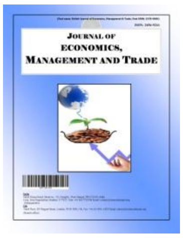

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Environmental Tax and Wage Inequality when Pollution Impacts Health or Agricultural Productivity in Developing Economy

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Many developing countries face severe environmental pollution and the preservation policy, such as the environmental tax, is widely adopted by many governments. This paper investigates the impacts of an increase in environment tax on wage inequality between skilled and unskilled labor when pollution affects labor health or agricultural productivity. We first build a basic model and assume pollution affects labor health and drives parts of labor out of the factor market. And we obtain that the elasticity of substitution between labor and dirty input in the unskilled sector determines the result of an increase in environmental tax on wage inequality. And when skilled and unskilled labor raise its cost of self mitigation, wage inequality will be narrowed down.The robustness of the basic model on the impact of a stricter environmental protection and the self-mitigation cost of unskilled labor is substantiated by the extended model that incorporates the bad externality of pollution on agricultural production; however, the impact of increased cost of mitigation of skilled labor on wage gap in the extended model is different, depending on the elasticity of pollution.

Keywords: Environmental tax; self-mitigation cost; wage inequality.

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1. INTRODUCTION

Wage gap between skilled labor and unskilled labor in developing economy has received plentiful attention from theoretical scholars. Previously, scholars explained this phenomenon from international trade and international factor mobility [1-3]. Recently, scholars have described the rising wage gap from domestic factors aspect and established various models to explore the impact of domestic factors on wage inequality. For example, Chao et al. [4] considered this issue from privatization of state owned enterprises, Pi and Chen [5] and Beladi et al. [6] investigated the effect of capital market distortion on wage gap, Chao et al. [7] described this issue from minimum wage aspect. Regarding to environment and pollution perspective, Pi and Zhang [8] used pollution quantity control to explain this phenomenon, Wang [9] analyzed the impact of manufacturing and agricultural pollution control on wage gap.

Meanwhile, many developing countries also face severe environmental pollution in the form of air and water pollution. Pollution generates a greater negative influence on the economy as the worse the pollution. In view of the huge cost, the government enacted environmental regulations to combat pollution. In this study, we examine the issue of wage inequality but offer a different mechanism. The paper considers environmental tax and skilled and unskilled labor self-mitigation cost (the cost to cure the negative effect exerted by pollution) into a general equilibrium model. The justifications for accommodating these two domestic factors are twofold. First, the industrialization of the developing world is creating unsustainable industrial pollution and developing countries, in general, are facing the severe environmental problem. Taxation from polluted sector is a common environmental policy to address this problem. And its impacts are also investigated by many scholars [10,11]. However, existing literature on the environmental tax ignores to analyze wage inequality issue, and thus neglects to analyze the impact of the environmental tax on the wage gap. Second, the fact that increasingly serious pollution poses a threat to labor health has become more pronounced[1].People have to invest more money and time to prevent or cure the bad effect generated by pollution. Existing literature on the negative externality of pollution in developing countries focuses on the negative externality on agricultural productivity [8,12]. And scholars give little attention to its effect on labor health. Therefore, we need to answer when pollution affects labor health, how a change of self-mitigation cost affects wage inequality.

To answer the issues mentioned above, we build three-sector general equilibrium models to analyze how an increase in environmental tax and skilled and unskilled labor self-mitigation cost on wage gap. We first build a basic model and assume pollution affects labor health and drives parts of labor out of the factor market. And we obtain that the elasticity of substitution between labor and dirty input in the unskilled sector determines the result of an increase in environmental tax on wage inequality. And when skilled and unskilled labor raise its cost of self mitigation, wage inequality will be narrowed down.The robustness of the basic model on the impact of a stricter environmental protection and the self-mitigation cost of unskilled labor is substantiated by the extended model that incorporates the bad externality of pollution on agricultural production; however, the impact of increased cost of mitigation of skilled labor on wage gap in the extended model is different, depending on the elasticity of pollution.

It is worth mentioning that Wang [9] also analyzed the impacts generated by pollution control and skilled and unskilled labor self-mitigation cost on the wage gap with consideration of the negative externality of pollution. Main differences between this paper and Wang [9] are reflected mainly in the treatment of agricultural pollution and agricultural input factor. Wang [9] not only considered manufacturing pollution but also incorporated agricultural pollution. Agriculture employs unskilled labor and pollutant factor. However, the land is ignored in agricultural production. In reality, the land is an essential factor for agricultural production. In addition, Wang [9] established a complex general equilibrium model to analyze an increase in tax rate and agricultural pollutants control on wage rate and wage inequality. However, this paper shows that even if we simplify the theoretical model, we still obtain similar results with similar mechanisms.

The remaining parts of this paper are organized as follows. We establish a basic model with three sectors in Section 2 and investigate the impacts of an increasing in environmental tax and skilled

[1] *We could not accurately estimate this data. Here, we give one data from WHO. And detailed description could refer to http://www.who.int/phe/health_topics/outdoorair/databases/cities/en/*

and unskilled labor self-mitigation cost on wage gap. In Section 3, we incorporate the negative externality of pollution on agricultural productivity . Concluding remarks are provided in Section 4.

2. BASIC MODEL AND ANALYSIS

2.1 Theoretical Model

Following literature of wage gap in a dual economy, we investigate this issue under a small open economy. The assumed economy has three sectors: a skilled sector (sector 1), an unskilled sector (sector 2) and an agricultural sector (sector 3). The skilled sector and unskilled sector locate in the urban region. Skilled labor L_{S1} and capital K_1 are input factors in sector 1, which produces an exportable good X_1 . Unskilled labor L_{U2} , capital K_2 and dirty input *D* are utilized by sector 2, which produce an import-competing good X_2 [2]. Sector 3 employs unskilled labor L_{U3} and land *T* to produce an agricultural good X_3 . To reflect the backward agriculture in developing countries, sector 3 only uses traditional input and capital is not input factor in this sector. Two urban sectors are advanced sector and capital could move freely between two sectors. Due to labor union or other reason, unskilled labor market faces distortion, and wage rate of unskilled labor in the urban region is downward rigid. Here we discuss the difference between two urban sectors. The skilled sector mainly refers to high-end manufacturing which needs expertise and skilled labor in production, while traditional manufacturing, like plastic material, chemical, could be classified as an unskilled sector. In the setting, labor is heterogeneous and capital could mobile between sectors. Such assumptions are strongly backed by the fact that high-end and traditional manufacturing still coexists by using different ability employees but having access to similar sources of capital. Generally, due to high skill, skilled labor face no unemployment. However, because of the rigid wage rate in the urban region, unskilled labor encounters unemployment. Since unskilled labor receives different wage rate, unskilled labor market exists labor migration. And rural labor migration satisfies the Harris-Todaro equilibrium condition [13][3]. Production functions of three sectors are $X_1 = F^1(L_{S1}, K_1)$, $X_2 = F^2(L_{U2}, K_2, D)$, and $X_3 = F^3(L_{U3}, T)$, where these functions satisfy strict quasi-concavity and linear homogeneity properties. Following Pi and Zhang [8] and Wang [9], there is no dirty input market.. The price of dirty input is the environmental tax ρ . For simplicity, we assume all the goods and factor markets are perfectly competitive, except the unskilled labor market. Set agricultural price as numeraire, price-unit cost equality conditions relating to three sectors are given by:

$$p_1 = a_{S1} w_S + a_{K1} r \quad (1)$$

$$p_2 = a_{U2} \bar{w}_U + a_{K2} r + a_{D2} \rho \quad (2)$$

$$1 = a_{U3} w_U + a_{T3} \tau \quad (3)$$

where relative price of sector 1 (sector 2) is p_1 (p_2) .Under the small open economy assumption, all three goods prices are constant. $a_{ij} (i = S, U, K, D, T; j = 1, 2, 3)$ is the amount of factor *i* employed to produce unit of good *j* in sector *j*. w_S expresses wage rate of skilled labor. $\bar{w}_U$ is urban minimum wage rate of unskilled labor, which is downward rigid. w_U denotes the elastic wage rate of unskilled labor in the rural region. Note that $\bar{w}_U$ is higher than w_U ,which generates rural labor migration. r is the interest rate of capital. τ indicates the rent of land. ρ represents the price of dirty input.

Set $\lambda = L_{UU} / a_{U2} X_2$,and λ denotes the Harris-Todaro type unemployment rate.

The unskilled labor migration equilibrium condition is

$$w_U \left(1 + \lambda\right) = \bar{w}_U \quad (4)$$

Among three sectors, only unskilled sector generates pollution. And assume that production of unskilled sector emits pollution. δ is a positive

[2] *We assume the polluted sector employs dirty input during production process. This approach could refer to Yohe [14], Yu and Ingene [15], Beladi and Frasca [16], Daitoh [17].*

[3] *Harris and Todaro [13] described a model of migration in which a long-run equilibrium is characterized by the existence of urban unemployment in dual economy. Since the model matches the existence of unemployment in the urban region, many papers employ this model to investigate issues in developing countries.*

parameter and this parameter denotes the generation rate of pollution, and $0<\delta<1$. Thus, total pollution is $E=\delta X_2$. Pollution affects health of both skilled and unskilled labor. Following Williams [10] and Wang [9], the negative impact of pollution on labor health is expressed by reducing total labor amount. Specifically, pollution E loses $t_S E$ and $t_U E$ amounts of skilled and unskilled labor away from the endowment of skilled and unskilled labor, respectively. $t_i(i=S,U)$ is a positive parameter and determines the effect of pollution on *i* type labor.Therefore, this parameter indicates self-mitigation cost of *i* type labor. An increase in t_i indicates a greater effect of pollution on labor health. The conditions of skilled and unskilled labor market are:

$$a_{S1}X_1=L_S-t_S E \tag{5}$$

$$(1+\lambda)a_{U2}X_2+a_{U3}X_3=L_U-t_U E \tag{6}$$

$$a_{K1}X_1+a_{K2}X_2=K \tag{7}$$

$$a_{T3}X_3=T \tag{8}$$

where L_S , L_U ,*K*,*T* are the endowment of skilled labor, unskilled labor, capital and land, respectively. Noting that urban unemployment is $L_{UU}=\lambda a_{U2}X_2$, the first item in equation (4) $(1+\lambda)a_{U2}X_2$ expresses the total unskilled labor in the urban region.

Following Beladi et al. [1] and Li and Xu [12], we uses the skilled labor wage and the average wage of unskilled labor, as well as their relative change to address the issue concerning the skilled-unskilled wage gap. Using (4) and (6), the average wage of unskilled labor is w_U .

So far, the theoretical model has been established. Eight endogenous variables, w_S , w_U , r , τ , λ , X_1 , X_2 and X_3 , are determined by equation (1)–(8).

2.2 Comparative Analysis

Now, under the framework, we analyze the impacts of an increase in *ρ* on the wage gap, which is summarized by Proposition 1.

Proposition 1: Suppose the share of exited skilled labor is not large. An increase in environmental tax brings a reduction of the wage gap if the elasticity of substitution between labor and dirty input in the polluted sector is large enough; however, the wage gap will be expanded if the elasticity of substitution is small enough.

Proof: We divided the system into two sub-systems. Equation (1), (2), (5) and (7) constitute a sub-system that decides four endogenous variable: w_S , r , X_1 ,and X_2 . Totally differentiating equation (1), (2), (5) and (7), we obtain these results:

$$\frac{\hat{w}_S}{\hat{\rho}}=\frac{\theta_{K1}\theta_{D2}}{\theta_{S1}\theta_{K2}}>0,\ \frac{\hat{r}}{\hat{\rho}}=-\frac{\theta_{D2}}{\theta_{K2}}<0,$$

$$\frac{\hat{X}_1}{\hat{\rho}}=\frac{\lambda_{ts}\theta_{D2}\Psi_1-\lambda_{K2}\Psi_2}{\Delta_1}$$

And

$$\frac{\hat{X}_2}{\hat{\rho}}=\frac{\lambda_{K1}\Psi_2-\lambda_{S1}\theta_{D2}\Psi_1}{\Delta_1}$$

where "∧" denotes the relative rate of change (e.g., $\hat{w}_S=dw_S/w_S$), $\Delta_1=\lambda_{K1}\lambda_{ts}-\lambda_{K2}\lambda_{S1}$, $\Psi_1=-\left[\lambda_{K1}\sigma_{SK}^1+\lambda_{K2}(\theta_{D2}\sigma_{KD}^2+\theta_{K2}\sigma_{KD}^2+\theta_{U2}\sigma_{UK}^2)\right]/\theta_{K2}<0$, $\Psi_2=\lambda_{S1}\theta_{D2}\theta_{K1}\sigma_{SK}^1/\left(\theta_{K2}\theta_{S1}\right)>0$. θ_{ij} (*i*=*S*,*U*,*K*,*D*,*T*; *j*=1,2,3) is the distributive share of factor *i* employed in sector *j* (e.g. $\theta_{K1}=a_{K1}r/p_1$), λ_{ij} indicates the allocative share of factor *i* in sector *j* (e.g. $\lambda_{U3}=a_{U3}X_3/L_U$), $\lambda_{ts}=t_S E/L_S$ is share of exited skilled labor, σ_{ij}^h (*i*, *j*=*S*,*U*,*K*,*D*,*T*; *h*=1,2,3) represents the elasticity of substitution between factors *i* and *j* in sector *h*.

By calculation, we could not determine the sign of Δ_1. To obtain the sign of Δ_1, we assume an inequality $\lambda_{S1}/\lambda_{K1}>\lambda_{ts}/\lambda_{K2}$ holds. Note that λ_{ts} is the share of exited skilled labor caused by the unskilled sector, which is be viewed as the skilled labor "employed" by the unskilled sector. And in this perspective, we call $\lambda_{ts}/\lambda_{K2}$ as the per capita capital of the skilled labor in unskilled sector. $\lambda_{S1}/\lambda_{K1}$ expresses the per capita capital of the skilled labor in skilled sector. And the inequality means the per capita capital of the skilled labor in skilled sector is larger than the per capita capital of the skilled labor in the unskilled sector. Considering the reality, λ_{ts} is relatively small and this assumption is easily satisfied . Therefore, we have $\Delta_1 < 0$, $\hat{X}_1/\hat{\rho} > 0$ and $\hat{X}_2/\hat{\rho} < 0$.

Totally differentiating equation (3), (4), (6) and (8),

$$\left\{(1+\lambda)\lambda_{U2}\theta_{D2}(\sigma_{UD}^2-\sigma_{UK}^2)+(\lambda_{K1}\Psi_2-\theta_{D2}\lambda_{S1}\Psi_1)[(1+\lambda)\lambda_{U2}+\lambda_{tu}]/\Delta_1\right\}\hat{\rho}$$
$$-\lambda_{K1}\lambda_{ts}[(1+\lambda)\lambda_{U2}+\lambda_{tu}]/\Delta_1\hat{t}_S+\lambda_{tu}\hat{t}_U=[(1+\lambda)\lambda_{U2}+\sigma_{UT}^3\lambda_{U3}/\theta_{T3}]\hat{w}_U \quad (9)$$

where $\lambda_{tu} = t_U E/L_U$ is share of exited unskilled labor. Substitution relevant results into (9), we have

$$\frac{\hat{w}_U}{\hat{\rho}} = \frac{\theta_{T3}\left\{(1+\lambda)\lambda_{U2}\theta_{D2}(\sigma_{UD}^2-\sigma_{UK}^2)+(\lambda_{K1}\Psi_2-\theta_{D2}\lambda_{S1}\Psi_1)[(1+\lambda)\lambda_{U2}+\lambda_{tu}]/\Delta_1\right\}}{(1+\lambda)\lambda_{U2}+\sigma_{UT}^3\lambda_{U3}/\theta_{T3}}$$

and

$$\frac{\hat{w}_S-\hat{w}_U}{\hat{\rho}} = \frac{\theta_{K1}\theta_{D2}}{\theta_{S1}\theta_{K2}} - \frac{\theta_{T3}\left\{\begin{array}{l}(1+\lambda)\lambda_{U2}\theta_{D2}(\sigma_{UD}^2-\sigma_{UK}^2)\\+(\lambda_{K1}\Psi_2-\theta_{D2}\lambda_{S1}\Psi_1)[(1+\lambda)\lambda_{U2}+\lambda_{tu}]/\Delta_1\end{array}\right\}}{(1+\lambda)\lambda_{U2}+\sigma_{UT}^3\lambda_{U3}/\theta_{T3}}$$

Suppose that σ_{UD}^{2*} is the solution of $(\hat{w}_S-\hat{w}_U)/\hat{\rho}=0$. If $\sigma_{UD}^2 > \sigma_{UD}^{2*}$, then $(\hat{w}_S-\hat{w}_U)/\hat{\rho}<0$; and if $\sigma_{UD}^2 < \sigma_{UD}^{2*}$, $(\hat{w}_S-\hat{w}_U)/\hat{\rho}>0$.

The economic mechanism of Proposition 1 is as follows. An increase in *ρ* raises the cost of input factor and drops the dirty input. Consequently, sector 2 reduces the employment of capital and unskilled labor. Therefore, the output of sector 2 and pollution reduces. The supply of skilled labor raises due to the improvement of the environment, which generates a negative on its wage.Meanwhile, the inflow of capital increases the marginal productivity and exerts a positive effect on its wage. Under the assumption that the share of exited skilled labor is not large, the latter aspect is dominant, and skilled wage increases. Regarding the impact of a reduction of dirty input on employment of unskilled labor in sector 2, less input of dirty decreases the demand for unskilled labor; however, a higher price of pollution stimulates the substitution of dirty input with unskilled labor. Consequently, the demand for unskilled labor rises. If the elasticity of substitution between dirty input and unskilled labor is relatively small, which implies the substitution is relatively hard, and the decrease of demand for unskilled labor will be dominant. More unskilled labor will be located in the agricultural sector and reduces the average wage of unskilled labor.Thus, the wage gap expands. If the substitution is large enough and the demand for unskilled labor and the average wage of unskilled labor will increase. A larger environmental tax will exert a relatively greater positive impact on the wage of unskilled labor than that of skilled labor and wage gap will be narrowed down.

Next, consider the impacts of an increase in the self-mitigation cost. From the established model, an increase in t_S and t_U does not affect w_S. Its impact on unskilled wage is obtained by equation (9),

$$\frac{\hat{w}_U}{\hat{t}_S} = -\frac{\lambda_{ts}\theta_{T3}\lambda_{K1}[(1+\lambda)\lambda_{U2}+\lambda_{tu}]}{\left[(1+\lambda)\lambda_{U2}\theta_{T3}+\lambda_{U3}\sigma_{UT}^3\right]\Delta_1} > 0$$

$$\frac{\hat{w}_U}{\hat{t}_U} = \frac{\lambda_{tu}\theta_{T3}}{(1+\lambda)\lambda_{U2}\theta_{T3}+\lambda_{U3}\sigma_{UT}^3} > 0$$

where $\lambda_{tu} = t_U E/L_U$ is share of exited unskilled labor. Thus, $(\hat{w}_S-\hat{w}_U)/\hat{t}_S<0$ and $(\hat{w}_S-\hat{w}_U)/\hat{t}_U<0$. From the above analyses, use Proposition 2 to state the effect exerted by t_S and t_U on wage gap.

Proposition 2: An increase in t_S and t_U narrows down the wage inequality.

Under the setting, an increase in t_S and t_U will not affect w_S and we focus their impacts on wage rate of unskilled labor. Obviously, an increase in t_U will raise the unskilled wage due to less supply of unskilled labor in the market. Here, we need to explain why a change of t_S increases the unskilled wage. An increase in t_S will make less skilled labor available and reduces the marginal marginal productivity of capital employed in sector 1. Capital moves from sector 1 into sector 2 and reduces *r*. Since the wage rate of unskilled labor is rigid in sector 2,, this sector uses capital to substitute unskilled labor until the interest rate equals to its previous equilibrium value. Fewer unskilled labor will be employed in sector 3 and raises w_U.

3. EXTENSION: POLLUTION AFFECTS AGRICULTURAL PRODUCTION

3.1 Extended Model

Here, we consider pollution not only affects labor health but also exerts a negative impact on agricultural production. Pollution, which imposes damage to the agricultural environment through agents such as air and water, is the bad public good. Since the pollution affects the whole sector, we incorporate the pollution into the agricultural production function as "creation of atmosphere" type in Meade's terminology. The technology of agricultural sector exhibits constant returns to scale only in the primary factors (labor and land in the model) in production. Thus, the production function of agricultural sector is expressed as $X_3 = g(E)F^3(L_{U3}, T)$,where $E = \delta X_2$ is the pollution, *g*(*E*) expresses the impact of pollution on the agricultural sector. And *g*(*E*) has the properties that $g'(E) < 0$, $g''(E) > 0$, $g(0) = 1$, and $0 < g(E) < 1$. In addition, the negative impact of pollution on the agricultural output can be captured by the elasticity:

$$\varepsilon = (dg/g)/(dE/E) < 0$$

Thus, equation (3) will be changed to:

$$g(E) = a_{U3}w_U + a_{T3}\tau \tag{10}$$

where $a_{i3}(i = U, T)$ represents the factor *i* used in producing one unit of goods (without pollution effect) in the agricultural sector (e.g., $a_{U3} = L_{U3}/F^3$). And equation (6) and (8) will be changed to

$$(1+\lambda)a_{U2}X_2 + a_{U3}F^3 = L_U - t_U E \tag{11}$$

$$a_{T3}F^3 = T \tag{12}$$

The extended model has been built. Eight equations (i.e., (1), (2), (4), (5), (7), (10), (11), and (12)) determine eight endogenous variables, w_S , w_U , r , τ , λ , X_1 , X_2 and X_3 , are determined, t_S , t_U and ρ are policy variables. Equation (1), (2), (5) and (7), constitute a sub-system which determines w_S , r , X_1 ,and X_2 .

3.2 Comparative Analysis

Totally differentiating equation (1), (2), (5), (7), we obtain these results are same with these in the section 2. Totally differentiating equation (4), (10), (11),and (12),and substituting relevant results in the section 2,

$$[(1+\lambda)\lambda_{U2} + \lambda_{tu} + \lambda_{U3}\varepsilon\sigma_{UT}^3/\theta_{T3}]\left[\hat{\rho}\left(\lambda_{K1}\Psi_2 - \theta_{D2}\Psi_1\lambda_{S1}\right)/\Delta_1 - \lambda_{ts}\lambda_{K1}\hat{t}_S/\Delta_1\right] + (1+\lambda)\lambda_{U2}\theta_{D2}(\sigma_{UD}^2 - \sigma_{UK}^2)\hat{\rho} + \lambda_{tu}\hat{t}_U = \left[(1+\lambda)\lambda_{U2} + \lambda_{U3}\sigma_{UT}^3/\theta_{T3}\right]\hat{w}_U \tag{13}$$

From the equation (13),

$$\frac{\hat{w}_U}{\hat{\rho}} = \frac{(1+\lambda)\lambda_{U2}\theta_{D2}(\sigma_{UD}^2 - \sigma_{UK}^2) + \dfrac{(\lambda_{K1}\Psi_2 - \theta_{D2}\lambda_{S1}\Psi_1)}{[(1+\lambda)\lambda_{U2} + \lambda_{tu} + \lambda_{U2}\varepsilon\sigma_{UT}^3/\theta_{T3}]}\Big/\Delta_1}{(1+\lambda)\lambda_{U2} + \sigma_{UT}^3\lambda_{U3}/\theta_{T3}}$$

and

$$\frac{\hat{w}_S - \hat{w}_U}{\hat{\rho}} =$$

$$\frac{\theta_{K1}\theta_{D2}}{\theta_{S1}\theta_{K2}} - \frac{(1+\lambda)\lambda_{U2}\theta_{D2}(\sigma_{UD}^2 - \sigma_{UK}^2) + \dfrac{(\lambda_{K1}\Psi_2 - \theta_{D2}\lambda_{S1}\Psi_1)}{[(1+\lambda)\lambda_{U2} + \lambda_{tu} + \lambda_{U2}\varepsilon\sigma_{UT}^3/\theta_{T3}]}\Big/\Delta_1}{(1+\lambda)\lambda_{U2} + \sigma_{UT}^3\lambda_{U3}/\theta_{T3}}$$

When ε is large enough (i.e., $\varepsilon > -\theta_{T3}[(1+\lambda)\lambda_{U2} + \lambda_{tu}]/\left(\lambda_{U2}\sigma_{UT}^3\right)$) (small enough, i.e. $\varepsilon < -\theta_{T3}[(1+\lambda)\lambda_{U2} + \lambda_{tu}]/\left(\lambda_{U2}\sigma_{UT}^3\right)$), and suppose that $\sigma_{UD}^{2\&}$ ($\sigma_{UD}^{2\&\&}$)is the solution of $\left(\hat{w}_S - \hat{w}_U\right)/\hat{\rho} = 0$. If $\sigma_{UD}^2 > \sigma_{UD}^{2\&}$ ($\sigma_{UD}^2 > \sigma_{UD}^{2\&\&}$), then $\left(\hat{w}_S - \hat{w}_U\right)/\hat{\rho} < 0$; and if $\sigma_{UD}^2 < \sigma_{UD}^{2\&}$ ($\sigma_{UD}^2 < \sigma_{UD}^{2\&\&}$), $\left(\hat{w}_S - \hat{w}_U\right)/\hat{\rho} > 0$. Thus, when incorporating the situation where pollution affects agricultural productivity, the wage inequality depends on the substitution of unskilled labor and dirty inputs in sector 2, regardless of the value of *ε*. Note that the parameter *ε* affects the crucial value of the substitution of unskilled labor and dirty inputs, and $\sigma_{UD}^{2\&}$ is larger than $\sigma_{UD}^{2\&\&}$.

From the equation (13),

$$\frac{\hat{w}_U}{\hat{t}_S} = \frac{-\lambda_{K1}\lambda_{ts}[(1+\lambda)\lambda_{U2} + \lambda_{tu} + \varepsilon\lambda_{U3}\sigma_{UT}^3/\theta_{T3}]/\Delta_1}{(1+\lambda)\lambda_{U2} + \sigma_{UT}^3\lambda_{U3}/\theta_{T3}}$$

And

$$\frac{\hat{w}_U}{\hat{t}_U} = \frac{\lambda_{tu}}{(1+\lambda)\lambda_{U2} + \sigma_{UT}^3 \lambda_{U3} / \theta_{T3}} > 0$$

Since $\hat{w}_S / \hat{t}_S = 0$ and $\hat{w}_S / \hat{t}_U = 0$, $(\hat{w}_S - \hat{w}_U) / \hat{t}_U < 0$ and

$$\frac{\hat{w}_S - \hat{w}_U}{\hat{t}_S} = \frac{\lambda_{K1}\lambda_{ts}[(1+\lambda)\lambda_{U2} + \lambda_{tu} + \varepsilon\lambda_{U3}\sigma_{UT}^3 / \theta_{T3}] / \Delta_1}{(1+\lambda)\lambda_{U2} + \sigma_{UT}^3 \lambda_{U3} / \theta_{T3}}$$

If the parameter *ε* is large enough (i.e., $\varepsilon > -\theta_{T3}[(1+\lambda)\lambda_{U2} + \lambda_{tu}] / (\lambda_{U2}\sigma_{UT}^3)$) (small enough, i.e. $\varepsilon < -\theta_{T3}[(1+\lambda)\lambda_{U2} + \lambda_{tu}] / (\lambda_{U2}\sigma_{UT}^3)$,), $(\hat{w}_S - \hat{w}_U) / \hat{t}_S < 0$ ($(\hat{w}_S - \hat{w}_U) / \hat{t}_S > 0$).

Summarizing the above results,

Proposition 3: When pollution affects labor health as well as agricultural productivity,

(1) An increase in *ρ* falls the wage gap if the elasticity of substitution between labor and dirty input in sector 2 is large enough; the wage gap will be expanded if the elasticity is small enough. Moreover, the elasticity of pollution on agricultural production affects the crucial value of the elasticity of substitution.

(2) If t_U increases, the wage inequality will be narrowed down ambiguously; however, the impact of a rise in t_S on wage gap depends on the elasticity of pollution on agricultural production.

The economic explanation of the first part of Proposition 3 is similar as that in Proposition 1, except for the effect of *ε* on the value of the elasticity of substitution between labor and dirty input. An increase in *ρ* reduces the output of sector 2 and pollution. If the parameter ε is large enough, the positive effect exerted by reduced pollution as well as unskilled wage is relatively small. Thus, the crucial value of the elasticity of substitution between labor and dirty input is relatively large. If the parameter *ε* is small enough, the positive effect exerted by reduced pollution as well as unskilled wage is relatively large. Thus, the crucial value of the elasticity of substitution between labor and dirty input is relatively small.

The result of an increase in t_U on the wage gap is identical to that in Proposition 2. However, different from the previous result that an increase in t_S reduces the wage gap unambiguously, when considering the pollution affects agricultural production, its effect depends on the parameter *ε*. A change in t_S will not affect the skilled wage and here focus its impact on the unskilled wage. From the explanation of Proposition 2, an increase in the self-mitigation cost of skilled labor will expand the demand for unskilled labor and output of unskilled sector. Expansion of the sector 2 exerts two contrasting effects on the wage rate of unskilled labor. More demand for unskilled labor and more pollution emitted as a result of an expansion. The former raises the unskilled wage, while the latter reduces the unskilled wage. If the parameter *ε* is large enough (small enough), which implies a change of pollution affects the production and unskilled wage of agricultural sector in a relatively small (large) magnitude, the former (latter) effect is dominant, and a rise in t_S reduces (raises) wage gap.

4. CONCLUSION

This paper analyzes the issue of wage inequality between skilled and unskilled labor in the situation where manufacturing sector generates pollution that harms labor health. That is, pollution raises the cost of production from labor health perspective. By establishing three-sector general equilibrium models, we analyze the impacts of an increase in the environmental tax and self-mitigation cost of skilled and unskilled labor on wage gap. In the basic theoretical model, we consider the pollution affects the labor and find that results of a larger environmental tax on wage inequality rely on the elasticity of substitution between labor and dirty input in the unskilled sector, an increase in the self-mitigation cost of skilled and unskilled labor narrows down wage inequality. The robustness of the basic model on the impact of a greater environmental tax and the self-mitigation cost of unskilled labor is substantiated by the extended model that incorporates the bad externality of pollution on agricultural production; however, the impact of a rise in the self-mitigation cost of skilled labor on wage inequality is different, which depends on the elasticity of pollution on agricultural productivity.

Since governments in developing countries attach importance to wage inequality to avoid social instability and political disorder, governments have incentives to reduce the inequality. The major result on the distributional effect of pollution-control and self-mitigation cost involves policy implications. First, when the elasticity of substitution between labor and dirty input in the unskilled sector is large enough, a stricter environmental policy not only reduces pollution but also contributes to declining wage inequality. However, if the elasticity is relatively small, the implementation of environmental protection policies should pay attention to the issue of wage inequality. Second, when pollution exerts a decreasing impact on labor health, governments should pay attention to the wage inequality issue and complementary policies that favors unskilled sector should be implemented.

Here, we point out several possible avenues. Firstly, pollution may affect the utility of labor. The paper focuses on the externality of pollution on the supply side of economy instead of demand side. In the future, we can take pollution to the demand side of economy and investigate the optimal amount of tax rate. Secondly, this paper only considers the exogenously determined wage rate of unskilled sector. Other cases, such as endogenous minimized wage of unskilled sector, with practical significance in developing countries can also be taken into consideration.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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