher-skilled workers—which is the case as will be shown below—equation (6) yields that b will be greater for a high-skilled worker. In particular, the right-hand side highlights that higher skills lead to an increase in both consumption and utility during unemployment which, as will be discussed below, plays a central role in shaping the workers' bargaining power against their employers.

For instance, the workers with the highest skill, $s = 1$, are able to finance their consumption during unemployment to the extent that their per-period utility during unemployment is the same as their per-period utility during employment. In that case, the workers will not have to fear the possibility of getting fired as much as those with $s < 1$, i.e. those who are able to finance their consumption during unemployment to the extent that their per-period utility during unemployment is less than their per-period utility during employment. Thus, it is evident that they will have a greater bargaining power than the workers with $s < 1$. A similar comparison can be made regarding the bargain power among the workers within the entire spectrum of skill range.

To derive a closed form solution for v and z, we adopt a specification of the utility function similar to the one in Bowles (2004) as follows.

$$u = w - \frac{1}{w(1 - \varepsilon)} \tag{7}$$

which satisfies all the conditions imposed on the utility function in equation (1). Now, simultaneously solving equations (3) and (5) along with the utility function in equation (7) yields

$$v = \frac{[s(1 - \varepsilon) + r + \lambda][w^2(1 - \varepsilon) - 1]}{rw(1 - \varepsilon)(1 - \varepsilon + r + \lambda)} \tag{8}$$

$$z = \frac{[s(1 - \varepsilon + r) + \lambda][w^2(1 - \varepsilon) - 1]}{rw(1 - \varepsilon)(1 - \varepsilon + r + \lambda)}. \tag{9}$$

To see how skills affect the fallback positions for given ε, w, λ, and r, we verify the following holds.[4]

$$\frac{\partial z}{\partial s} = \frac{[w^2(1-\varepsilon)-1](1-\varepsilon+r)}{rw(1-\varepsilon)(1-\varepsilon+r+\lambda)} > 0 \tag{10}$$

It implies that higher-skilled workers have a greater fallback position than lower-skilled workers do. This relation is the main driver of the results we derive below. As an anticipation of the discussion, let us note that a greater fallback position provides the workers a stronger negotiation power vis-á-vis their employers than less skilled workers do.

Now, using equations (7), (8), and (9), with λ taken as given, we can solve the first-order condition in equation (4) to obtain the best effort response function, or labor extraction function, as for the worker with skill level s as follows.

$$\varepsilon = \frac{2(w^2-1) - s(2w^2-1) - \sqrt{(2-s)^2 + 4(1-s)(r+\lambda)w^2}}{2(1-s)w^2} \tag{11}$$

It can be verified that $d\varepsilon/dw < 0$ holds implying that by offering a higher wage rates as the rent the employer can extract more efforts from the workers, which is a typical result in the standard efficiency wage model. It will be shown below that this relationship between ε and w continues to hold in equilibrium where the equilibrium level of λ is considered.

2.3 Employers

We next turn to the employer. Knowing the workers' best response function, $\varepsilon = \varepsilon(w; s, \cdots)$ in equation (11), she decides the wages and the number of hired labor hour, denoted by L, to maximize profits in a competitive market for the output. Following Bowles (2004) we assume that production in all industries requires only labor inputs. Suppose the production function is

$$y = (s\varepsilon L)^{\beta}, \quad 0 \leq \beta \leq 1. \tag{12}$$

The profit is expressed as

$$\pi = py - wL. \tag{13}$$

The first-order conditions of the employer's optimization problem yield the solution for L as

$$L^* = \left(\frac{w^*}{\beta(s\varepsilon^*)^{\beta}}\right)^{\frac{1}{\beta-1}} \tag{14}$$

[4]Note that ε, w, and λ are all a function of s which therefore needs to be considered for the full description of the equilibrium relationship between s and z. As will be presented shortly, the positive correlation between the two remains true in equilibrium.

and the Solow condition,

$$\varepsilon_w = \frac{\varepsilon}{w} \tag{15}$$

which defines the Nash equilibrium, ε^* and w^*.

Once the equilibrium level of λ is incorporated, the the workers' best response function will not obtain analytically as in equation (11) but only implicitly. Therefore, we find the Nash equilibrium numerically by simulation exercises in the next section.

2.4 The Nash equilibrium

We need to first find the equilibrium level of the probability of the unemployed being hired in the next period. Suppose in every industry there are n identical employers, each of them employing L units of labor. Recalling that every employer in each period considers the t percentage of her workers as shirking and lays them off, the number of workers losing job measured in terms of labor hour is tnL and the total employment of labor hour is $(1-t)nL$. Since the labor supply, also in terms of labor hour, is normalized to unity, the total unemployment is $1-(1-t)nL$.

Then by definition, the probability of any unemployed finding a job in each period is expressed as

$$\lambda = \min\left\{\frac{tnL}{1-(1-t)nL}, 1\right\} \tag{16}$$

Substituting equation (2) and (14) into (16) yields the equilibrium level of λ as

$$\lambda = \min\left\{\frac{n(1-\varepsilon)\left(\frac{w}{\beta(s\varepsilon)^\beta}\right)^{\frac{1}{\beta-1}}}{1-n\varepsilon\left(\frac{w}{\beta(s\varepsilon)^\beta}\right)^{\frac{1}{\beta-1}}}, 1\right\} \tag{17}$$

Now, substituting equations (7), (8), (9), and (17) into equation (4) yields an implicit function as follows.

$$F(\varepsilon(w), w; \cdots) = 0. \tag{18}$$

in which the workers' best response function, $\varepsilon = \varepsilon(w; \cdots)$, is implicitly defined. Since the latter is not obtained analytically as in equation (11) any longer, we conduct simulation exericses to find it numerically. Figure 2 displays the result of simulating the workers best response function for various levels of skill, s, from 0.1 to 0.9 increasing by 0.1 along with the other parameters fixed at $n = 1$, $r = 0.1$, and $b = 0.7$.

Two things are noteworthy. First, the best response function is always increasing in w and concave, which implies that the employer has to offer higher wages to induce their

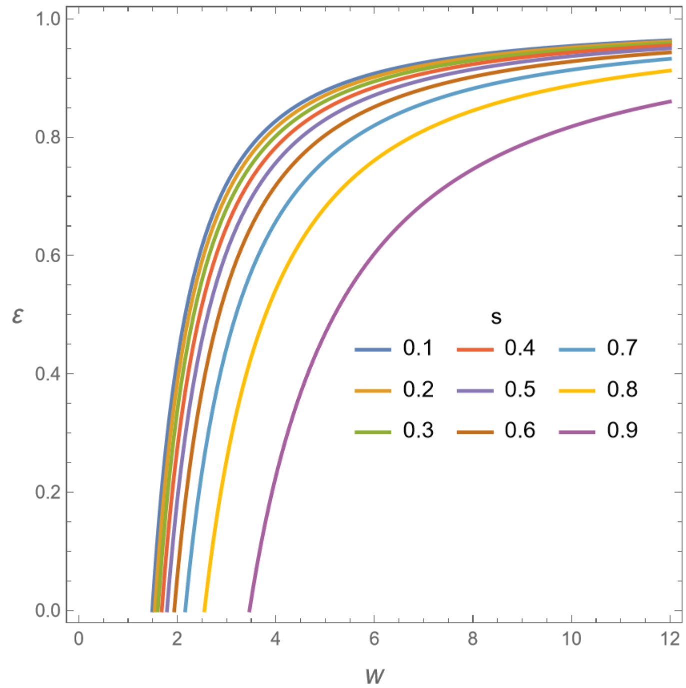


Figure 2: The simulation of the best response function for various levels of skills with the parameter values of $n = 1$, $r = 0.1$, $b = 0.7$

workers to exert more efforts, while the increase in wages required for an extra unit of effort is increasing. This is a standard result of the efficiency wage model, which in turn is partly due to the standard assumptions about the utility function adopted in equation (1).

Second, which is one of the essential findings of this paper, the best response function shifts to the southeast direction with higher skills. It means that the higher-skilled workers will be paid higher wages for the same effort, or they will work with less efforts for the same wages. Interestingly, the best response function shifts to a greater extent as the skill level becomes higher. These properties related to the shift of the best response function with respect to skill change are a direct consequence of the relationship between skill and fallback position, which will be discussed more in detail below.

With the best response function, $\varepsilon = \varepsilon(w; \cdots)$, numerically derived as above, the Nash equilibrium can also be found numerically. Since the Nash equilibrium is defined by the Solow condition in equation (15), graphically it is the tangent point between the best response function and the ray from the origin as shown in figure 3. It visualizes a series of Nash equilibrium each indicated by a dot and corresponding to a certain skill level. It is immediately visible from the trajectory of the shift in the Nash equilibrium that an increase in skill leads to a fall in labor effort and an increase in wage. Figure 4 shows this more in

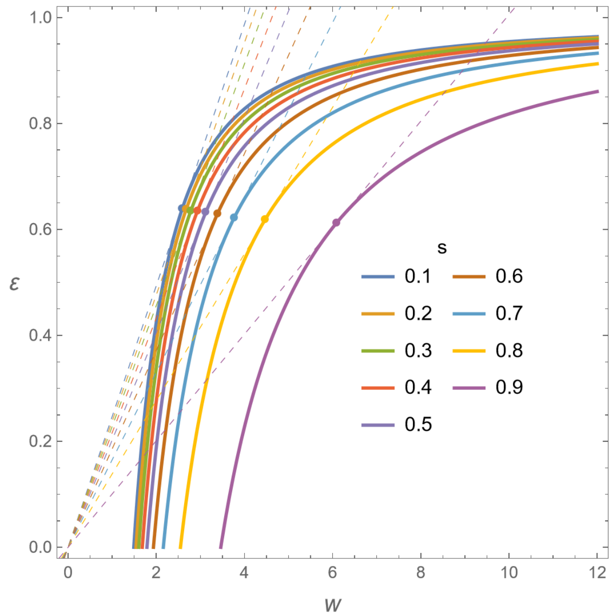


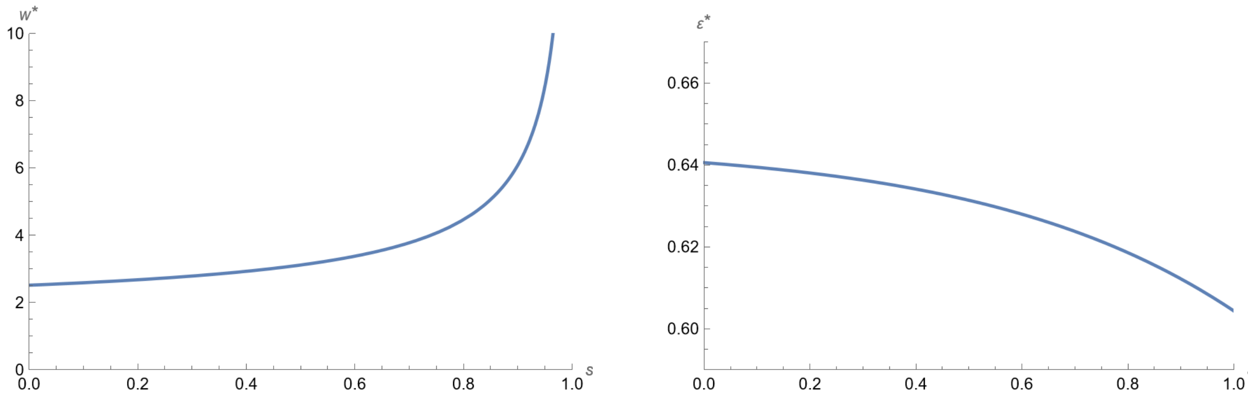
Figure 3: The simulations of Nash equilibrium for different levels of skills with the parameter values of $n = 1$, $r = 0.1$, $b = 0.7$

focus, plotting each of w^* and ε^* separately against s.

Figure 4a displays a positive correlation between wages and skills, implying that the skill premium is positive and hence the higher-skilled workers will enjoy higher wages. More interestingly, the relation between skills and wages is strongly convex. That is, while the wage increases at a slowly increasing rate until the skill is at around the 80 percentile, it starts to kick-off thereafter, further accelerating drastically from the 90 percentile and exploding at the upper limit, $s = 1$.

Next, figure 4b shows a negative correlation between skills and efforts, implying that higher-skilled workers work less intensively than lower-skilled workers do. Similarly to the case of the skill-wage relation, the skill-effort relation is also convex. That is, while the effort decreases as skill increases, it decreases at an increasing rate, which suggests that the amount of effort saved by the higher-skilled workers is greater as skill gets higher. In all, the higher-skilled workers are paid more while working with less labor intensity, and this relation gets progressively strengthened as skill gets higher.

These properties of the Nash equilibrium, w^* and ε^*, in relation to skill reflect the greater bargaining power of higher-skilled workers, which in turn is a direct consequence of the correlation between fallback position and skill. To see this, first note the iso-value curves for the worker as displayed in figure 5 with $v_0 < v_1 < v_2 < v_3 < v_4$ from which the best response function is derived by connecting all the points on an iso-value curve where the slope of the



(a) Wages for different skills

(b) Efforts of different skills

Figure 4: The simulations of the wages and efforts in equilibrium with the parameter values of $n = 1$, $r = 0.1$, $b = 0.7$

curve is vertical. Also note from equation (3) that v is positively correlated with the fallback position, $z = u(\underline{w}, \underline{\varepsilon}) = v_0$. Then an increase in z will shift all the iso-curves to the right, thereby moving the best response function to the right as well.

Therefore, as long as we confirm the positive correlation between skill and fallback position in equilibrium, we would be able to establish the connection of the rightward shift of best response functions to an increase in skill. In this context, figure 6b simulates the skill-fallback position relationship, which is obtained by substituting the Nash equilibrium, $w^*(s)$ and $\varepsilon^*(s)$, into the solution for z in equation (9) with the equilibrium value of λ in equation (17) incorporated. It is evident from the figure that higher-skilled workers enjoy a greater fallback position.

Also note that one important linkage between skills and fallback positions is the probability of getting (re)hired, λ for the unemployed. As can be verified in equation (9), the fallback position z is a positive function of λ. The equilibrium level of λ derived in equation (17) can be simulated against skill. The result is displayed in figure 6a, which demonstrates that higher-skilled workers have a higher chance of getting (re)hired when unemployed. This is another factor that positively affects the higher-skilled workers' fallback position thereby enhancing their bargaining power.

From all this it follows that an increase in skill makes the fallback position greater which shifts the best response function of the worker to the right, thereby bringing the Nash equilibrium to the southeast where the wage is higher and the effort is lower. More interesting about the skill-fallback position relationship in figure 6b is that z increases at a slowly

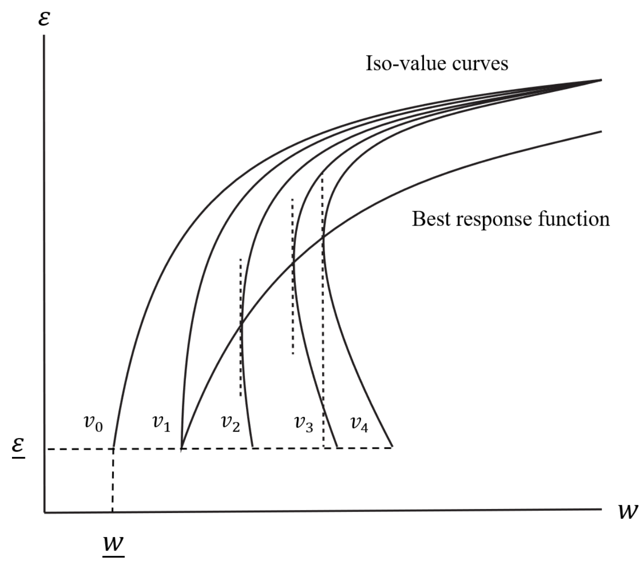


Figure 5: The derivation of the best response function from the iso-value map

increasing rate up until when s is at around the 80th percentile, after which it speeds up reaching a precipitous rate when s is at around the 90th percentile and beyond. This strongly convex relationship is directly reflected in the skill-wage relationship, which exhibits a similar pattern as shown in figure 4a.

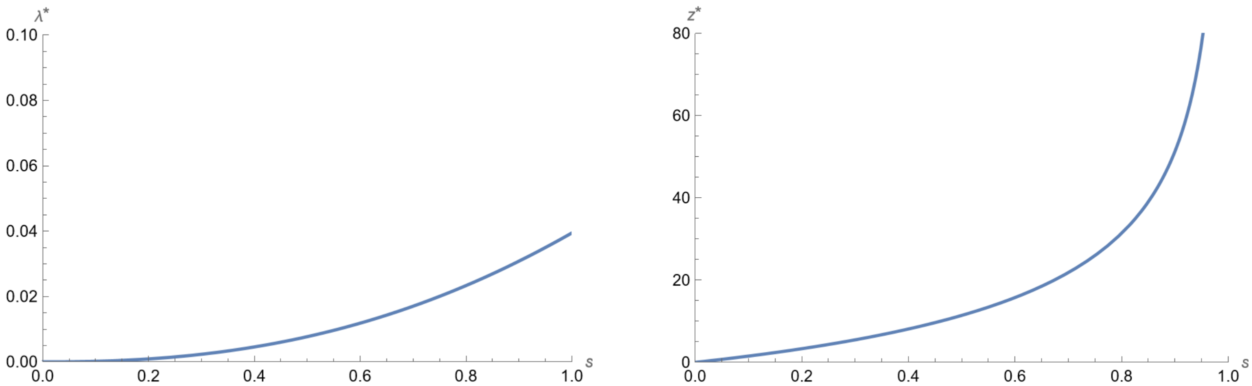
We summarize the central result of simulation exercises thus far as follows.

Result 1 (The simulation of the Nash equilibrium in figure 4) *Within the context of the model with the parameter values of* $n = 1$, $r = 0.1$, $b = 0.7$, *it holds that*

(i) the higher (lower) the skill the higher (lower) the wage;

(ii) the higher (lower) the skill the lower (higher) the effort.

Let us highlight that the main driver of Result 1 is the correlation between the fallback position and skill. In this model, the fallback position is the source of the worker's bargaining power. Therefore, the central message thus far is that the higher-skilled workers have a greater fallback position and thus have a stronger negotiation power against their employers, which enabled them to get paid higher and work less intensively compared to the lower-skilled workers. Then does this mean that the higher-skilled workers are exploited to a lesser degree than the lower-skilled workers are?



(a) The probability of getting (re)hired

(b) The fallback position

Figure 6: The simulation of fallback position and the probability of getting (re)hired with the parameter values of $n = 1$, $r = 0.1$, $b = 0.7$

3 The degree of exploitation

As a way to examine who are better-off between higher-skilled and lower-skilled workers in terms of both wages and efforts, we employ the concept of exploitation. And we adopt the theory of exploitation as an unequal exchange of labor, which suggests that exploitation is defined in terms of differences between the amount of labour an individual agent supplies to the economy and the amount of labor she receives, with the amount of labor defined in some relevant sense. More specifically, we characterize exploitation as the relation between agents' contribution to production in terms of the amount of effective labor and what they receive as compensations.

In terms of our model, recall that the agents whose wealth is less than the minimum required level to become a capitalist become a worker and the rest whose wealth is greater than that become a capitalist and hire others. Each and every agent, whether a worker or an employer, can be said to be engaging in economic activities of spending a certain amount of effective labor, denoted by $\Lambda \equiv s\varepsilon L$, and receiving a certain amount of income, denoted by I. Thus far we have focused only on economic activities of employees whose labor L is wage labor and income is wages, i.e. $I \equiv wL$. Now we also consider economic activities of employers. Their labor L would be managerial labor and the income is profits; it is possible that the capitalist hires managers and does not work at all, in which case her labor is zero.

Suppose all employers are exploiters and all employees are exploited.[5] Then the ratio be-

[5]Roemer (1982) has proved the correspondence between class and exploitation, called Class Exploitation Correspondence Principle (CECP), according to which an agent's class position depends on her wealth and

tween the wage income and the effective labor, i.e. $\Lambda/I = s\varepsilon L/wL = s\varepsilon/w$ can be considered as providing information on the degree of exploitation. And since ε and w are a function of s, workers with different skills will have different ratios of $s\varepsilon/w$.

In this context, as a way to compare the degree of exploitation each skill type of workers may experience in her workplace, we propose two different measures. First is the ratio between effort and wage,

$$\frac{\varepsilon}{w} \tag{19}$$

which we call labor discipline, following Yoshihara (1998), or a effort-wage ratio. Within the context of the labor discipline model, it measures the labor effort an employer can extract from each of her workers for unit wage. If it is higher, it implies a greater power of the employer and a stronger labor discipline imposed on her workers, and vice versa; or, it implies a greater hardship or exhaustiveness per unit wage a worker experiences physiologically and mentally as a human being regardless of how high or low her labor skill is.

In a model without skill differentials among the workers, ε/w would be sufficient to compare the effort per wage across workers since the same amount of effort by different workers would contribute to production to the same extent. In our model with skill differentials, however, the same amount of efforts workers with different skill levels do not make the same contribution to production. Hence, depending on what aspect of exploitation is to be measured, labor discipline that considers skill may be more proper. It is defined as

$$\frac{s\varepsilon}{w} \tag{20}$$

and we call it skill-adjusted labor discipline, or a skill-adjusted effort-wage ratio.

The difference between the two alternative measures of the degree of exploitation can be understood as follows. On one hand, the effort-wage ratio treats a high-skilled worker's unit effort and that of a low-skilled worker equal, presupposing that the same amount of effort will give the same amount of exhaustiveness, physiologically and mentally, to both high-skilled and low-skilled workers as a human species. Hence, labor discipline takes more of a perspective of workers and measures the exhaustiveness per wage each of them experiences. On the other hand, from the perspective of an employer, a high-skilled worker's unit effort and that of a low-skilled worker are not the same thing since the former can make a greater contribution to production than the latter can. Hence, skill-adjusted labor discipline takes more of a perspective of the employers and measures the workers' contribution to production per wage.

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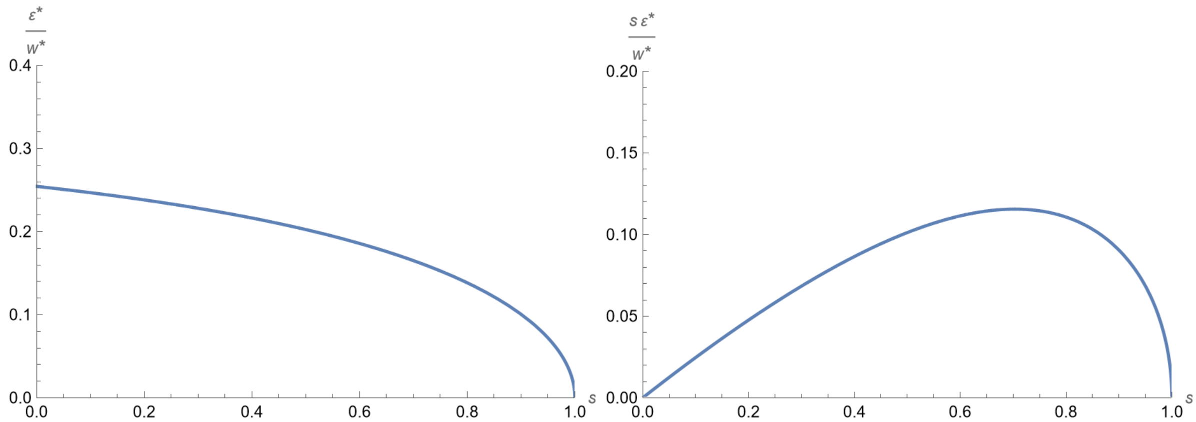
those who hire others (capitalists) are an exploiter and those who are hired by others (proletariat) are exploited



(a) Labor discipline

(b) Skill-adjusted labor discipline

Figure 7: The simulations of labor discipline and skill-adjusted labor discipline with the parameter values of $n = 1$, $r = 0.1$, $b = 0.7$

In all, an increase (decrease) in the effort-wage ratio, or labor discipline, implies that the workers experience a greater (less) hardship and exhaustiveness per wage, while an increase (decrease) in the skill-adjusted effort-wage ratio, or the skill-adjusted labor disciplines, implies that the workers make greater (lesser) contribution to production per wage. In either case, an increase (decrease) in the ratio means that the workers are exploited to a greater (lesser) degree.

Now, using the simulation results for the Nash equilibrium we can plot the distribution of the two measures of the degree of exploitation across skills. The results are reported in figure 7. According to figure 7a, the higher-skilled workers experience weaker labor discipline and the lower-skilled workers stronger labor discipline. This result is consistent with figures 4a and 4b where w is increasing and ε is decreasing against s; hence, the decrease in the ratio between ε and w. Furthermore, the convexity of both w and ε and especially the drastic surge in w towards the top percentile of s are all reflected in the convex shape of the ε-w ratio, which reaches zero in case of the skill at its upper bound, i.e. $s = 1$; the latter is definitely an interesting result and we will come back to this shortly for more discussion.

It can also be verified graphically from figure 3, where the ε/w line—the tangent line—for each best response function curve is getting flatter as the best response function shifts towards right, recalling that a rightward shift of the labor extraction function is due to an increase in s and hence an increase in the fallback position.

Before turning to the distribution of the skill-adjusted effort-wage ratio, examining some analytics behind will be helpful in understanding the result. Note that since both w and ε are a function of s, the effort-wage ratio itself is also a function of s. But since we already know from figure 7a that the effort-wage ratio is negatively correlated to s, how the skill-adjusted effort-wage ratio will vary depending on s can be examined as follows.

$$\frac{\partial\left(\frac{s\varepsilon}{w}\right)}{\partial s} \gtreqless 0 \Longleftrightarrow -\frac{\partial\left(\frac{\varepsilon}{w}\right)/\left(\frac{\varepsilon}{w}\right)}{\partial s/s} \gtreqless 1 \tag{21}$$

The above relation suggests that the distribution of skill-adjusted labor discipline across different skill levels depends on the skill-elasticity of the labor discipline. That is, if an 1% increase in s leads to less than 1% decrease in the ε-w ratio, the skill-adjusted ε-w ratio will exhibit a positive correlation with s, but if it leads to more than 1% decrease in the ε-w ratio, the skill-adjusted ε-w ratio will exhibit a negative correlation with s, and if it leads to the exact 1% decrease in the ε-w ratio, the skill-adjusted ε-w ratio's correlation with s will be zero.

The distribution of skill-adjusted ε-w ratio is reported in figure 7b. It is interesting that the ratio is exhibiting an inverted u-shape, i.e. it is slowly increasing at a decreasing rate up until the skill is at around the 80th percentile, after which it declines precipitously, eventually reaching zero when $s = 1$. In terms of the elasticity relation in equation (21), in the range of s from zero to around the 80th percentile, the ε-w ratio declines inelastically as s increases while in the range of s from the 80th to 100th percentile, the ratio declines elastically. Similar to the convex shape of the ε-w ratio, the convex shape of the skill-adjusted ε-w ratio is also caused by the convex shapes of w and ε as displayed in figure 4.

Note that both the workers at the low end and those at the high end of the skill distribution similarly experience the lowest skill-adjusted effort-wage ratio among all the workers. However, the weak skill-adjusted labor discipline—and hence a low degree of exploitation—experienced by the low end workers, on the one hand, is *due to* their low skills and hence modicum contributions to production, meaning that they do not produce much value to be exploited in the first place. On the other hand, the weak skill-adjusted labor discipline—and hence a low degree of exploitation—experienced by the high end workers is of different nature; it is *despite* their high skills and hence huge contributions to production, meaning that they produce a great amount of value available to be exploited but their degree of exploitation is low due to their strong negotiation power.

We summarize the results of simulation in figure 7 as follows.

Result 2 (The simulations on the degrees of exploitation in figure 7) *Within the context of the model with the parameter values of* $n = 1$, $r = 0.1$, $b = 0.7$, *it holds that*

(i) *the higher (lower) the skill the weaker (stronger) the labor discipline, and the workers with the highest skill, $s = 1$, experiencing zero labor discipline;*

(ii) *when the range of s is from zero to around the 80th percentile, the higher-skilled workers experience stronger skill-adjusted labor discipline, while when the range of s is from around the 80th to the 100th percentile, an increase in skill leads to a lesser skill-adjusted labor discipline, and the workers with the highest skill, $s = 1$, experiencing zero skill-adjusted labor discipline.*

Result 2, (i) implies, on the one hand, that the lower-skilled workers persistently experience more hardship and exhautiveness per wage, both physiogically and mentally, compared to the higher-skilled workers. In this sense, the lower-skilled workers can be said to be more exploited than the higher-skilled workers in terms of the effort-wage ratio.

On the other hand, result 2, (ii) implies that in the skill range from zero to around the 80th percentile the higher-skilled workers' contribution to production per wage is greater than the lower-skilled workers' case, but when it comes to the top quintile group, an increase in skill leads to a decline in the degree of exploitation. In other words, there is a certain threshold level of skill—around 80th percentile in the simulation—below which the higher-skilled workers can be said to be more exploited than the lower-skilled workers in terms of the skill-adjusted labor discipline, but after which the degree of exploitation for the super-higher-skilled workers declines at a drastic rate.

Another interesting result is that as the skill approaches to its upper bound, $s = 1$, the degree of exploitation converges to zero in terms of both measures, i.e. the effort-wage ratio and the skill-adjusted effort-wage ratio, eventually reaching exactly zero when $s = 1$. An implication is profound. There is a certain threshold level of skill close to $s = 1$ after which the workers are hardly exploited, and in the case of exactly $s = 1$ they are not exploited at all. In this sense, one may ask whether such workers can be considered as members of the working class.

Then what type of workers fall in this group, equipped with (close to) *the* highest level of skill and experience (close to) zero degree of exploitation? Most plausibly, those skills that are related to the activities capitalists are supposed to conduct such as management, enterprenuerial activities, and monitoring workers, etc. would be deemed the most desired and valuable skill in a capitalist economy and those workers hired to perform these activities on behalf of the capitalist-owners would be the ones who are difficult to be considered as members of the working class according to the standard class analysis. In fact, most of the literature on top income and top-end inequality consider managerial skills as among the top. Relatedly, although this is not a place to have a in-depth discussion, worth noting is Dumenil and Levy (2018)'s thesis of managerial capitalism that considers the conventional two–class approach to capitalism as outdated and introduces the managerial class as the third class.

4 Conclusion

Against a background of observed data of growing wage inequality between high-skilled and low-skilled workers, we presented the efficiency wage model embedded in a multi-sector setup with skill differentials to compare the welfare of the workers of different skills in terms of exploitation. We employed two different measures of the degree of exploitation, the effort-wage ratio and the skill-adjusted effort-wage ratio. According to the former, on the one hand, higher-skilled workers are persistently better-off in terms of exploitation than lower-skilled workers. On the other hand, however, according to the latter measure, it depends on the skill level. When the range of skill is from zero to around 80th percentile, lower-skilled workers are better-off in terms of exploitation than higher-skilled workers but for the top quintile of skill, higher-skill leads to a significant decline in the degree of exploitation.

For majority of the skill levels ranging from zero to around the 80th percentile, the relation between skill and exploitation is the opposite for the two measure of the degree of exploitation. In this range of skill level, the lower-skilled workers have to exert more effort per wage and hence experience more exhaustiveness physiologically and mentally as a human species than the higher-skilled workers, but the higher-skilled workers can be said to be more exploited in the sense that their contribution to production per wage is greater than that of the lower-skilled workers. In contrast, for the top quintile group of very high skill levels, super-higher-skilled workers are better-off than simply-higher-skilled workers in terms of both experiencing much less exhaustivness per wage and making much less contribution to production per wage.

More research is needed to be done to better understand how the threshold that yields the top skill group is determined—around the 80th percentile in our simulation results—and the nature of this group of workers in terms of exploitative relations. For instance, examining variations in the way the per-period consumption b during unemployment is determined, which may affect the workers' fallback positions and hence their bargaining power, could be helpful in understanding the factors that affect the determination of the threshold. An empirical analysis of the relationship among skill, effort, and wage within the framework of the current paper would be an interesting application. This, however, faces a challenge of data availability for skill and effort. We leave these for future discussion.

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