Original Research Article

Agricultural and Manufacturing Pollution: Labor Health and Technology Progress

Abstract

In this paper, we hold that it is the input of capital in agricultural production that is the main reason for agricultural pollution in developing countries under existing technical conditions.We try to integrate agricultural pollution into a general equilibrium model with environmental pollution caused by labor movement by setting up environmental "health factor" and undertake a comparative static analysis about theimpacts of manufacturing and agricultural technology progress. The main conclusions of this article are thatmanufacturing and agricultural technology progress improve the environment under the model with agricultural pollution; however, the economic impacts ofmanufacturing and agricultural technology progress are different:manufacturing technologyprogressdrops manufacturing output,while agricultural technology progressraises agricultural output.

Keyword: Agricultural Pollution,Environmental Health Factor, Environmental Technology Progress.

JEL:Q5,R23,I1.

1. Introduction

The issue of environmental pollution has been highly valued in theoretical studies of labor movement since 2000, emerging some articles which analyzed the environmental pollution resulted from labor movement in developing countries. The majority of related literatures, employing the Harris–Todaro labor movement model (1970), followed the assumption made by Copeland and Taylor (1999). They assumed the manufacturing production causes emission of pollution, worsening environment. The harmful substances emitted, such as waste gas, residue, pollute water and soil for agricultural use through atmosphere, rivers and other media, exerting negative effects on agricultural production. The recent studies can be referred to Li andZhou(2013),Wu and Li(2020),Li and Fu(2020)and Fu and Li(2022).Li and Zhou(2013) considered an economy consisting of three sectors: the rural agricultural sector, the urban producer services sector, and the urban manufacturing sector. The production procedure of the manufacturing sector does not depend on environmental factors. However, manufacturing production will generate pollution, which imposes damage to the rural environment. The production procedure of agricultural sector depends not only on production factors but also on environmental factors. Production from the producer services sector neither generates pollution nor depends on environmental factors. They conducted the analysis of the environmental and economic effects of the government and producer services sector's training of rural-urban migrants and reached the main conclusions: when the government lowers the interest rate of training loans, environmental conditions will worsen; when the producer services sector increases the unit cost of training rural labor, environmental conditions will improve. Li and Wu(2020) analyze the environmental impacts of international factor flows through a general equilibrium model that incorporates a modern agriculturalsector in different stages. They argue that the results and impacts of international factor mobility on environmental problems are different at different stages of modern agricultural development. They concluded that when modern agricultural capital occupies a certain proportion in the economy, international factor inflows can improve the environment of developing countries, so it is possible for international factor flows to be compatible with the environmental problems of developing countries.Fu and Li(2022) established an open general equilibrium model containing three sectors to study the impact of international capital and labor mobility on the environment of developing countries under the development of modern agriculture, and concluded that for a developing economy like China with both agricultural dual structure and urban-rural dual economy, The conclusion that policies that encourage migrant workers to increase their remittance rates can increase production and national welfare in the agricultural sector, thereby reducing agricultural pollution.Li and Fu(2020) believe that private mitigation is an instinctive response of people to environmental pollution, so they study the issue of wage inequality and unemployment rate from the perspective of agricultural pollution. They propose that in the capital mobility case, increasing unit private mitigation expenditure can not only reduce urban unemployment rate and narrow urban-rural wage inequality, but also increase national income and improve environmental pollution.Li and Fu(2023) constructed a three-sector general equilibrium model including agricultural producer services, studied the influence of government price subsidies, interest subsidies and wage subsidies on agricultural producer services on agricultural pollution and other economic indicators, and concluded that under certain conditions, Increasing the price subsidy and wage subsidy of agricultural producer services will increase the output of agricultural producer services and reduce the output of agricultural producer services, but will aggravate agricultural pollution. At the same time, an increase in the interest subsidy for agricultural producer services will reduce the output of the agricultural sector, conditionally increase the output of agricultural producer services, and reduce agricultural pollution.All in all , Copeland and Taylor'smodel has a certainrationality, for the major sources of pollution are from manufacturing production and agricultural sector isthe victim of environmental pollution, therefore the model is widely accepted bythe current theoretical economics. But the problem is that such theoretical assumption ignored the fact that agriculturalproduction also generates pollution. Nowadays,there are already ample evidences linking agricultural pollution resulted from excessive use of fertilizers and pesticides to increase output in many developing countries.One explanation is that due to the rapid development of manufacturing sector, tons of labor force departure from agricultural sector and move to the manufacturing sector, forcing farmers to usemore capital to replace transferred labor in the process of agricultural production. Increasing the input of chemical fertilizers and pesticides is the most convenient method. According to the Table 1, China's fertilizer input was 35.9 million tons in 1995, then the amount of consumption raisedsharply, arriving at54.1 million tons in 2019;similarly, the amount of pesticide usage was 1.08 million tons in 1995,and this figure was 1.4 million tons in 2019.The figures of chemical fertilizer and pesticide input in China are the largest among the world, and farmers use far more fertilizer and pesticides than the global average.Agricultural production has been increasing through large input of fertilizer and pesticide, however, usingfertilizer and pesticideexcessively has a side effect: pollution. For example, it is fertilizer and pesticide residues on large amounts of agricultural products that illustrate the effect of environmental pollution generated by agricultural production(hereinafter, we call such pollution "agricultural pollution"). According to related reports, in China, there are 12 million tons of food contaminations due to agricultural pollution every year[1]. Note that the use of fertilizers and pesticides in agricultural production comes from the input of capital in agricultural sector;by contrast,traditional agricultureproduction, which relies mainly on labor, seldom generates agricultural pollution. Therefore, we conclude that it is the input of capital in agricultural production that is the main reason for agricultural pollution in developing countries under existing technical conditions.

[Table 1]

On the other hand, under the framework of labor movement, there are not many theoreticalstudies of improving the environment throughtechnical progress. Li(2005) made a theoretical analysis on the economic effects of technical progress with Chinese characteristics

[1]Research Report on Land Consolidation and Rehabilitation of China(No.1),Beijing, Social Sciences Academic Press

(the existence of Hukou Policy), and concluded technology progress of environmental protection will improve environment, increase the employment and agricultural wage and decrease the number of migrants of rural area and unemployment of urban area.Fukuyamaand Naito(2007) showed that the improvement of pollution reduction technologymay increase the laborinput of the agricultural goods sector, it does not affect the labor inputof the manufactured goods sector and may decrease the unemployment rate. However, the above studies also do not integrate agricultural pollution.It must be pointed out that Li(2005) and Fukuyamaand Naito(2007) did not specialize in investigating the relationship of technical progress and environmental improvement and results from the two articles were obtained under specific conditions, excluding agricultural pollution.

In a word, both from labor movement aspect and from technical progress point of view are not analyzed agricultural pollution. It is fact that agricultural pollution has become increasingly apparent. And if we do not take agricultural pollution into consideration,our research will not accurately reflect real economychange; thus, it is necessary to incorporate agricultural pollution when we study current economy situation. That's whythis paper constructs a general equilibrium model thatmanufacturing pollution imposes damages upon agricultural production and agricultural production also generates pollution and employs the model to investigate the economic impacts of technical progress in dual economy with labor movement from rural to urban area. The paper divides the model into two cases. The first case is that the input of agricultural capital enters a rapid growth period, which alwaysoccurs in the economy take-offstage and the early period of emergence of agricultural pollution when the economic and environmental impacts of agricultural pollution are considerablydifferent from those of manufacturing pollution.The second case is that the input of agricultural capital enters a steady period. "Steady" here is a relative concept,i.e.,in this period,the use of capital in agricultural production has become the normal state and agricultural and manufacturing pollution are gradually integrated. The main conclusions of this paper are thatmanufacturingand agricultural technology progresswill improve the environment and agricultural technology progresscould increase agricultural production both in the rapid growth period and steady period of agricultural capital. It's the first time that we get such conclusions in the theoretical economic research. As for agricultural sector, the results have at least two implications: first, unlike traditional knowledge, the results conclude that the expansion of agricultural production and the improvement of the environment can be obtained at the same time; second, agricultural sector reaps the benefits of technology progress and has more incentives to improve pollution-abatement technology.

The paper proceeds as follows. In the first part of the second section, we set upa theoretical model and conduct the theoretical analysisof the established model in the rapid growth period of agricultural capital; in the second part, we establish a model and make relevant analyses in the steady period of agricultural capital; in the last part of this section, we present partial elasticityanalyses of economic and environmental factors. Finally, section 3 contains our concludingremarks.

2. The model and analysis

2.1 The model and analysis in the rapid growth period of agricultural capital

Consider a small and open economy consisting of two sectors: urban manufacturing sector (sector 1) and rural agricultural sector (sector 2). Manufacturing sector produces importable goods, while agricultural sector produces exportable goods. Both sectors employ capital and labor for production, and factors can move between sectors.

With regard to the effect of manufacturing pollution on external environment of agricultural production, this paper based on Copeland and Taylor's model. Define E as the environmental stock of productionwhich expresses the externalenvironment of agricultural production.As to the effect of agricultural pollution on environment, we consider a periodwhen the input of agricultural capital rises rapidly. The agricultural capitalmainly used for purchasing fertilizers and pesticides during agricultural production and the usage of chemical materials soars at this stage. The feature of agricultural pollution is thatfertilizers and pesticides affect labor health mainly through residues on agricultural products, like rice,vegetables and fruits, and labor forces in manufacturing and agricultural sector would experience a drop in their efficiencies because of declining health status, which is the most immediately and most directly effectof agricultural pollution(Wilson and Tisdell,2001). What needs illustration is that the agricultural pollution is not generated by whole agricultural capital, however, it is an undeniable fact that such capital does exist. The paper assumes that agricultural capital will generate pollution in order to focus analysis on agricultural pollution. Define$H$ as the environmental stock of health which expresses the environmental status of health; and we assume that Hassociates with the amount of capital in agriculture. The environmental stock of production and health are given by:

$$E=\bar{E}-\xi_1 X_1 \quad (1)$$

$$H=\bar{H}-\xi_2 K_2 \quad (2)$$

where X_1 is manufacturingoutput, K_2 isagricultural capital; $\bar{E}$ is the natural stock level of environmental before emitted manufacturing pollution,which is the best quality of the environmental stock of production; $\bar{H}$ is the environmental stock level of health without agricultural pollution, which is the best quality of the environmental stock of health; ξ_1

expresses the units of pollution generated by one unit manufacturingproduction; ξ_2 expresses the units of pollution generated by one unit agriculturalproduction; Manufacturing and agricultural technology progress meancomprehensive technical progress, including environmentaltechnology, and also refer to the declines of ξ_1 and ξ_2 .

We set up environmental "health factor" $h(H)$,which represents the effect of environmental pollution on labor productivity; $g(E)$ is environmental "production factor " and represents the effect of external environment on agricultural productivity. Production functions of manufacturing and agricultural sector are given by:

$$X_1 = F^1(h(H)L_1, K_1)$$

$$X_2 = g(E)F^2(h(H)L_2, K_2)$$

where L_i (i =1,2)and K_i(i =1,2)are labor and capital employed by sector i.F^i(i =1,2)is the strictly quasi concave and linearly homogenous function of sector i. $g(E)$ with the properties, $0<g(E)<1$, $g'(E)>0$, $g''(E)<0$; $h(H)$with the properties,$0<h(H)<1$, $h'(H)>0$, $h''(H)<0$.

Under the condition that markets are perfectly competitive, we obtain that:

$$p = a_{L1}h(H)w_U + a_{K1}r \quad (3)$$

$$g(E) = a_{L2}h(H)w + a_{K2}r \quad (4)$$

where a_{i1}(i=L, K) represents factor i used in producing one unit of goods in manufacturing sector, a_{i2}(i=L, K) represents factor i used in producing one unit of goods (without external effect) in agricultural sector(e.g. $a_{K2} = K_2 / F^2$). w_U is a institutionally fixed wage in manufacture, w is a flexible wage in agriculture. r is the interest rate of capital. p is the relative price of manufacturing product in terms of agricultural product. We assume all the products are tradable and hence prices are given internationally.

We use $L_U$to denote the number of unemployed labor in the urban region and μ to denote the unemployment rate, $\mu = L_U / L_1 = L_U / a_{L1}X_1$.Therefore, in the labor market equilibrium, the wage in agriculture equals the expected wage in manufacture:

$$w = w_U / (1+\mu) \quad (5)$$

The market clearing conditions of labor and capital could be shown as:

$$(1+\mu)a_{L1}X_1 + a_{L2}F^2 = L \qquad (6)$$

$$a_{K1}X_1 + a_{K2}F^2 = K \qquad (7)$$

where *L* and *K* represent the endowments of labor and capital.

Differentiating the equations. (1)–(7)and writing in a matrix notation

$$\begin{pmatrix} -\theta_{L1}AB & -\theta_{L1}A & -\theta_{L1}AS_{KL}^2 & \theta_{K1}-\theta_{L1}AS_{KK}^2 \\ -\theta_{L2}AB & -\theta_{L2}A & \theta_{L2}(1-AS_{KL}^2) & \theta_{K2}-\theta_{L2}AS_{KK}^2 \\ \lambda_{K1}+\lambda_{K2}B & \lambda_{K2} & \lambda_{K2}S_{KL}^2 & \lambda_{K1}S_{KK}^1+\lambda_{K2}S_{KK}^2 \\ D & \lambda_{L2} & G & C \end{pmatrix} \begin{pmatrix} \hat{X}_1 \\ \hat{X}_2 \\ \hat{w} \\ \hat{r} \end{pmatrix} = B \begin{pmatrix} \theta_{L1}A \\ \theta_{L2}A \\ -\lambda_{K2} \\ -\lambda_{L2} \end{pmatrix} \hat{\xi}_1 + A \begin{pmatrix} \theta_{L1} \\ \theta_{L2} \\ 0 \\ 0 \end{pmatrix} \hat{\xi}_2 \quad (8)$$

where "^" represents the rate of change, θ_{ij}(i=L,K,j=1,2) is the distributive share of factor *i* in the *j* thsector (e.g. $\theta_{L2} = a_{L2}h(H)w/g(E)$). λ_{ij} is the allocated share of factor*i* in the *j* th sector (e.g. $\lambda_{L2} = a_{L2}F^2/L$); $S_{ij}^h (i = L, K,\ j = L, K, h = 1,2)$ is the partial elasticity of substitution between factors *i* and *j* in the *h* th sector (e.g. $S_{KL}^2 = \frac{\partial a_{K2}}{\partial w}\frac{w}{a_{K2}}$), $S_{ij}^h > 0 (i \neq j)$ and $S_{ij}^h < 0 (i = j)$. We also have: $A = \frac{h'}{h}\xi_2 K_2 > 0$, $B = \frac{g'}{g}\xi_1 X_1 > 0$,

$C = \lambda_{L1}(1+\mu)S_{LK}^1 + \lambda_{L2}S_{LK}^2 > 0$, $D = \lambda_{L1}(1+\mu) + \lambda_{L2}B > 0$, $G = \lambda_{L2}S_{LL}^2 - \lambda_{L1}(1+\mu) < 0$.

According to characteristics of developing economies, we assume that the size of population living in rural is greater than that of urban area, $\lambda_{L2} > (1+\mu)\lambda_{L1}$; the amount of capital employed in manufacturing sector is greater than that of agricultural sector, $\lambda_{K1} > \lambda_{K2}$ .Moreover, the capital per capita of manufacturing sector is bigger than that of agricultural sector.

The determinant of the coefficient matrix of equation (8) is denoted as Δ_1,

$$\Delta_1 = A\lambda_{K1}(\theta_{L1}\theta_{K2} - \theta_{K1}\theta_{L2})[\lambda_{L2}(S_{LL}^2 - S_{KL}^2) - \lambda_{L1}(1+\mu)] - \theta_{K1}\theta_{L2}[\lambda_{K1}\lambda_{L2} - \lambda_{K2}\lambda_{L1}(1+\mu)]$$
$$-A\theta_{L1}\theta_{L2}[\lambda_{K1}\lambda_{L1}(1+\mu)S_{KL}^1 + \lambda_{K1}\lambda_{L2}(S_{LK}^2 - S_{KK}^2) - \lambda_{K1}S_{KK}^1\lambda_{L1}(1+\mu)] < 0$$

Solving Eq. (8) by using the Cramer's rule, we obtain the Table 2.

[Table 2]

From the Table 2, the impacts of manufacturing technology progress on environmental stock of production and agricultural output are similar with those of agricultural technology progress; however, the impacts of manufacturingtechnology progresson environmental stock of health and other economic variables are different with those of agricultural technology progress. One different aspect shows in the environment, manufacturing and agricultural technology progresshas no impact on the environmental stock of health, while agricultural technology progress will improvethe environmental stock of health. The other aspect represents in economic variables, manufacturing technology progress has no impact on the production, labor employment and capital of its respective sector, while agricultural technology progress will increase the production of its respective sector, affect the amount of labor and capital in both sectors and change the agricultural wage, interest rate and unemployment rate.

A decline of ξ_1 has no impact on the manufacturing production, therefore, the amount of capital and labor employed do not change. A decline of ξ_1 will increase E, which improve the external production environment, and boost the agricultural production even though the input of labor and capital unchanged. Since a decline of ξ_1 has no impact on the interest rate, agricultural capital does not change, so does H.

A decline of ξ_2 increases$H$ as well as the environmental "health factor" $h(H)$. The improvement of health status leads to the increase of labor productivity and the total units of labor $h(H)L$, which has an effect similar toan increase in the labor endowment.Because the agricultural sector is more labor intensive than the manufacturing sector, according to the RybczynskiTheorem, an increase in $h(H)$leads to an expansion of the agriculturalsector and a contraction of the manufacturing sector.Due to minimum wage rate of the manufacturing sector, the number of employed labor units $h(H)L_1$is a constant number, therefore,a contraction of the manufacturing sector is only because of a decrease of capital, and part of capital flows into agricultural sector. Meanwhile, a decrease of X_1 leads to the improvement of externalenvironment of agricultural production$E$. Both the improvement of externalenvironment and the increase of labor productivity contribute to an expansion of the agriculturalsector. Owing to an increase of labor productivity, agricultural wage increases, attracting unemployed labor moves to agricultural sector and decreasing the unemployment rate. Because the structure of agricultural productionpredominated by small-scale, home-based methods in developing countries, when labor and capital increase,agricultural sector will use more labor and less capital, which makes capital relatively abundant and the interest rate drops.

In view of the results in Table 2, we can establish the followingpropositions:

Proposition 1. *Agricultural technology progress will improve the environmental stock of production and health, lead to an expansion of the agricultural sector and a contraction of the manufacturing sector.Manufacturingtechnology progress will improve the environmental stock of production, increasetheagriculturaloutput; however, it has no impact on the manufacturing output and the environmental stock of health.*

The economic and environmentalimpacts of agriculturaltechnologyprogress in the rapid growth period of agricultural capitalcould be illustrated by the Figure1.O is the original point. The left half the horizontal axis is the environmental stock of health*H*, and its right half represents the manufacturingoutputX_1. The upper half of the vertical axis is the agriculturaloutputX_2, and the right side of lower half of the vertical axis is the level of agricultural technology ξ_2 and the left side is the environmental stock of production *E*. We use line *bb* to represent the relation between *H* and X_2,and use line *cc* to represent the relation betweenX_1andX_2. The increase of *H* leads to the increase of total units of labor $h(H)L$, which leads to an expansion of the agricultural sector and a contraction of the manufacturing sector. Hence, both line *bb* and line *cc*slant right upward. From equation(1), we use line *dd* to represent the relation between X_1 and *E*. From equation.(2), the direction of *H* dependson ξ_2 and the agricultural capital K_2:a decrease of ξ_2 increases *H*, and an increase of K_2 decreases *H*; a decrease of ξ_2 leads to an increase of *H*, reflecting a negative correlation betweenthem, so line *aa*shows a positive slopein this fourth quadrant. Given exogenous variable ξ_2^*,we obtain the equilibrium values of H , X_2 , X_1 and E are H^* , X_2^* , X_1^* and E^* , respectively.According to calculation, the impact of decrease of ξ_2 on *H* is larger than that of increase of K_2.When ξ_2^* reduces to ξ_2^{**} , the value of *H* increases from H^* to H^{**} . Following the above relations, it can be obtained that the value of other three variables are X_2^{**}, X_1^{**} and E^{**}, respectively.Here, we conclude that the environment improves.

[Figure 1]

2.2 The model and analysis in the steady period of agricultural capital

When the input of fertilizer and pesticides in agricultural production has become the normal state and the amount of capital in agricultural sector becomes steady, the agricultural pollution not only affects labor health but also damages the quality of the water and soil, like manufacturing pollution. Thus, both manufacturing and agricultural pollution affect the environmental stock of production; similarly, manufacturing pollution also affects the environmental stock of health mainly through atmosphere and rivers. From this perspective, both environmental stock of health and environmental stock of production are affected by manufacturing and agricultural pollution.In addition, since the technical level of manufacturing sector is higher than that of agricultural sector, the paper assumes that the ratio of manufacturing pollution to manufacturing capital is smaller than the ratio of agricultural pollution to agricultural capital. In the following, we will spread out analysesin accord with this situation.

Define *E*as the stock of environment in the economy, which depends on environmental technology of two sectors, manufacturing outputand agricultural capital. Thus:

$$E=\bar{E}-\xi_1 X_1-\xi_2 K_2 \quad (9)$$

$\bar{E}$ is the natural stock level of environmental;the definitions of ξ_1 and ξ_2 are set as before. Production functions of manufacturing and agricultural sector are given by:

$$X_1=F^1(h(E)L_1,K_1)$$

$$X_2=g(E)F^2(h(E)L_2,K_2) \quad (10)$$

where, $0<h(E)<1$, $h'(E)>0$, $h''(E)<0$, and other notations are set as before.

Under the condition that markets are perfectly competitive, we obtain that:

$$p=a_{L1}h(E)w_U+a_{K1}r \quad (11)$$

$$g(E)=a_{L2}h(E)w+a_{K2}r \quad (12)$$

and the meanings of all notations are same as previous.

Thetheoretical model has been built, which consists of six equations(5),(6),(7),(9),(11),(12).Differentiating the six equations and writing in a matrix notation, we can obtain the following equation:

$$\begin{pmatrix} \theta_{L1}\frac{h'}{h}M & \theta_{L1}\frac{h'}{h}N & \theta_{L1}\frac{h'}{h}NS_{KL}^2 & \theta_{L1}\frac{h'}{h}NS_{KK}^2+\theta_{K1} \\ \theta_{L2}\frac{h'}{h}M & \theta_{L2}\frac{h'}{h}N & \theta_{L2}+\theta_{L2}\frac{h'}{h}NS_{KL}^2 & \theta_{L2}\frac{h'}{h}NS_{KK}^2+\theta_{K2} \\ \lambda_{K1}-\lambda_{K2}\frac{g'}{g}M & \lambda_{K2}(1-\frac{g'}{g}N) & \lambda_{K2}S_{KL}^2(1-\frac{g'}{g}N) & \lambda_{K1}S_{KK}^1+\lambda_{K2}S_{KK}^2(1-\frac{g'}{g}N) \\ \lambda_{L1}(1+\mu)-\lambda_{L2}\frac{g'}{g}M & \lambda_{L2}(1-\frac{g'}{g}N) & G-\lambda_{L2}\frac{g'}{g}NS_{KL}^2 & C-\lambda_{L2}S_{KK}^2\frac{g'}{g}N \end{pmatrix} \begin{pmatrix} \hat{X}_1 \\ \hat{X}_2 \\ \hat{r} \\ \hat{w} \end{pmatrix} = \begin{pmatrix} -\theta_{L1}\frac{h'}{h}M \\ -\theta_{L2}\frac{h'}{h}M \\ \lambda_{K2}\frac{g'}{g}M \\ \lambda_{L2}\frac{g'}{g}M \end{pmatrix}\hat{\xi}_1 + \begin{pmatrix} -\theta_{L1}\frac{h'}{h}N \\ -\theta_{L1}\frac{h'}{h}N \\ \lambda_{K2}\frac{g'}{g}N \\ \lambda_{L2}\frac{g'}{g}N \end{pmatrix}\hat{\xi}_2 \quad (13)$$

where $M=\xi_1 X_1/(\xi_2 K_2\frac{g'}{g}-1)$, $N=\xi_2 K_2/(\xi_2 K_2\frac{g'}{g}-1)$. The determinant of the coefficient matrix of equation (13) is denoted as Δ_2. According to the stability condition of the system, we obtain that $\Delta_2<0$ (see Appendix).

As to the relation of agricultural pollution, environment and environmental production factor, we make the following assumption.

Assumption : $\frac{E}{\xi_2 K_2}>\frac{\hat{g}}{\hat{E}}$, namely, the ratio of environmental stock to agricultural pollution is larger than environmental stockelasticity ofenvironmental production factor.

Though the assumption is made from the mathematical point of view, the assumption does not against the real-world situation. Compared with the whole environment situation, agricultural pollution still accounts for a small proportion; general speaking, the one percent change of environment will bring less than one percent change of environmental production factor. Therefore, the left side of inequalityusually bigger than the right side of inequality in the Assumption, the assumption also has wide representation in thereal-world situation.

Under Assumptions, solving the equation (13) by using the Cramer's rule, we obtain Table 3.

[Table 3]

From the Table 3, note that the economic and environmentalimpacts of a decrease ξ_1 are the same with those of a decrease ξ_2 , and thereis no need to make such distinctions. However, the results of a decrease ξ_1 are different from those of a decrease ξ_2 in some aspects, and we will make analyses in the next part.

A decline of ξ_1 improves the environment, drops the interest rate, and increases the agricultural wage, which lead to the increase of labor and capital and the expansion of the agriculturalsector.Due to improvement of environment, the health condition of labor in manufacturing sector rises and its output has an upward trend. However, because of fixed wage, the number of employed labor units $h(E)L_1$is a constant number, hence, the improvement of environment could not favor the manufacturing output from labor perspective. On the other hand, capital outflows from manufacturing sector causes a decrease of X_1. In addition, the employment of agricultural sector increases, reducing unemployment pressure and decreasing unemployment rate in urban area.

A decline of ξ_2 improves the environment, and the economic impacts of a decline of ξ_2 are similar to a decline of ξ_1 . However, in terms of reason and impetus, the main driving forces for a declining of ξ_1 and ξ_2 come from the desire that each sector strives to decrease pollution during the process of production. Hence, the reason and impetus for a declining of ξ_1 and ξ_2 are different. From the Table 3, though agricultural and manufacturing technology progressboth improve environment, manufacturing technology progressimproves the environment at the expense of own production, whileagricultural technology progressimproves the environment and raises agricultural production simultaneously. Thus, in general, agricultural sector has more incentives to improve environment than manufacturing sector and works more vigorously to advance technology in the absence of outside intervention.Therefore, compared the Table 2 to the Table 3, though the results of a decline of ξ_2 are similar with those in the rapid growth period of agricultural capital,there are some differences in economic significance of a decline of ξ_2 in two models when we consider the different results of a decline of ξ_1: in the rapid growth period of agricultural capital, manufacturing technology progress brings greater output effect than that in the steady period of agricultural capital.

To sum up, we obtain following propositions:

Proposition 2.*In the steady period of agricultural capital, agricultural and manufacturingtechnology progress improve the environment, augment agricultural wage, and reduce interest as well as unemployment rate. However, manufacturing technology progress drops manufacturing output, agricultural technology progress raises agricultural outputin the steady period of agricultural capital.*

The academic circlelargely agrees upon the conclusion that a larger output would has more damage to the environment. Here, we need to explain why manufacturing and agricultural technology progressraise the agricultural output and improve the environment simultaneously. From the equation (9), an increase of agricultural output deteriorates environment. However, from the Table 3, agricultural and manufacturing technology progressalso drop manufacturing output, which leads to improving environment. Therefore, one possible result is that the effect of environmental improvement is greater than degradation, and environmental situation improves eventually. The result means that agricultural and manufacturing technology progress bring less damage due to the increase of agricultural output than improvement of environment due to the decrease of manufacturing output in the steady period of agricultural capital. Particular attention should be paid to the negative effect because of a decrease of manufacturing output at this period.

[Figure 2]

The economic and environmentalimpacts of agricultural technology progressin the steady period of agricultural capitalcould be illustrated by the Figure2. The left half the horizontal axis is the amount of capital in agricultural sector K_2, and its right half represents the environmental stock E. The upper half of the vertical axis is the agriculturaloutputX_2, and the lower half of the vertical axis is the agricultural technology ξ_2. In our model, from equation (9), we use line *aa*to represent the relation between ξ_2 andK_2; fromequation(10),use line *bb* to represent the relation between X_2andK_2 in the first quadrant,use line *cc* to represent the relation between $X_2$and E in the second quadrant. Agricultural technology progress causes the value of ξ_2 decreases from ξ_2^* to ξ_2^{**}, the value of K_2 increases from K_2^* to K_2^{**}

through line *aa*; the value of X_2 increases from X_2^* to X_2^{**} through line *bb*;the value of E increases from E^* to E^{**} through line *cc*;At this point, we can confirm that agricultural output increases and the environment improves.

2.3Partial elasticity analyses of economic and environmental factors

In the steady period of agricultural capital, the economic and environmental impacts of agricultural technology progressare different with those ofmanufacturing technologyprogressin following three aspects.

(1) The results in the rapid growth period of agricultural capital differ with those in the steady period of agricultural capital. Compared with the Table 2, the results of agricultural technology progress are roughly the same in both two tables, however, there are many differences in the results of manufacturing technology progress between two tables.

(2) The impacts of output of respective sector are different. According to the Proposition 2, the impact of agricultural technology progresson the output of respective sector is different with that ofmanufacturing technology progress

(3)The extents of influence on environment and economy are different. If manufacturing pollution is unequal to agricultural pollution, when manufacturing and agricultural technologyprogress, the manufacturing output, agricultural output, agriculturalwage, interest rate and environmental stockelasticityof manufacturing technology are different from those of agricultural technology. If manufacturing pollution is larger than agricultural pollution, namely, $\xi_1 X_1 > \xi_2 K_2$, we could obtain the following inequalities:

$$\left|\frac{\hat{X}_1}{\hat{\xi}_1}\right| - \left|\frac{\hat{X}_1}{\hat{\xi}_2}\right| > 0,\ \left|\frac{\hat{X}_2}{\hat{\xi}_1}\right| - \left|\frac{\hat{X}_2}{\hat{\xi}_2}\right| > 0,\ \left|\frac{\hat{w}}{\hat{\xi}_1}\right| - \left|\frac{\hat{w}}{\hat{\xi}_2}\right| > 0,\ \left|\frac{\hat{r}}{\hat{\xi}_1}\right| - \left|\frac{\hat{r}}{\hat{\xi}_2}\right| > 0,\ \left|\frac{\hat{E}}{\hat{\xi}_1}\right| - \left|\frac{\hat{E}}{\hat{\xi}_2}\right| > 0.$$

The above five inequalities reflect that if manufacturing pollution is larger than agricultural pollution,the extents of influence of agricultural technology progress on manufacturing output, agricultural output, agricultural wage, interest rate and environmental stock are less than those of manufacturing technology progress. However, if manufacturing pollution is smaller than agricultural pollution, namely, $\xi_1 X_1 < \xi_2 K_2$, we could obtain the opposite conclusions. Thus, we get Proposition 3.

Proposition 3.*If manufacturing pollution is larger than agricultural pollution, the manufacturing output, agricultural output, agricultural wage, interest rate and environmental stock elasticity of manufacturing technology arebigger than those of agricultural technology;*

if manufacturing pollution is smaller than agricultural pollution, we could obtain the opposite conclusions.

The Proposition 3 shows that if manufacturing pollution is smaller than agricultural pollution, a change of ξ_1 has greater impacts than a change of ξ_2 on environment and economy; As agricultural pollution grows serious, a change of ξ_2 has an increasing impacts on environment and economy and is graduallyapproachingthe impacts of a change of ξ_1 ; if manufacturing pollution is larger than agricultural pollution, a change of ξ_2 has greater impacts than those of a change of ξ_1 on environment and economy.

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3. Conclusion

In this paper, we hold that it is the input of capital in agricultural production that is the main reason for agricultural pollution in developing countries under existing technical conditions.We try to integrate agricultural pollution into a general equilibrium model with environmental pollution caused by labor movement and undertakes a comparative static analysis about theimpacts of manufacturing and agricultural technology progress. First, we establish a theoretical modelin the rapid growth period of agricultural capital and define environmental "health factor" and "production factor", environmental stock of health and production; then we expand the model, and set up a model in the steady period of agricultural capital; In our paper, we obtain three propositions andexpatiate the theme that agricultural pollution cannot be ignored from different aspects in labor movement. Both the models in the rapid growth period and steady period of agricultural capital reflectof the real economy. At the early stage when the issue of agricultural pollution highlights and increase rapidly, the results of the model in the rapid growth period are relatively more important; when the seriousness of agricultural pollution gradually diminishes, the results of extended model are relatively more significant.According to our research, agricultural pollution has impacts on output of both sectors, agricultural wage, unemployment rate and interest rate and shouldn't be overlooked in the economy. We show that manufacturing technology progress drops manufacturing output, agricultural technology progress raises agricultural output, such conclusions not only have an academic significance, but also have a certain guiding significance for actual economic operation. Relative departments of government will take full advantage of both sectors if they could consider the conclusions while setting relevant policies, making environmental policies to become more efficient.

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Appendix

Stability

From (5),(6),(7),(9),(11)and (12), the adjustment process of the economy can be specified, as follows:

$$\dot{X}_1 = \alpha_1[p - (a_{L1}h(E)w_U + a_{K1}r)]\,(\text{A1})$$

$$\dot{X}_2 = \alpha_2[g(E) - (a_{L2}h(E)w + a_{K2}r)]\,(\text{A2})$$

$$\dot{E} = \alpha_3[E - (\bar{E} - \lambda_1 X_1 - \lambda_2 K_2)]\,(\text{A3})$$

$$\dot{r} = \alpha_4[a_{K1}X_1 + a_{K2}F^2 - K]\,(\text{A4})$$

$$\dot{w} = \alpha_5[(1+\mu)a_{L1}X_1 + a_{L2}F^2 - L]\,(\text{A5})$$

$$\dot{\mu} = \alpha_6[(1+\mu)w - w_U]\,(\text{A6})$$

where a dot over a variable denotes the time derivative and α_j is the positive speed of adjustments. Marshallian adjustment process is assumed for quantities when thedemand price differs from the supply price in the goods markets.A Walrasian adjustment mechanism is assumed for the factor priceswith the fixed endowment in the factor markets. The determinant ofthe Jacobian matrix of Eqs. (A1)-(A6) is:

$$\left|J\right| = \alpha_1\alpha_2\cdots\alpha_6 pKL \begin{vmatrix} 0 & 0 & -\theta_{L1}\frac{h'}{h}E & -\theta_{K1} & 0 & 0 \\ 0 & 0 & -\theta_{L2}\frac{h'}{h}E & -\theta_{K2} & -\theta_{L2} & 0 \\ -M & -N & E & -NS_{KK}^2 & -NS_{KL}^2 & 0 \\ \lambda_{K1} & \lambda_{K2} & -\lambda_{K2}\frac{g'}{g}E & \lambda_{K1}S_{KK}^1 + \lambda_{K2}S_{KK}^2 & \lambda_{K2}S_{KL}^2 & 0 \\ (1+\mu)\lambda_{L1} & \lambda_{L2} & -\lambda_{L2}\frac{g'}{g}E & C & \lambda_{L2}S_{LL}^2 & \lambda_{L1}\mu \\ 0 & 0 & 0 & 0 & (1+\mu)w & w\mu \end{vmatrix}$$

It can also be written as follows:

$$\left|J\right| = -\alpha_1\alpha_2\cdots\alpha_6 pKL\Delta_2$$

Therefore, according to the Routh–Hurwitz Theorem, a necessarycondition for the local stability of the system is that the determinantof the Jacobian matrix is positive. Hence, it is assumed that the equilibriuminthis paper is stable under the condition that $\left|J\right| > 0$.We could obtainthat $\Delta_2 < 0$.

Table 1 The amount of fertilizers and pesticides use in China from1995 to 2019

Year	Amount of fertilizer use (million tons)	Amount of pesticide use (million tons)
1995	35.937	1.087
1996	38.279	1.141
1997	39.807	1.195
1998	40.837	1.232
1999	41.243	1.322
2000	41.464	1.28
2001	42.538	1.275
2002	43.394	1.312
2003	44.116	1.325
2004	46.366	1.386
2005	47.662	1.46
2006	49.277	1.537
2007	51.078	1.623
2008	52.39	1.672
2009	54.044	1.709
2010	55.617	1.758
2011	57.042	1.787
2012	58.388	1.806
2013	59.119	1.802
2014	59.959	1.807
2015	60.226	1.783
2016	59.844	1.704
2017	58.594	1.655
2018	56.534	1.504
2019	54.136	1.392

Data Source:China Agricultural Yearbook from 1995 to 2019,Beijing: China Agriculture Press.

Table 2 Results of equation(8) of ξ_1 and ξ_2

	$\hat{E}$	$\hat{H}$	$\hat{X}_1$	$\hat{X}_2$	$\hat{w}$	$\hat{r}$	$\hat{\mu}$
$\hat{\xi}_1$	—	0	0	—	0	0	0
$\hat{\xi}_2$	—	—	+	—	—	+	+

Note: "–"and"+"mean that the changes of exogenous variables will make endogenous variables change in opposite and same directions respectively."0"means that the changes of exogenous variables have no impacts on endogenousvariables;

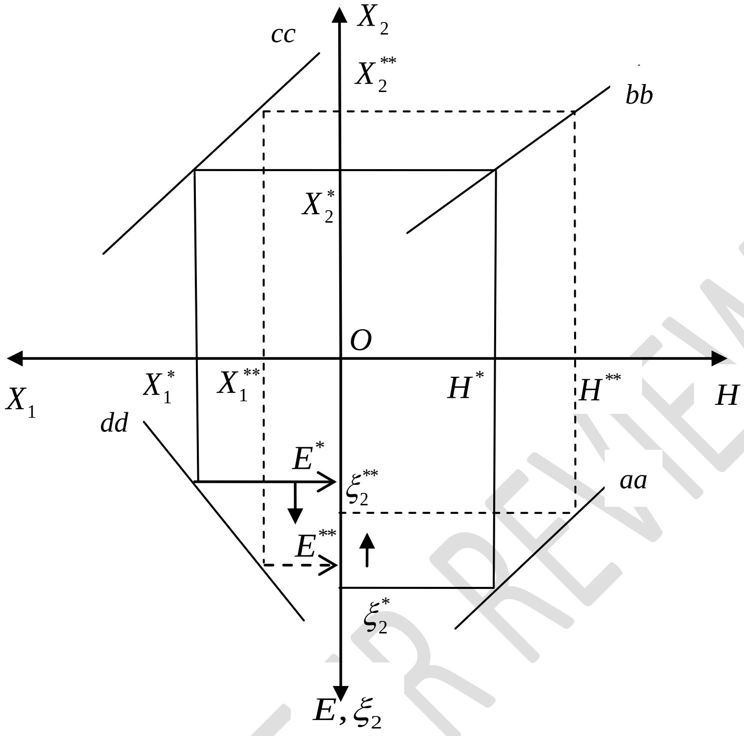

Figure 1 The economic and environmentalimpacts of agricultural technology progress(in the rapid growth period of agricultural capital)

Table 3 Results of equation(13) of ξ_1 and ξ_2

	$\hat{E}$	$\hat{X}_1$	$\hat{X}_2$	$\hat{w}$	$\hat{r}$	$\hat{\mu}$
$\hat{\xi}_1, \hat{\xi}_2$	—	+	—	—	+	+

Note: "–"and"+"mean that the changes of exogenous variables will make endogenous variables change in opposite and same directions respectively.

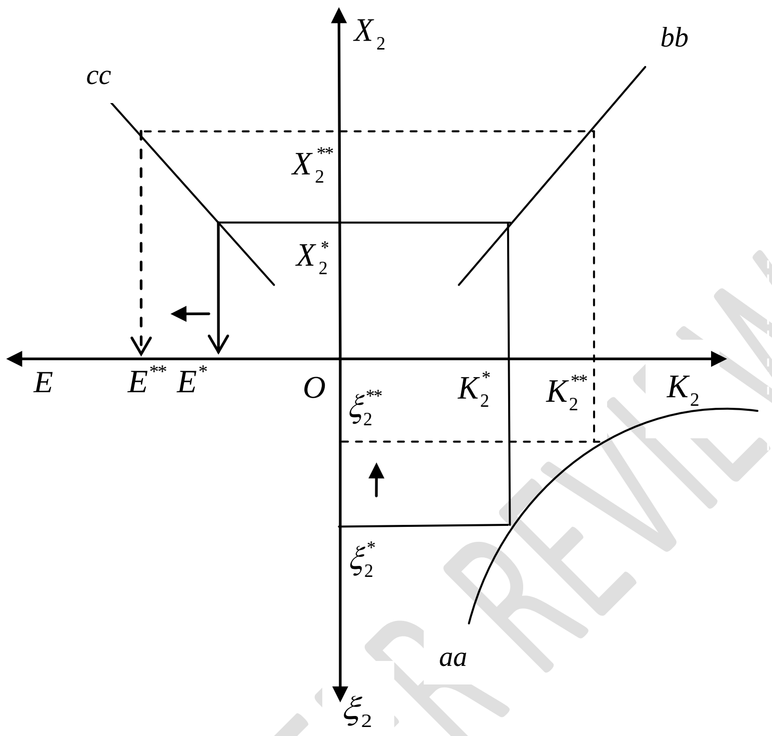

Figure 2 The economic and environmental impacts of agricultural technology progress(in the steady period of agricultural capital)