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General Equilibrium Implications of Privatization on Environment and Unemployment in Vertically Related Markets

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This paper is aimed at theoretically analyzing the environmental implications of privatization, adopted by many developing countries, using a three-sector general equilibrium model. The partially privatized firm owns a monopolistic position in upstream market and offers an essential intermediate input for downstream manufacturing sector. Both the privatized firm and manufacturing generate pollution that harms agricultural productivity. We obtain that the price elasticity of demand for manufacturing goods is crucial for determining the environmental impact of privatization. When the price elasticity is relatively small (large), deepening privatization raises (decreases) price of partial privatized firm and improves (deteriorates) the environment. We also show a paradoxical result that improving pollution abatement technology deteriorates the environment instead.

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1. INTRODUCTION

Privatization of state-owned enterprises (SOEs) is adopted by some developing countries, such as China, Vietnam, as a means of improving economic performance and growth. The massive magnitude of privatization has received attention from many scholars who have considered the implications of privatization under the framework of "mixed oligopoly", where both public and private firms produce the same goods and compete in the final market [1-4]. However, there exists a huge gap between the assumption and economic reality in developing economies. The sectoral distribution of SOEs has in recent decades become ever more skewed toward a few upstream "strategic" sectors of great importance to the rest of the downstream sectors[1]. SOEs and non-SOEs have formed the vertical structure: SOEs withdraw from competitive sectors and monopolize key industries and markets in upstream sectors, whereas the downstream industries are largely open to private competition. Meanwhile, many developing countries are plagued by significant environmental pollution and high levels of unemployment, particularly in urban areas. Privatization may significantly affect overall employment, sectoral output and environment under the vertical structure [5]. However, few papers investigate how privatization affects environment and unemployment and this paper tries to answer this question from a new perspective.

Since the vertical structure becomes increasingly prominent, scholars have analyzed the impacts of the privatization of upstream SOEs by utilizing game theory [6-9]. Under this approach, the investigation is bound to be limited because it ignores factor markets. In general, privatization affects goods markets and factor markets simultaneously. For example, privatization changes the objectives of SOEs and the partially privatized firms pay more attention to profits than social welfare. Such changes exert a direct impact on factors' rewards and factor employment, through which influences the output of private firms. When incorporating factor markets and employing the general equilibrium approach, we can "offset or even reverse sensible partial equilibrium conclusions" [10]. Much fewer studies explore privatization from the general equilibrium approach. For instance, Beladi and Chao [11] consider the employment and welfare implications of partial privatization for a developing economy. Pi and Zhang (2018) investigate how partial privatization affects the skilled-unskilled wage inequality in developing countries. Wang and Li [12] analyze the privatization issue in vertically related markets and find the efficiency-enhancing effect is crucial for determining the impacts of privatization. Li and Jia [5] incorporate producer service sector into a three sector general equilibrium model, and investigate the impacts of partial privatization of the mixed-ownership firm in the manufacturing sector on output, unemployment, and social welfare in developing countries. Li and Jia [5] obtain that partial privatization lowers unemployment and raises output conditionally if the profit of producer service firms is zero in the long run. The paper arrives that partial privatization lowers the social welfare in the short run and enlarges social welfare in the long-run due to the mobility of capital. However, with the existence of the vertical structure, the existing literature could not answer the question what environmental implications of privatization.

Meanwhile, many developing countries face severe environmental problem. Scholars explore this issue from different angles and propose many mechanisms to provide theoretical explanations. One strand of literature focuses on the role of external factors, such as international factor mobility, trade, in deteriorating environment (e.g., [13-15]. The other strand of literature centers on the role of internal factors, such as remittance of rural-urban migrants, skill formation, public-good, in worsening the environment (e.g., [16-18]). However, the existing literature on the environmental problem fails to consider the environmental implications of privatization.

Since the SOEs hold a crucial upstream position in the whole economy, literature needs to address the question that what effects does privatization have on the environment. In order to achieve our goal, this paper constructs a three-

[1] *Such phenomena prevails in transition and developing countries. Transition Report 2020-21 published by EBRD summaries stylized facts in transition countries(Available at https://2020.tr-ebrd.com/state-owned-enterprises).We provide the discussion in Section 2.*

sector general equilibrium model to analyze how privatization affects the environment [2]. We assume the partial privatized firm and manufacturing sector generate pollution that harms the environment and affects agricultural productivity. The partial privatized firm cares not only its profits but also social welfare. And more pollution reduces social welfare. When we incorporate the environmental responsibility, the paper obtains the price elasticity of demand for manufacturing goods is crucial for determining the environmental impact of privatization. When the price elasticity is relatively small (large), deepening privatization raises (decreases) price of the partial privatized firm and improves (deteriorates) the environment. In the assumed economy, the result shows a paradox result that improving pollution abatement technology deteriorates the environment instead.

This paper adds to the existing studies on the environmental implications of privatization of an upstream SOE by using general equilibrium approach. When investigating privatization, most papers utilize game theory approach. However, this approach ignores factor markets and leave the effects of privatization on factor allocation aside. Among existing literature that employs the general equilibrium approach, scholars assume no vertical production structure and SOEs produce final goods to consumer. Nevertheless, this assumption is seriously out of touch with reality and SOEs are concentrate on upstream markets and provide essential intermediate inputs to downstream markets. Therefore, this paper builds a vertical production structure to reflect this reality. Based on those two frameworks, the paper analyzes the implications of privatization on environment and unemployment in a developing economy. To our best acknowledge, this aspect is ignored by existing literature and this paper bridges the gap.

The rest of this paper is organized as follows. We build a three-sector general model in Section 2. Section 3 conducts the comparative static analysis to investigate how privatization and pollution abatement technology influence the environment and urban unemployment. Concluding remarks and policy implications are given in Section 4.

[2] *In this paper, we do not consider the impacts of environmental policies for two reasons. First, most developing countries concentrate on economic development and levy no or little environmental tax. Second, the paper focuses on the environmental implication of privatization and how to remedy this problem and its economic effect are not the scope of this paper.*

2. THE MODEL

Consider a developing economy with dual development between rural and urban regions. The rural sector produces agricultural goods X under perfect competition. In the urban region, there is a vertical structure with an upstream monopolistic state-owned enterprise, which is facing partial privatization, producing essential intermediate input Z and the downstream manufacturing sector producing a consumption goods Y. Consumers demand for goods X and Y, Utility function is represented by the following quasi-linear function: $U = X + v(Y)$, and the budget constraint is: $I = X + p_Y Y$, where I is total income, $v' > 0$, $v'' < 0$. And suppose the price of goods X is numeraire, p_Y is the relative price of goods Y. The inverse demand for Y, $p_Y = p_Y(Y)$, and $p_Y' < 0$.

During the process of production in two urban sectors, by-products such as air and water pollution are generated, which damages the environment. Denote that e is the quality of environment after pollution. The environmental quality can be represented as

$$e = \frac{\bar{E} - \lambda_Y Y - \lambda_Z Z}{\bar{E}} \tag{1}$$

where $\bar{E}$ is the environmental endowment when there is no pollution in the economy, which is regarded as given; λ_Y (λ_Z) expresses the units of pollution generated by one unit of production of goods Y(Z). Therefore, total pollution is $\lambda_Y Y + \lambda_Z Z$. $0 < e < 1$,and $e=1$ means no pollution in the economy. A reduction in e indicates the deterioration of environment quality.

Assume that the production of goods X depends on environmental quality, the environmental improvement (deterioration) will create correspondingly higher (lower) levels of output. Labor and land enter into the production of goods X under the constant return to scale technology. The production function for goods X is as follows: $X = \alpha^{-\alpha}(1-\alpha)^{\alpha-1} e^{\delta} L_X^{\alpha} T^{1-\alpha}$,where α and δ are parameters in the range $(0,1)$. And δ expresses the effect of environment pollution on agricultural productivity. The corresponding unit cost function is denoted by $e^{-\delta} w^{\alpha} \tau^{1-\alpha}$, where w is the wage rate and τ is the land rent. Under the condition

that its market is perfectly competitive, we could obtain

$$w^{\alpha}\tau^{1-\alpha}e^{-\delta}=1 \tag{2}$$

By Shephard's lemma, demands for labor and land are $\alpha X/w$ and $(1-\alpha)X/\tau$, respectively.

Next considering two urban sectors. The final goods *Y* is produced under perfectly competitive conditions by using labor L_Y and intermediate input *Z*. The production function is $Y=\beta^{-\beta}(1-\beta)^{\beta-1}L_y^{1-\beta}Z^{\beta}$, where β is parameter in the range $(0,1)$. Assume firms in this sector are also pricing-taking in factor markets, in equilibrium, its unit cost is equal to unit price:

$$p_Y(Y)=\bar{w}^{1-\beta}p^{\beta} \tag{3}$$

where $\bar{w}$ is the minimum wage in the urban region, which exceeds the labor wage in the rural region. *p* is the price of intermediate input. Equation (3) shows the amount that the downstream manufacturing sector will pay for its intermediate input as a function of its output and wage rate, $p=\left[p_Y(Y)\right]^{1/\beta}\bar{w}^{(\beta-1)/\beta}$. Demand for labor and intermediate input are given by $L_Y=(1-\beta)p_Y(Y)Y/\bar{w}$ and $Z=\beta p_Y(Y)Y/p$, respectively.

The state upstream firm produces goods *Z* with a technology that uses labor alone and has increasing returns to scale. The cost of firm involves fixed cost, *f* units labor. After investing in fixed inputs, output *Z* requires *bZ* amount of labor, where *b* denotes the unit labor requirement. Thus, the profit of firm is $\pi=pZ-\bar{w}(f+bZ)$. Since the firm is partially privatized, it cares not only in profits, but also is social welfare generated. After incorporating pollution, a modified form of social welfare, *W*, is defined as the sum of firm profits and consumer surplus less pollution damage to the consumers: $W=\pi+CS-\varphi(\lambda_Y Y+Z\lambda_Z)$,where *CS* denotes consumers' surplus from goods *Y*,and $CS=v(Y)-p_Y(Y)Y$. φ measures the unit pollution damage to the public. Borrowing from the setting of Beladi and Chao [19], the partially privatized firm aims to maximize the objective *V*, which is a mix of its profit and social welfare *W*, $V=\theta\pi+(1-\theta)W$, where $\theta\in[0,1]$ represents the degree of partial privatization. The larger the value of θ, the more privatized the public firm. That is, when $\theta=0$($\theta=1$), the firm is a completely public-owned (privatized) firm in pursuit of the maximization of social welfare (its profit). The firm chooses the output *Z* to maximize the objective, and the consequent first-order condition is:

$$p\left(1-\frac{\theta}{\varepsilon_Y}\right)=\bar{w}b+(1-\theta)\left[\varphi\lambda_Z+\frac{\varphi\lambda_Y p}{p_Y(Y)}\right] \tag{4}$$

where $\varepsilon_Y=-p_Y/\left(Yp_Y'\right)>0$ is the price elasticity of demand for the goods *Y*. The left hand side expresses the standard marginal revenue of producing goods Z[3]. For the public sector, its marginal loss includes both the standard marginal cost $\bar{w}b$ and the extra loss because of environmental responsibility. Note that the liability also incorporates pollution from manufacturing sector, and an increase in the output of the upstream sector lowers the price of intermediate input, and thus raises the pollution. When $\theta=1$, we obtain the standard pricing rule of one monopolistic firm. When $\theta=0$, the fully nationalized firm not only considers pollution emitted by itself but also pollution generated by its downstream firms.

The higher downward rigid urban wage leads to rural-urban migration, thereby resulting in urban unemployment, L_U. Defining the unemployment ratio in the urban sector by $\lambda=L_U/\left(L_Y+Zb+f\right)$. The Harris-Todaro (1970) migration equilibrium is:

$$w=\bar{w}/\left(1+\lambda\right) \tag{5}$$

Equation (5) shows that in the labor market equilibrium, the wage rate in the agricultural sector equals the expected wage income in the two urban sectors, which is equal to the downward rigid wage rate multiplied by the probability of finding a job in these two sectors.

We turn our attention to the factor markets. The equilibrium condition for labor, land and intermediate input are:

$$\alpha X/w+\left(1+\lambda\right)\left[L_Y+Zb+f\right]=L \tag{6}$$

[3] *Even though the elasticity is expressed in the final goods Y, we can calculate from (3) the demand function for intermediate input that the price elasticity of Z equals* ε_Y.

$$(1-\alpha)X/\tau = T \tag{7}$$

$$p_Y(Y)\beta Y/p = Z \tag{8}$$

where *L* and *T* are the endowments of labor and land in the economy, respectively.

So far, the construction of the model has completed. There are eight equations, from (1) to (8), determining seven endogenous variables, namely *e*,*w*,τ,*X*,*Y*,*Z*,*p*,*λ*.

3. COMPARATIVE STATIC ANALYSIS

3.1 Privatization and Environment

Analyzing the established economic system, we know that given the value of *p*, from Eqs. (3), we can solve for the equilibrium values of *Y*, and $\hat{Y} = -\beta\varepsilon_Y \hat{p}$, where a circumflex represents a percentage change. Therefore, total differentiation of Eq. (4),

$$\frac{\hat{p}}{\hat{\theta}} = \left[-\frac{\theta}{1-\theta}\left(1+\lambda_C^w \frac{\varepsilon_Y}{\theta-\varepsilon_Y}\right) - \frac{\theta}{\theta-\varepsilon_Y} \right] \Big/ \Omega_1 \tag{9}$$

where $\lambda_C^w = \bar{w}b/p$ is marginal wage cost to price ratio. From Eq. (4), $\theta-\varepsilon_Y<0$ and $1+\lambda_C^w\frac{\varepsilon_Y}{\theta-\varepsilon_Y}>0$.

$$\Omega_1 = -\frac{\beta\varepsilon_Y}{\theta-\varepsilon_Y}\left[1-\lambda_C^w+\theta(\gamma+1)\right] + 1 - \left(1+\lambda_C^w\frac{\varepsilon_Y}{\theta-\varepsilon_Y}\right)\left[\lambda_Y^R-\beta\left(1-\lambda_Y^R\right)\right]$$

where $\lambda_Y^R = \lambda_Z/(\lambda_Z+\lambda_Y p/p_Y)$,γ=*Yp*$_Y$″/*p*$_Y$′ measures the curvature of the demand function and 1+γ> 0 is assumed by the stability condition (as shown in Appendix), and $\Omega_1>0$ .Therefore, the sign of $\hat{p}/\hat{\theta}$ determined by the sign of numerator. From (9), it is easy to arrive that when $\varepsilon_Y<1/(1-\lambda_C^w)$, $\hat{p}/\hat{\theta}>0$. If $\varepsilon_Y>1/(1-\lambda_C^w)$, $\hat{p}/\hat{\theta}<0$.

Lemma 1. When the price elasticity of demand for manufacturing goods is relatively small, deepening privatization raises intermediate input price. However, the price decreases if the elasticity is sufficiently large.

An increase in the degree of private ownership corresponds to more commercial objectives, which encourages it to reduce its output and raise its price. This is the negative effect of privatization on output and its price highlighted in the literature, and we refer to it as the profit-seeking effect. When incorporating pollution and assuming the partially privatized firm cares about social welfare, the implementation of privatization also reduces the environmental liability, which encourages it to expand its output and reduce its price. Authors refer to it as the liability-reducing effect. From (9), the liability-reducing effect is expressed by the first term in brackets, and the profit-seeking effect is expressed by the second term.

Obviously, the magnitudes of two effects are determined by the price elasticity of demand for manufacturing goods. And the elasticity directly affects the profit-seeking effect. With a larger elasticity, the partial privatized firm faces a smaller the profit-seeking effect. Meanwhile, the elasticity indirectly affects the liability-reducing effect, and they have a positive relationship. Thus, when the elasticity is relatively small, the profit-seeking effect dominates the price change, resulting in raising the price. However, if the elasticity is sufficiently large, the liability-reducing effect outnumbers the profit-seeking effect, and deepening privatization cuts down the price instead.

Next, we consider the environmental effect. Total differentiation of Eq. (1) and (8) yields:

$$\frac{\hat{Z}}{\hat{\theta}} = (\beta-1-\beta\varepsilon_Y)\frac{\hat{p}}{\hat{\theta}} \tag{10}$$

and

$$\frac{\hat{e}}{\hat{\theta}} = \left[\lambda_{EY}\beta\varepsilon_Y - \lambda_{EZ}(\beta-1-\beta\varepsilon_Y)\right]\frac{\hat{p}}{\hat{\theta}} \tag{11}$$

where $\lambda_{EY} = \lambda_Y Y/\bar{E}$ ($\lambda_{EY} = \lambda_Z Z/\bar{E}$)denotes environmental deterioration attributing to pollution from sector *Y* (*Z*). Summarizing the results, we establish Proposition 1 as follows:

Proposition 1. *In the economy assumed by researchers, deepening the privatization level will deteriorate the environment if the price elasticity of demand for manufacturing goods is sufficiently large. The environment improves if the price elasticity is relatively small.*

Beladi and Chao [11] holds that when pollution taxes are absent, privatization level and pollution emissions have a negative relationship. The reason is that privatization encourages the state firm to focus more on its profit, which lowers output and hence pollution emissions. However, when authors consider privatization in vertically related markets and incorporate the environmental liability of privatized firm, privatization may not improve the environment. From Lemma 1, if the price elasticity of demand for manufacturing goods is sufficiently large, privatization brings down the price of sector Z and expands its output. The downstream manufacturing sector enlarges its output and generates more pollution correspondingly. In this case, deepening the privatization level will deteriorate the environment. However, privatization raises intermediate input price when the price elasticity is relatively small. At this situation, privatization cuts down output of two urban sectors and reduces pollution emissions and improves the environment.

Now, we analyze how the deepening of privatization influences unemployment and output of sector *X*. Using (9), (10)and (11), and total differentiation of Eq. (2),(5),(6) and (7) yields:

$$\frac{\hat{w}}{\hat{\theta}} = -\frac{\lambda}{1+\lambda}\frac{\hat{\lambda}}{\hat{\theta}} \tag{12}$$

$$\frac{\hat{X}}{\hat{\theta}} = \frac{\delta\left[\lambda_{EY}\beta\varepsilon_Y - \lambda_{EZ}\left(\beta-1-\beta\varepsilon_Y\right)\right]-\alpha\Omega_2}{(\alpha\lambda_{LX}+1-\alpha)}\frac{\hat{p}}{\hat{\theta}} \tag{13}$$

And

$$\frac{\hat{w}}{\hat{\theta}} = \frac{+(1-\alpha)\Omega_2}{(\alpha\lambda_{LX}+1-\alpha)}\frac{\hat{p}}{\hat{\theta}} \tag{14}$$

where $\delta\lambda_{LX}\left[\lambda_{EY}\beta\varepsilon_Y - \lambda_{EZ}\left(\beta-1-\beta\varepsilon_Y\right)\right]$

$\Omega_2 = (1+\lambda)\left[\beta\lambda_{LY}(1-\varepsilon_Y) + \lambda_{LZ}^V\left(\beta-1-\beta\varepsilon_Y\right)\right] < 0$. $\lambda_{LY}(\lambda_{LX})$ is the allocative share of labor in the production of product *Y*(*X*) and λ_{LZ}^V represents the allocative share of labor in the variable cost of production of product Z. With the existence of rural-urban migration, from (12), the wage rate and the urban unemployment rate change reversely. The lower (higher) the wage rate, the larger (smaller) urban unemployment rate. Obviously, the value of *λ* reflects the demand for labor in the urban region, and a low *λ* means the demand is strong and rural agricultural sector has to pay its labor a higher wage. From (13), the sign of $\hat{X}/\hat{\theta}$ is same with the sign of $\hat{p}/\hat{\theta} > 0$. However, the effect of *θ* on *w* is more complicated. If $\hat{p}/\hat{\theta} > 0$ and $\delta > \delta^*$ ($\delta < \delta^*$), $\hat{w}/\hat{\theta} > 0$ ($\hat{w}/\hat{\theta} < 0$) and $\hat{\lambda}/\hat{\theta} < 0$ ($\hat{\lambda}/\hat{\theta} > 0$),where $\delta^* = (\alpha-1)\Omega_2 \Big/ \left\{\lambda_{LX}\left[\lambda_{EY}\beta\varepsilon_Y - \lambda_{EZ}\left(\beta-1-\beta\varepsilon_Y\right)\right]\right\}$. If $\hat{p}/\hat{\theta} < 0$ and $\delta < \delta^*$ ($\delta > \delta^*$), $\hat{w}/\hat{\theta} > 0$ ($\hat{w}/\hat{\theta} < 0$) and $\hat{\lambda}/\hat{\theta} < 0$ ($\hat{\lambda}/\hat{\theta} > 0$).

Proposition 2. *(i) When the price elasticity of demand for manufacturing goods is sufficiently large,an increase in the degree of partial privatization contracts agricultural output, and cuts down (resp. expands) the rural wage and raises unemployment rate if the magnitude of environment on agricultural production is sufficiently small (resp. large); (ii) when the price elasticity of demand for manufacturing goods is relatively small, an increase in the degree of partial privatization enlarges agricultural output, and expands (resp. cuts down) the rural wage and raises unemployment rate if the magnitude of environment on agricultural production is sufficiently small (resp. large).*

According to Proposition 1,if the price elasticity of demand for manufacturing goods is sufficiently large, then deepening privatization deteriorates the environment and reduces agricultural productivity. Hence, labor outflows from this sector and factor rewards reduce, cutting down agricultural output.

The outflow of agricultural labor raises the supply of labor in the urban region. However, its effect on urban unemployment rate is ambiguous. On the one hand, if the magnitude of environment on agricultural production is sufficiently small, then environment deterioration has a relatively small effect on agricultural productivity. Thus, the

demand for labor will decrease slightly in the agricultural sector. Meanwhile, two urban sector expands their output and enlarge labor demand. As a result, urban employment will increase, leading to the shrink of the unemployment rate. On the other hand, if the magnitude of environment on agricultural production is large enough, environment deterioration has a significant effect on agricultural productivity, and the demand for labor falls greatly. Due to the downward rigid wage rate, the enlargement of two urban sectors is relatively limited. Thus, an outflow of agricultural labor outnumbers the enlargement of employment, resulting in the expansion of the unemployment rate.

When the price elasticity of demand for manufacturing goods is relatively small, we know that the environment improves. In this situation, agriculture raises its productivity because of the positive external environment and attracts the inflow of labor. If the magnitude of environment on agricultural production is sufficiently small, which means the positive effect has little influence on agricultural productivity, and the demand for labor increases slightly. Meanwhile, two urban sectors contract their outputs and cut down employment. In this case, the reduction of employment will be dominant, and the unemployment rate rises [20,21]. However, if the magnitude of environment on agricultural production is relatively large, then the demand for labor will increase greatly. As a consequence, the limited decrease of the demand in the urban region cannot effectively stop the increase of agricultural employment. So, the increase of employment of agricultural labor will be dominant, which leads to the reduction of the unemployment rate.

3.2 Pollution Abatement Technology and Environment

Improving the technology level of pollution abatement means a decrease in λ_Y and λ_Z. Since two parameters affect endogenous variables in the same direction, here, we only consider the case of a decrease in λ_Z. Total differentiation of Eq. (4),

$$\frac{\hat{p}}{\hat{\lambda}_Z}=\left(1+\lambda_C^w\frac{\varepsilon_Y}{\theta-\varepsilon_Y}\right)\left(1-\lambda_Y^R\right)>0 \tag{15}$$

And from (10) and (11)

$$\frac{\hat{Z}}{\hat{\lambda}_Z}=\left(\beta-1-\beta\varepsilon_Y\right)\left(1+\lambda_C^w\frac{\varepsilon_Y}{\theta-\varepsilon_Y}\right)\left(1-\lambda_Y^R\right)<0 \tag{16}$$

and

$$\frac{\hat{e}}{\hat{\lambda}_Z}=\left[\lambda_{EY}\beta\varepsilon_Y-\lambda_{EZ}\left(\beta-1-\beta\varepsilon_Y\right)\right]\left(1+\lambda_C^w\frac{\varepsilon_Y}{\theta-\varepsilon_Y}\right)\left(1-\lambda_Y^R\right)>0 \tag{17}$$

Summarizing the results, we establish Proposition 3 as follows:

Proposition 3. *Improving pollution abatement technology deteriorates the environment.*

Generally, improving pollution abatement technology has a positive effect on enthronement. However, Proposition 3 obtains a paradoxical result and shows that more green technology does not necessarily reduce pollution levels and improve the environment. The result crucial depends on the environmental liability of the partial privatized upstream firm. With an improvement of pollution abatement, the partial privatized firm faces a lower marginal loss from (4). Therefore, the firm reduces its price and expands its output. With more intermediate input, the downstream manufacturing sector increases its output correspondingly. Thus, two sectors generate more pollution and deteriorate the enthronement.

Using (15), (16) and (17), and total differentiation of Eq. (2),(5),(6) and (7) yields:

$$\frac{\hat{w}}{\hat{\lambda}_Z}=-\frac{\lambda}{1+\lambda}\frac{\hat{\lambda}}{\hat{\lambda}_Z} \tag{18}$$

$$\frac{\hat{X}}{\hat{\lambda}_Z}=\frac{\delta\left[\lambda_{EY}\beta\varepsilon_Y-\lambda_{EZ}\left(\beta-1-\beta\varepsilon_Y\right)\right]-\alpha\Omega_2}{(\alpha\lambda_{LX}+1-\alpha)}\left(1+\lambda_C^w\frac{\varepsilon_Y}{\theta-\varepsilon_Y}\right)\left(1-\lambda_Y^R\right)>0 \tag{19}$$

And

$$\frac{\hat{w}}{\hat{\lambda}_Z}=\frac{\delta\lambda_{LX}\left[\lambda_{EY}\beta\varepsilon_Y-\lambda_{EZ}\left(\beta-1-\beta\varepsilon_Y\right)\right]+(1-\alpha)\Omega_2}{(\alpha\lambda_{LX}+1-\alpha)}\left(1+\lambda_C^w\frac{\varepsilon_Y}{\theta-\varepsilon_Y}\right)\left(1-\lambda_Y^R\right) \tag{20}$$

In view of the above results, we establish Proposition 4 to summary its effect on agricultural output and unemployment rate.

Proposition 4. *Improving pollution abatement technology reduces agricultural output. When the magnitude of environment on agricultural production is relatively small (resp. large), more green technology reduces(raises) the unemployment rate.*

From Proposition 2 and Proposition 3, the economic insight is straightforward. From Proposition 3, improving pollution abatement technology deteriorates the environment and harms agricultural output. In this situation, labor outflows from rural area. Just like the mechanism of Proposition 2, more green technology leads to an ambiguous effect on unemployment rate, depending on the magnitude of environment on agricultural production. Therefore, it is unnecessary to repeat the process.

4. CONCLUSION

The vertical structure between SOEs and private firms is prevalent in developing countries: SOEs monopolize key upstream industries and provide essential intermediate inputs to downstream private firms. Thus, privatization of SOEs could affect the environment and unemployment. We build a three-sector general equilibrium model to investigate the environmental implication of privatization. We obtain that the price elasticity of demand for manufacturing goods is crucial for determining the environmental impact of privatization. When the price elasticity is relatively small (large), deepening privatization raises (decreases) price of partial privatized firm and improves (deteriorate) the environment. We also show a paradox result that improving pollution abatement technology deteriorates the environment instead.

The policy implications of this paper are as follows. Privatization is usually regarded as a tool to spur economic growth in the sense that it can realize better resource allocation and improved efficiency. However, with implementation of this policy, environment and unemployment issues are increasingly prominent. Following the theoretical results in this paper, privatization may deteriorate the environment and raise the unemployment rate. That is to say, privatization could lead to positive and negative effects simultaneously. Thus, when carrying out this policy, the government should take those two negative effects into account.

DECLARATION

We confirm that this manuscript has not been published elsewhere and is not under consideration by another journal. All authors have approved the manuscript and agree with submission to Asian Journal of Economics, Business and Accounting. The authors have no conflicts of interest to declare.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX

Stability

The dynamic adjustment for the goods Z is:

$$\dot{Z} = d\left\{ p\left(1-\frac{\theta}{\varepsilon_Y}\right) - \bar{w}b - (1-\theta)\left[\varphi\lambda_Z + \frac{\varphi\lambda_Y p}{p_Y(Y)}\right]\right\}$$

where a dot over *Z* denotes the time derivative and *d* is the positive speed of the adjustment. The adjustment process means when the marginal revenue is larger than the marginal loss, sector *Z* will expand its output. Linearizing the above equation around the equilibrium values,

$$\dot{\hat{Z}} = -\frac{d}{\varepsilon_Y}\left[\bar{w}b + (1-\theta)\varphi\lambda_Z + p\beta\theta(1+\gamma) + \frac{\beta\theta p}{\varepsilon_Y} + \frac{\beta(1-\theta)\varphi p\lambda_Y}{p_Y(Y)}\right]\hat{Z}$$

Because of ε_Y >0, a sufficient condition for stability requires 1+γ >0. The similar condition could refer to Beladi and Chao [19].

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