https://doi.org/10.17221/79/2018-AGRICECON

Manufacturing and agricultural pollution, private mitigation and wage inequality in the presence of pollution externalities

*Dianshuang Wang**

Graduate School of Economics, Nagoya University, Nagoya, Japan

**Corresponding author: wangds07@126.com*

Citation: Wang D. (2019): Manufacturing and agricultural pollution, private mitigation and wage inequality in the presence of pollution externalities. Agricultural Economics – Czech, 65: 51–58.

Abstract: The paper incorporates manufacturing and agricultural pollution into a three-sector general equilibrium model with pollution externalities both on agricultural production and labour health. Manufacturing generates pollution that affects agricultural production and health, while agriculture employs the pollutant as a factor for production that only affects health. Under the framework, this paper investigates the impacts of environmental protection policies and a rise in the self-mitigation cost of skilled and unskilled labour on wage inequality. A larger environmental tax expands wage gap if partial elasticity of substitution between labour and dirty input in the urban unskilled sector is small enough. More restrictive agricultural pollutants control narrows down the wage gap. The impact of an increase in the self-mitigation cost of skilled labour on wage inequality is ambiguous, depending on the factors substitution in agriculture and the elasticity of manufacturing pollution on agricultural production, while a larger self-mitigation cost of unskilled labour brings down the wage gap.

Keywords: environmental protection; manufacturing and agricultural pollution; pollution externalities; private mitigation; wage inequality

Pollution is one of the most severe challenges facing developing countries. In the last few years, development economists have engaged in a discussion over the possible effects of environmental policies on the environment and the whole economy[1]. They assumed that only manufacturing production causes the emission of pollution. The harmful substances emitted pollute water and soil for agricultural use through the atmosphere, rivers and other media, exerting negative effects on agriculture. Perhaps one of the most serious limitations of such theoretical works is that they ignore that agricultural practices also generate non-negligible pollution and bring a massive impact on the developing world. Pollution by agricultural practices has come up ever since the demand for food has increased. To increase the yield of farms, farmers have to resort to additional chemical fertilisers, pesticides, weedicides, nutrient-laden feed and many such practices which changed the way farming was done traditionally. A good example may be China. In 2010, the government released results of national pollution census, and agriculture resulted in a bigger source of water pollution in China than manufacturing.

Pollution, both from manufacturing and agriculture, exerts a negative effect on production and labour health. According to the World Bank (2016), pollution costs trillions of dollars a year and severely impedes development in many developing countries (China lost nearly 10% of its gross domestic product, India 7.69% and Sri Lanka and Cambodia roughly 8% in 2013).

[1]For theoretical papers, see Copeland and Taylor (1999), Beladi and Chao (2006), Kondoh and Yabuuchi (2012), Nakamura (2013), Li and Zhou (2015).

Supported by National Social Science Foundation for Youth of Art in China, Grant No. 16CH172. The author also gratefully acknowledges financial support from China Scholarship Council.

https://doi.org/10.17221/79/2018-AGRICECON

Moreover, pollution also exposes a great threat to labour health, especially in developing countries[2]. Facing a severe environmental problem, governments adopt certain policies to remedy negative externalities. Regarding manufacturing pollution, an environmental tax is a common preservation policy and has a substantial cost advantage over other instruments such as pollution control. Its effects are also explored by many scholars from different perspectives (Williams 2002; Daitoh 2008; Yanase 2010; Kuo et al. 2018). As for the solution of agricultural pollution, Ahodo and Svatonova (2014) discussed the advantages and disadvantages of economic instruments to mitigate agricultural pollution in developed countries. However, with the undeveloped market, agricultural pollutants control is the most direct and effective approach for the developing world. Some developing countries launched a program to replace chemical fertilises with organic alternatives to curb agricultural pollutants[3].

Environmental protection (a rise in environmental tax and more restrictive agricultural pollutants control) and a greater negative effect of pollution on health (an increase in the cost of self-mitigation to prevent or cure the bad effect) affect domestic employment and wage in developing countries, and exert an impact on inequality between skilled and unskilled labour consequently. Academicians have already investigated this issue and focused on international factor mobility to explain it (Marjit and Kar 2005; Beladi et al. 2008; Chaudhuri 2008). Until recently, one line of research has paid attention to domestic factors to explain it. In these studies, a variety of mechanisms are proposed to model impacts of a change in a domestic factor on wage gap such as public infrastructure provision (Pi and Zhou 2012), taxation on labour income (Anwar and Sun 2015), privatization (Chao et al. 2016), capital market distortion (Pi and Chen 2016), skill-biased technical change (Behar 2016), pollution control (Pi and Zhang 2017). However, on the one hand, existing literature on wage inequality neglects to consider the issue of the environmental tax and agricultural pollutants control, and thus fails to analyse effects of environmental tax and agricultural pollutants control on the wage gap.

On the other hand, previous studies on bad externalities of pollution in developing countries focused on bad effects on agricultural production (Kondoh and Yabuuchi 2012; Pi and Zhang 2017; Li and Wu 2018) and paid little attention to its effect on labour health. When health is affected by pollution, and labour's productivity reduces, which drops the total available labour in the market, wages are also affected. Thus, the role of the private self-mitigation effort in determining the wage gap has largely been ignored.

In order to fill the current research gap and address issues mentioned above, this paper establishes a three-sector general equilibrium model to investigate impacts of an increase in environmental tax, and self-mitigation cost and more restrictive agricultural pollutants control on wage inequality. Manufacturing sector generates pollution that affects agricultural production and labour health, while agriculture employs the pollutant as a factor for production which only affects labour health. Labour have to spend time or money, i.e. self-mitigation cost, to curb or prevent bad effects. It was found that a larger environmental tax expands wage gap if partial elasticity of substitution between unskilled labour and dirty input in the unskilled sector is small enough. More restrictive agricultural pollutants control narrows it down. The impact of a greater self-mitigation cost of skilled labour on wage inequality is ambiguous, depending on factors substitution in the agriculture and the elasticity of manufacturing pollution on agricultural production, while a larger self-mitigation cost of unskilled labour brings down wage gap.

MODEL

Consider a small open economy that composes of three sectors: a skilled urban sector, an urban unskilled sector and an agriculture sector. The skilled sector (sector 1) uses skilled labour L_{S1} and capital K_1 to produce an exportable good X_1, while unskilled sector (sector 2) uses unskilled labour L_{U2}, capital K_2 and dirty input D to produce an import-competing good X_2[4]. Production in the unskilled sector generates pollution E and damages the environment. The agriculture (sector 3) employs unskilled labour L_{U3} and

[2]Pollution was responsible for 9 million premature deaths in 2015, and nearly all of these deaths (92%) took place in developing nations (Das and Horton 2018).

[3]For example, China's Ministry of Agriculture (MOA) released an action plan that key growing areas for fruit, greenhouse vegetables and tea should cut chemical fertiliser and pesticide use by 2020 (MOA 2015a; MOA 2015b).

[4]Here, the model treats the dirty input as an input in the production of the unskilled sector. The similar setting could refer to Daitoh (2008), Pi and Zhang (2017), and Kuo et al. (2018).

https://doi.org/10.17221/79/2018-AGRICECON

pollutant factor T to produce X_3. Furthermore assume that agricultural production depends on E: a smaller E brings more agricultural output. Skilled labour, dirty input and pollutant factor are specific to the skilled sector, unskilled sector and agriculture, respectively. Capital moves freely between skilled and unskilled sector; however, unskilled labour moves imperfectly between the unskilled sector and agriculture due to the rigid downward wage in the unskilled sector. Since skilled labour is a shortage in developing countries, urban unemployment only exists among unskilled labour and the movement of unskilled labour from agriculture to unskilled sector satisfies the Harris-Todaro equilibrium condition (Harris and Todaro 1970). The production functions are $X_1 = F^1(L_{S1}, K_1)$, $X_2 = F^2(L_{U2}, K_2, D)$, and $X_3 = g(E)F^3(L_{U3}, T)$, where the three functions satisfy neoclassical properties (i.e. strict quasi-concavity and linear homogeneity); $g(E)$ expresses the impact of E on the agriculture, and $g'(E) < 0$, $g''(E) > 0$, $g(0) = 1$, and $0 < g(E) < 1$.

For simplicity, assume that the dirty input market does not exist. To control externality of the dirty input, the government levies a corrective tax ρ of per unit of the dirty input. All the goods and factor markets, except the unskilled labour market, are perfectly competitive. The cost minimisation conditions are described as:

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

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

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

where p_1 and p_2 are good prices of skilled and unskilled sector relative to that of agriculture, respectively, and p_1 and p_2 are assumed to be given; constant a_{ij} ($i = S, U, K, D$; $j = 1, 2$) represents that factor i used in producing one unit of good in j^{th} sector; a_{i3} ($i = U, T$) represents factor i used in producing one unit of goods (without pollution effect) in agriculture (e.g. $a_{U3} = L_{U3}/F^3$); w_S is elastic skilled wage; $\bar{w}_U$ is fixed unskilled wage in the unskilled sector; w_U is fully elastic wage in agriculture; r is interest rate; ρ is tax per capita and represents price of dirty input; τ indicates price of the agricultural pollutants.

Use $\lambda = L_{UU}/(a_{U1}X_1 + a_{U2}X_2)$ to denote the unemployment rate in the urban region. The unskilled labour market equilibrium condition is given by:

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

The unskilled sector and agricultural pollutants generate manufacturing pollution and agricultural pollution, respectively[5]. Assume that manufacturing pollution is generated during the production process of the unskilled sector and δ expresses units of pollution generated by one unit of production, and $0 < \delta < 1$, while agricultural pollution is the amount of the pollutant factor T[6]. Thus, manufacturing pollution $E = \delta X_2$. As previously mentioned, pollution discussed in this paper affects skilled and unskilled labour health, either causing labour to spend time sick or by reducing its productivity. Such kinds of impacts shift a part of labour away from productive activities, leading to a reduction in the available labour. Williams (2002) assume that pollution affects labour health, resulting in either reducing the amount or productivity of total labour. More specifically, the pollution $\delta X_2 + T$ drops $t_S(\delta X_2 + T)$ and $t_U(\delta X_2 + T)$ amounts of skilled and unskilled labour away from the skilled and unskilled labour market, respectively; $t_i (i = S, U)$ is the per capital effect of pollution on i type labour, and $t_i > 0$. $t_i (i = S, U)$ determines the effect of pollution on i type labour and also indicates the private cost to avoid bad effects of pollution. In the following equation, t_i is the self-mitigation cost of i type labour. A greater value of t_i means a larger effect of pollution on health and labour must spend a larger cost to keep health.

Market-clearing conditions yield:

$$a_{S1}X_1 = L_S - t_S(\delta X_2 + T) \quad (5)$$

[5]The reason is that the unskilled sector, like steel, printing, plastic material or chemical, is usually an emission-intensive sector in developing countries and uses dirty inputs to production. Agricultural pollution is mainly generated from synthetic organic chemicals, which also contributes to the agricultural output.

[6]Concerning pollution in the theoretical literature, there are two methods broadly associated with the generation of pollution. The first regards factor inputs that generate pollution in the production process and pollution equals the dirty input (Daitoh 2008; Pi and Zhang 2017; Kuo et al. 2018). The second approach views the generation of pollution as by-products during the production process (Tawada and Sun 2010; Li and Zhou 2015). Agricultural pollution is treated as an input-generation type while the manufacturing pollution is a by-product type.

https://doi.org/10.17221/79/2018-AGRICECON

$$(1+\lambda)a_{U2}X_2 + a_{U3}F^3 = L_U - t_U(\delta X_2 + T) \quad (6)$$

$$a_{K1}X_1 + a_{K2}X_2 = K \quad (7)$$

$$a_{T3}F^3 = T \quad (8)$$

where L_S, L_U, K, T are the endowment of skilled labour, unskilled labour, capital and agricultural pollutants, respectively. When considering the generation of manufacturing pollution, Equation 3 could be written as:

$$g(\delta X_2) = a_{U3}w_U + a_{T3}\tau \quad (3')$$

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 Equations 1, 2, 3', 4–8; ρ, T, t_S and t_U are policy variables. Other variables are exogenous. The whole model can be solved as follows: Equation 2 determines r, and substituting r into Equation 1 gets w_S. Given the equilibrium values of r and w_S, Equations 5 and 7 are solved to obtain X_1 and X_2. After getting the equilibrium of r, w_S, X_1 and X_2, all remaining four Equations 3', 4, 6 and 8 solve remaining variables, w_U, τ, λ, and X_3.

COMPARATIVE ANALYSIS

Environmental protection and wage inequality

First, the impacts of environmental protection policies (an increase in ρ and a decrease in T) on the output of skilled and unskilled sector were investigated, which can be summarised by Lemma 1.

Lemma 1. *Suppose the share of exited skilled labour is not large. A larger environmental tax rate and more restrictive agricultural pollutants control bring a reduction of unskilled output and an expansion of skilled output.*

Proof. The system could decompose into two subsystems. Equations 1, 2, 5, 7 constitute a sub-system which determines w_S, r, X_1 and X_2. Totally differentiating Equations 1, 2, 5, 7:

$$\frac{\hat{w}_S}{\hat{\rho}} = \frac{\theta_{K1}\theta_{D2}}{\theta_{S1}\theta_{K2}} > 0, \quad (9)$$

$$\frac{\hat{r}}{\hat{\rho}} = -\frac{\theta_{D2}}{\theta_{K2}} < 0, \quad (10)$$

$$\hat{X}_1 = \frac{(\lambda_{K2}\Omega_1 - \lambda_{s2}\Omega_2)\hat{\rho} - \lambda_{s3}\lambda_{K2}\hat{T} - \lambda_{ts}\lambda_{K2}\hat{t}_S}{\Delta_1} \quad (11)$$

and

$$\hat{X}_2 = \frac{\left(\lambda_{S1}\Omega_2 - \lambda_{K1}\Omega_1\right)\hat{\rho} + \lambda_{K1}\lambda_{s3}\hat{T} + \lambda_{ts}\lambda_{K1}\hat{t}_S}{\Delta_1} \quad (12)$$

where "∧" represents the rate of change

(e.g. $\hat{w}_S = dw_S/w_S$), $\Delta_1 = \lambda_{K2}\lambda_{S1} - \lambda_{K1}\lambda_{s2}$,

$$\Omega_1 = \left(S^1_{SK} - S^1_{SS}\theta_{K1}/\theta_{S1}\right)\lambda_{S1}\theta_{D2}/\theta_{K2} > 0,$$

$$\Omega_2 = \left(\lambda_{K1}S^1_{KK} + \lambda_{K2}S^2_{KK}\right)\theta_{D2}/\theta_{K2} - \lambda_{K2}S^2_{KD} - \lambda_{K1}S^1_{KS}\theta_{K1}\theta_{D2}/(\theta_{K2}\theta_{S1}) < 0.$$

θ_{ij} ($i = S, U, K, D$; $j = 1, 2$) is the distributive share of factor i in the j^{th} sector (e.g. $\theta_{S1} = a_{S1}w_S/p_1$), λ_{ij} is the allocated share of factor i in the j^{th} sector (e.g. $\lambda_{U2} = a_{U2}X_2/L_U$). $\lambda_{ts} = t_S(E + T)/L_S$ is share of total exited skilled labour, $\lambda_{s2} = t_SE/L_S$ ($\lambda_{s3} = t_ST/L_S$) is the share of exited skilled labour due to manufacturing(agricultural) pollution. S^h_{ij} ($i, j = S, U, K, D, T$; $h = 1, 2, 3$) is the partial elasticity of substitution between factors i and j in h^{th} sector (e.g. $S^1_{SK} = \frac{\partial a_{S1}}{\partial r} \times \frac{r}{a_{S1}}$), $S^h_{ij} > 0 (i \neq j)$ and $S^h_{ii} < 0$.

The sign of Δ_1 is ambiguous. Here, we impose inequality $\lambda_{S1}/\lambda_{K1} > \lambda_{ts}/\lambda_{K2}$. Note that λ_{ts} is the share of total exited skilled labour. Consider the economic reality, λ_{ts} is relatively small and allocated share of capital in the unskilled sector is larger than that of the skilled sector, and this inequality is easily satisfied in the real economy. Thus, $\Delta_1 > 0$.

From Equations 11–12,

$\hat{X}_1/\hat{\rho} > 0$, $\hat{X}_2/\hat{\rho} < 0$, $\hat{X}_1/\hat{T} < 0$, and $\hat{X}_2/\hat{T} > 0$.

The economic explanation of the Lemma 1 is as follows. An increase in environmental tax drops dirty input, which lowers the employment of capital and unskilled labour in the unskilled sector. The output of the unskilled sector and manufacturing pollution reduces. Meanwhile, an inflow of capital and an enlargement of skilled labour due to a smaller E expand the skilled sector. A reduction of agricultural pollutants improves the health condition of skilled and unskilled labour. The skilled sector has more available skilled labour and enlarges its employment, which attracts capital movement from unskilled into the skilled sector. Though more available unskilled labour exists in the market, the employment of unskilled sector is unchanged due to the rigid wage. Since capital moves out of the unskilled sector, its output drops consequently.

https://doi.org/10.17221/79/2018-AGRICECON

$$\begin{pmatrix} 0 & \theta_{U3} & \theta_{T3} \\ 1 & S^3_{TU} & S^3_{TT} \\ \lambda_{U3} & \lambda_{U3}S^3_{UU} - \lambda^*_{U2} & \lambda_{U3}S^3_{UT} \end{pmatrix} \begin{pmatrix} \hat{X}_3 \\ \hat{w}_U \\ \hat{\tau} \end{pmatrix} = \begin{pmatrix} \varepsilon\Psi_1 \\ \varepsilon\Psi_1 \\ \Omega_4 \end{pmatrix} \hat{\rho} + \Psi_2 \begin{pmatrix} \varepsilon \\ \varepsilon \\ -\Omega_3 \end{pmatrix} \hat{t}_S + \begin{pmatrix} \varepsilon\Psi_3 \\ 1+\varepsilon\Psi_3 \\ -(\Omega_3\Psi_3 + \lambda_{tu3}) \end{pmatrix} \hat{T} + \begin{pmatrix} 0 \\ 0 \\ -\lambda_{tu} \end{pmatrix} \hat{t}_U \quad (13)$$

$$\frac{\hat{w}_U}{\hat{T}} = \frac{\varepsilon\Psi_3(\lambda_{U3}S^3_{UU} - \lambda^*_{U2} - \lambda_{U3}S^3_{TU}) + \theta_{U3}(\Omega_3\Psi_3 + \varepsilon\lambda_{U3}\Psi_3 + \lambda_{U3} + \lambda_{tu3})}{\Delta_2} < 0 \quad (15)$$

Next, consider the wage gap. In accordance with the denotation of skilled-unskilled wage inequality in Beladi et al. (2008), Li and Xu (2016) and Pi and Zhang (2017), use skilled labour wage and an average wage of unskilled labour, as well as their relative change to address the issue. Combing with Equations 4 and 6, the average unskilled wage is w_U[7]. Totally differentiating Equations 3, 4, 6 and 8, and substituting Equations 9–12, see Equation 13.

In Equation 13, $\theta_{U3} = a_{U3}w_U/g(E)$, $\theta_{T3} = a_{T3}\tau/g(E)$, $\varepsilon = g'E/g < 0$ captures the negative impact of pollution on agriculture; $\lambda^*_{U2} = (1+\lambda)\lambda_{U2}$, $\lambda_{tu} = t_U(E+T)/L_U$ is the share of total exited unskilled labour; $\lambda_{tu2} = t_U E/L_U$ ($\lambda_{tu3} = t_U T/L_U$) is the share of exited unskilled labour due to manufacturing (agricultural) pollution.

Moreover, $\Psi_1 = (\lambda_{S1}\Omega_2 - \lambda_{K1}\Omega_1)/\Delta_1 < 0$,

$\Psi_2 = \lambda_{ts}\lambda_{K1}/\Delta_1 > 0$, $\Psi_3 = \lambda_{K1}\lambda_{s3}/\Delta_1 > 0$,

$\Omega_3 = \lambda^*_{U2}(\varepsilon + 1) - \varepsilon(1 - \lambda_{tu}) + \lambda_{tu2} > 0$,

$\Omega_4 = \lambda^*_{U2}\left(\theta_{D2}S^2_{UK}/\theta_{K2} - S^2_{UD}\right) - \Omega_3\Psi_1$.

Define the determinant of a matrix in Equation 13 as Δ_2 and

$$\Delta_2 = \theta_{T3}(\lambda_{U3}S^3_{UU} - \lambda^*_{U2} - \lambda_{U3}S^3_{TU}) - \theta_{U3}\lambda_{U3}(S^3_{UT} - S^3_{TT}) < 0$$

By Cramer's rule,

$$\frac{\hat{w}_U}{\hat{\rho}} = \frac{\theta_{T3}\Omega_4 - \varepsilon\lambda_{U3}\Psi_1(\theta_{T3} + S^3_{UT} - S^3_{TT})}{\Delta_2} \quad (14)$$

and Equation 15.

Using Equations 9 and 14, the effect of an increase in environmental tax on the wage gap can be expressed as:

$$\frac{\hat{w}_S - \hat{w}_U}{\hat{\rho}} = \frac{\theta_{K1}\theta_{D2}}{\theta_{S1}\theta_{K2}} - \frac{\theta_{T3}\Omega_4 - \varepsilon\lambda_{U3}\Psi_1(\theta_{T3} + S^3_{UT} - S^3_{TT})}{\Delta_2} =$$

$$= \frac{\theta_{K1}\theta_{D2}}{\theta_{S1}\theta_{K2}} - \frac{\theta_{T3}\theta_{D2}\lambda^*_{U2}S^2_{UK}}{\Delta_2\theta_{K2}} + \frac{\Psi_1[\varepsilon\lambda_{U3}(S^3_{UT} - S^3_{TT}) + \theta_{T3}(\lambda^*_{U2} + \lambda_{tu2})]}{\Delta_2} + \frac{\theta_{T3}\lambda^*_{U2}S^2_{UD}}{\Delta_2}$$

Suppose that S^{2*}_{UD} solves $(\hat{w}_S - \hat{w}_U)/\hat{\rho} = 0$.

If $S^2_{UD} \in (S^{2*}_{UD}, +\infty)$, then $(\hat{w}_S - \hat{w}_U)/\hat{\rho} < 0$;

and if $S^2_{UD} \in (0, S^{2*}_{UD})$, then $(\hat{w}_S - \hat{w}_U)/\hat{\rho} > 0$.

The above results are summarised as Proposition 1:

Proposition 1. *A larger environmental tax expands the wage gap if the partial elasticity of substitution between labour and dirty input in the urban unskilled sector is small enough. However, wage inequality can be reduced if the elasticity of substitution is large enough.*

An increase in environmental tax raises the shadow price of dirty input. As a result, the employment of dirty input drops, which decreases the marginal productivity of capital employed in the unskilled sector. Consequently, the demand for capital also decreases in this sector, which leads to a decrease in interest rate in the economic system. The unskilled sector experiences a reduction in its output. Due to a smaller share of manufacturing pollution, more available skilled labour drops its wage, while an inflow of capital increases the marginal productivity of skilled labour and raises its wage. Considering that the share of exited skilled labour is not large, the latter impact is dominant and skilled wage increases finally. The unskilled wage is determined by two aspects: the demand for unskilled labour in the unskilled sector and the positive impact of reduced manufacturing pollution on agricultural output. The latter has a positive effect on unskilled wage unambiguously, while the change of the former is more complicated.

[7]Only the wage of skilled and unskilled labour in the market was considered, and the dropped skilled and unskilled labour was not included.

https://doi.org/10.17221/79/2018-AGRICECON

On the one hand, less dirty input and capital decrease the marginal productivity of unskilled labour in this sector and lead to a reduction in the demand for unskilled labour. On the other hand, substitution of unskilled labour with relatively expensive dirty input occurs. If the partial elasticity of substitution between labour and dirty input in the unskilled sector is relatively large and the substitution is relatively easy, then this sector will employ more unskilled labour. The increase in the demand for unskilled labour will be then dominant. Less unskilled labour will be employed in agriculture, which will raise the *status quo* of unskilled wage. If the partial elasticity of substitution is relatively small, the decrease in demand for unskilled labour will be dominant and more unskilled labour will be located in agriculture, thus dropping the *status quo* of unskilled wage. When the wage gap is taken into consideration, the logic of the partial elasticity of substitution is very similar.

If $S_{UD}^2 \in (S_{UD}^{2*}, +\infty)(S_{UD}^2 \in (0, S_{UD}^{2*}))$, wage gap will be reduced (expanded).

Since a change in T does not affect skilled wage, the effect of more restrictive agricultural pollutants control on wage gap is:

$$\frac{\hat{w}_S - \hat{w}_U}{\hat{T}} = \frac{\varepsilon\Psi_3(\lambda_{U3} S_{UU}^3 - \lambda_{U2}^* - \lambda_{U3} S_{TU}^3)}{\Delta_2} + \frac{\theta_{U3}(\Omega_3\Psi_3 + \varepsilon\lambda_{U3}\Psi_3 + \lambda_{U3} + \lambda_{tu3})}{\Delta_2} > 0$$

Proposition 2 is established to show how more restrictive agricultural pollutants control influences wage inequality.

Proposition 2. *More restrictive agricultural pollutants control narrow down the wage inequality.*

More restrictive agricultural pollutants control makes more skilled labour available and increases the marginal productivity of capital employed in the skilled sector. Capital moves from the unskilled sector to skilled sector and reduces interest rate initially. Due to the unskilled fixed wage, unskilled sector uses relatively cheap capital to substitute unskilled labour until the interest rate equals its previous equilibrium value. With the constant interest rate, the skilled wage is also invariant. However, more restrictive agricultural pollutants control exerts an impact on the unskilled wage in three aspects: more available unskilled labour, the decrease of the demand for unskilled labour in agriculture, reduction of manufacturing pollution. A reduction of agricultural pollutants implies the improvement of labour health, and more unskilled labour is available. Less agricultural pollutants bring down the marginal productivity of unskilled labour employed in agriculture and drop the demand for unskilled labour consequently. The constriction of the unskilled sector reduces the manufacturing pollution and improves labour health. Thus, the effects of more restrictive agricultural pollutants control on the unskilled supply, and the reduction of demand for unskilled labour in agriculture go a step further. All of the aspects reduce unskilled wage and wage gap expands.

Self-mitigation cost of skilled and unskilled labour and wage inequality

In this part, the impacts of a greater self-mitigation cost on the output of skilled and unskilled sector were investigated first. From Equations 11–12, $\hat{X}_1/\hat{t}_S < 0$, $\hat{X}_2/\hat{t}_S > 0$, $\hat{X}_1/\hat{t}_U = 0$ and $\hat{X}_2/\hat{t}_U = 0$. These results can be summarised by Lemma 2.

Lemma 2. *Suppose the share of exited skilled labour is not large. A greater self-mitigation cost of skilled labour drops the output of skilled sector and raises that of the unskilled sector. However, a change of the self-mitigation cost of skilled labour exerts no effect on the output of both sectors.*

A greater self-mitigation cost of skilled labour reduces the amount of available skilled labour and shrinks its employment in the skilled sector. The less available skilled labour decreases the marginal productivity of capital in this sector and the capital outflows from the skilled sector. As a consequence, the output of skilled sector drops and that of unskilled sector rises. A greater self-mitigation cost of unskilled labour also reduces the amount of available unskilled labour. Since the wage of the unskilled sector is rigid, a lesser amount of unskilled labour does not affect the employment of unskilled labour and capital in the unskilled sector.

Next consider the impacts of a greater self-mitigation cost on wage inequality. From Equation 13,

$$\frac{\hat{w}_U}{\hat{t}_S} = -\frac{\Psi_2\left[\varepsilon\lambda_{U3}(S_{UT}^3 + S_{TT}^3 + \theta_{T3}) + \theta_{T3}\Omega_3\right]}{\Delta_2} \quad (16)$$

and

$$\frac{\hat{w}_U}{\hat{t}_U} = -\frac{\lambda_{tu}\theta_{T3}}{\Delta_2} > 0 \quad (17)$$

Since a change of the self-mitigation cost of both skilled and unskilled labour does not affect the skilled wage, the effect of an increase in self-mitigation cost on wage gap:

https://doi.org/10.17221/79/2018-AGRICECON

$$\frac{\hat{w}_S - \hat{w}_U}{\hat{t}_S} = \frac{\Psi_2\left[\varepsilon\lambda_{U3}(S_{UT}^3 - S_{TU}^3 + \theta_{T3}) + \theta_{T3}\Omega_3\right]}{\Delta_2} = \frac{\Psi_2\left[\varepsilon\lambda_{U3}(S_{UT}^3 - S_{TU}^3) + \theta_{T3}(\lambda_{U2}^* + \lambda_{tu2})\right]}{\Delta_2}$$

and $\frac{\hat{w}_S - \hat{w}_U}{\hat{t}_U} = \frac{\lambda_{tu}\theta_{T3}}{\Delta_2} < 0$

If $S_{UT}^3 < S_{TU}^3$, $\left(\hat{w}_S - \hat{w}_U\right)/\hat{t}_S < 0$. If $S_{UT}^3 > S_{TU}^3$, then the sign of $\left(\hat{w}_S - \hat{w}_U\right)/\hat{t}_S$ relies on S_{UT}^3 and ε. If the partial elasticity of substitution between labour and agricultural pollutants is large enough or the elasticity of manufacturing pollution on agricultural production is small enough, $\left(\hat{w}_S - \hat{w}_U\right)/\hat{t}_S > 0$.

Summarised the above results, Propositions 3 and 4 were formulated.

Proposition 3. *If the self-mitigation cost of skilled labour is increased, the wage inequality will be narrowed down if the partial elasticity of substitution between labour and agricultural pollutants is smaller than the partial elasticity of substitution between agricultural pollutants and labour. However, the wage inequality may be expanded in the opposite situation when the partial elasticity of substitution between labour and agricultural pollutants is large enough, or the elasticity of manufacturing pollution on agricultural production is small enough.*

Less skilled labour exists as a result of an increase in the self-mitigation cost of skilled labour, reducing the employment of skilled labour in the skilled sector. Consequently, the marginal productivity of capital employed in the unskilled sector decreases and the demand for capital also reduces in this sector, which leads to a decrease in the interest rate initially. The unskilled sector employs more relatively cheap capital to substitute relatively expensive unskilled labour and increases its demand for capital until the interest rate equals its previous equilibrium value. A larger self-mitigation cost of skilled labour will not change the interest rate as well as the skilled wage at last. Capital moves from the skilled sector to the unskilled sector, expanding the demand for unskilled labour in the unskilled sector. Rural unskilled labour migrates out of agriculture into the unskilled sector. With more capital and labour, the unskilled sector raises its output which brings greater manufacturing pollution. The marginal productivity of agricultural pollutants drops as a result of the movement of unskilled agricultural labour, bringing down its reward. Thus, the agriculture faces the relatively cheap agricultural pollutants and the relatively expensive unskilled labour, and factors substitution occurs. When the partial elasticity of substitution between labour and agricultural pollutants is smaller than the partial elasticity of substitution between agricultural pollutants and labour, which implies unskilled labour is harder to substitute than pollutants, unskilled wage rises regardless of the magnitude of manufacturing pollution on agricultural production. In the opposite situation, the unskilled wage reduces in two situations. When the partial elasticity of substitution between labour and agricultural pollutants is large enough, then pollutants are harder to substitute than unskilled labour, a reduction of price of pollutants leads to a large decrease in demand for unskilled labour and unskilled wage decreases; when the negative externality of manufacturing pollution on agricultural production is small enough, an increase in manufacturing pollution exerts a large negative impact on agricultural production and drop the unskilled wage. In these two situations, the wage gap will expand.

Proposition 4. *A larger self-mitigation cost of unskilled labour brings down the wage gap.*

When the self-mitigation cost of unskilled labour increases, less amount of unskilled labour exists in the market. Due to the rigid wage rate in the unskilled sector, a larger self-mitigation cost of unskilled labour does not affect the variables of the two urban sectors. Since agricultural wage is elastic, less supply of unskilled labour raises the marginal productivity of unskilled labour in the agriculture as well as its wage, narrowing down the wage gap.

CONCLUSION

Currently, developing countries face severe pollution problems generated by not only the manufacturing sector but also by agricultural production. The deterioration of the environment poses negative externalities on both agricultural production and labour health. The government and private sector have made their efforts to reduce the bad externalities of pollution, and such efforts affect the employment and wage rate, and skilled and unskilled wage consequently.

This paper establishes a three-sector general equilibrium model to investigate the impacts of environmental protection policies and an increase in the self-mitigation cost on wage inequality. In the theoretical model, urban unskilled sector generates manufacturing pollution that affects agricultural production and labour health, while the agriculture employs pollutants as a factor for production which only affects labour health. Labour have to spend time or money, i.e. self-mitigation cost,

https://doi.org/10.17221/79/2018-AGRICECON

to curb or prevent the bad effect both from manufacturing and agricultural pollution. When agricultural pollution is incorporated, it was found that a larger environmental tax expands the wage gap if the partial elasticity of substitution between labour and dirty input in the unskilled sector is small enough. More restrictive agricultural pollutants control narrows down the wage inequality. The impact of an increase in the self-mitigation cost of skilled labour on wage inequality is ambiguous, depending on the factors substitution in the agriculture and the elasticity of manufacturing pollution on agricultural production, while a larger self-mitigation cost of unskilled labour brings down the wage gap.

REFERENCES

Ahodo K., Svatonova T. (2014): The use of economic instruments in environmental policies to mitigate diffuse pollution from agriculture. Agricultural Economics – Czech, 60: 74–81.

Anwar S., Sun S. (2015):Taxation of labour income and the skilled-unskilled wage inequality. Economic Modelling, 47: 18–22.

Behar A. (2016): The endogenous skill bias of technical change and wage inequality in developing countries. Journal of International Trade & Economic Development, 25: 1101–1121.

Beladi H., Chao C.C. (2006): Environmental policy, comparative advantage, and welfare for a developing economy. Environment and Development Economics, 11: 559–568.

Beladi H., Chaudhuri S., Yabuuchi S. (2008): Can international factor mobility reduce wage inequality in a dual economy? Review of International Economics, 16: 893–903.

Chao C., Nabin M., Nguyen X., Sgro P. (2016): Wage inequality and welfare in developing countries: Privatization and reforms in the short and long run. International Review of Economics & Finance, 42: 474–483.

Chaudhuri S. (2008): Wage inequality in a dual economy and international mobility of factors: do factor intensities always matter? Economic Modelling, 25: 1155–1164.

Copeland B.R., Taylor M.S. (1999): Trade, spatial separation, and the environment. Journal of International Economics, 47: 137–168.

Daitoh I. (2008): Environmental protection and trade liberalization in a small open dual economy. Review of Development Economics, 12: 728–736.

Das P., Horton R. (2018): Pollution, health, and the planet: time for decisive action. The Lancet, 391: 407–408.

Harris J.R., Todaro M.P. (1970): Migration, unemployment and development: a two sector analysis. American Economic Review, 60: 126–142.

Kondoh K., Yabuuchi S. (2012): Unemployment, environmental policy, and international migration. Journal of International Trade & Economic Development, 21: 677–690.

Kuo K.-H., Lee C.-T., Wu S.-F. (2018): Environmental policy and labour market imperfection. Bulletin of Economic Research, 70: 175–184.

Li X., Wu Y. (2018): Environment and economic in the modern agricultural development. Asia-Pacific Journal of Accounting & Economics, 25: 163–176.

Li X., Xu Y. (2016): Unemployment, wage inequality and international factor movement in the presence of agricultural dualism. Review of Development Economics, 20: 415–425.

Li X., Zhou J. (2015): Environmental effects of remittance of rural-urban migrant. Economic Modelling, 47: 174–179.

Marjit S., Kar S. (2005): Emigration and wage inequality. Economics Letters, 88: 141–145.

MOA (2015a): Plan for Zero Growth in Chemical Fertilizer Use in 2020. Ministry of Agriculture, Beijing. Available at www.moa.gov.cn/zwllm/tzgg/tz/201503/t20150318_4444765.htm (accessed Jan 31, 2019). (in Chinese)

MOA (2015b): Plan for Zero Growth in Pesticide Use in 2020. Ministry of Agriculture, Beijing. Available at www.moa.gov.cn/zwllm/tzgg/tz/201503/t20150318_4444765.htm (accessed Jan 31, 2019). (in Chinese)

Nakamura A. (2013): Environment, urban unemployment, and tariffs in the Harris–Todaro model. Review of Development Economics, 17: 585–593.

Pi J., Chen X. (2016): The impacts of capital market distortion on wage inequality, urban unemployment, and welfare in developing countries. International Review of Economics & Finance, 42: 103–115.

Pi J., Zhang P. (2017): Foreign capital, pollution control, and wage inequality in developing countries. International Review of Economics & Finance, 48: 280–288.

Pi J., Zhou Y. (2012): Public infrastructure provision and skilled-unskilled wage inequality in developing countries. Labour Economics, 19: 881–887.

Tawada M., Sun S. (2010): Urban pollution, unemployment and national welfare in a dualistic economy. Review of Development Economics, 14: 311–322.

Williams R.C. (2002): Environmental tax interactions when pollution affects health or productivity. Journal of Environmental Economics and Management, 44: 261–270.

World Bank (2016): The cost of air pollution : strengthening the economic case for action. World Bank, Washington D.C.

Yanase A. (2010): Tariff and environmental tax reforms in a polluted small open economy with public production. FinanzArchiv: Public Finance Analysis, 66: 333–349.

Received March 4, 2018
Accepted June 26, 2018
Published online February 7, 2018