Tourism, the Environment, and Public Infrastructure: the Case of Pure Public Intermediate Good

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Abstract

This paper constructs a general equilibrium model of a small open economy with pollution generated by the tourism industry. The national government issues emission permits and constructs the public infrastructure that has no congestion effect. A stricter environmental regulation, by reducing the amount of emission permits, unambiguously improves the tourism terms-of-trade. If the positive terms-of-trade effect is sufficiently large, stricter environmental regulation expands tourism sector. Domestic wage inequality narrows or widens, depending on the elasticity of substitution in each industry.

Keywords: Tourism, Pure public intermediate good, Environmental regulation, Tourism terms-of-trade, Wage inequality

1 Introduction

The number of tourists is steadily growing in the world. According to UNWTO (2019), international tourist arrivals reached 1.4 billion in 2018. However, the growing number of tourists poses a threat to the environment of the destination country. For example, concentration of people degrades the water quality of local community, and traffic congestion pollutes the air by emitting fumes. In order to mitigate these negative effects, a national government introduces environmental regulation by issuing emission permits and controlling the amount of pollution. At the same time, the tourism industry requires a large amount of infrastructure, such as, park, airport, highway, and water supply, which is rather difficult to be financed by only private fund. The government can

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use the revenue from selling pollution permits to construct the infrastructure. Some infrastructures include congestion effect, in which an increase in users lowers the efficiency. This paper considers an infrastructure with no congestion effect. That is, the public infrastructure in this paper is the creation of atmosphere type in the terminology of Meade (1952), or pure public intermediate good. Shimizu and Okamoto (2020) develops a model of polluted small open economy with tourism infrastructure that contributes to only tourism industry and has no congestion effect.[1] However, some infrastructures, such as wireless network, highway, or airport, contribute to many industries as well as tourism industry. Therefore, we develop a small open economy model where tourism industry emits pollution and the government constructs a public infrastructure that contributes all the industry in the economy. We then examine the effects of stricter environmental regulation on production, income inequality, and welfare. The remainder of the paper is organized as follows. Section 2 sets up the model. Then in section 3 we analyze the effect of stricter environmental regulation, taking the tourism terms-of-trade as given. In section 4, we examine the total effects of stricter environmental regulation, considering the change in the tourism terms-of-trade. Concluding remarks are made in section 5.

2 The model

Consider a small open economy. The home country consists of two private sectors and one public sector. The two private sectors are manufacturing (or traded good) sector and service sector. The public sector produces non-traded public infrastructure that enhances the productivity of both private sectors. The manufacturing good is traded while the tourism service is non-traded in the absence of foreign tourists. The service is exported through international tourism and thus manufacturing good is imported. We will call service T as tourism service and its price as the tourism terms-of-trade. The manufacturing sector employs skilled labor S and capital K to produce manufacturing good. The production of tourism service requires unskilled labor L and pollution permits Z. The public sector constructs public infrastructure using only capital input. The national government finances the cost of public infrastructure by taxing the income of domestic residents.

[1]Yanase (2015) considers the same type of tourism infrastructure.

The production functions satisfy the properties of quasi concavity and linear homogeneity.[2]

$$X = g_X(M)F(S, K_X),$$

$$T = g_T(M)N(L, Z),$$

where the functions $F(\cdot)$ and $N(\cdot)$ exhibit constant returns to scale and quasi-concave. M is the amount of public infrastructure. The above two equations imply that public infrastructure enhances the productivity of both industries. The contribution of infrastructure to the productivity of each industry is expressed by the function g_j. We assume g_j is twice continuously differentiable and has the following properties:

$$g_j(0) = 1, \quad g_j' > 0, \quad g_j'' < 0, \quad \lim_{M\to 0} g_j'(M) = \infty, \quad \lim_{M\to\infty} g_j'(M) = 0 \tag{1}$$

The first condition implies that if there is no public infrastructure, productivity of each industry does not change. The second and third conditions state that public infrastructure has positive and diminishing effect on the productivity of each industry. Finally, the last two conditions are known as the Inada conditions. Similar assumption is made in Yanase (2015).

The public infrastructure is produced by only capital input:

$$M = K_M/a_{KM}, \tag{2}$$

where a_{ij} is the amount of factor i to produce one unit of good j. We assume linear production function for public infrastructure, and thus a_{KM} is constant.

We now turn to describe the equilibrium conditions for the supply side of the economy. Assume that perfect competition prevails in manufacturing and tourism industries. The zero profit condition for traded good industry is given by

$$a_{SX}w_S + a_{KX}q = p_X, \tag{3}$$

where p_X is the price of traded good, w_S the wage of skilled labor, and q the rental rate of capital. Note that p_X is constant by the assumption of a small open economy.

[2]Pi and Zhou (2014) considers more specified functional form that describes the positive externality of public infrastructure and assumes the public infrastructure improves uniformly the productivity of each industry ($g_X = g_T = M^{\xi}, 0 < \xi < 1$ in our notation). Instead, following Okamoto (1985), we consider more general case where public infrastructure has different effects on both industries.

The zero profit condition for tourism service industry is given by

$$a_{LT}w_L + a_{ZT}r = p_T, \tag{4}$$

where p_T is the price of tourism service, w_L the wage of unskilled labor, r the price of emission permits.

The zero profit condition for tourism infrastructure industry is[3]

$$a_{KM}q = p_M, \tag{5}$$

where p_M is the shadow price of public infrastructure.

The full employment condition of capital is

$$a_{KX}X + a_{KM}M = K. \tag{6}$$

The demand-supply equality of skilled labor requires

$$a_{SX}X = S. \tag{7}$$

The equilibrium of unskilled labor market is given by

$$a_{LT}T = L. \tag{8}$$

The amount of pollution permits is

$$a_{ZT}T = Z. \tag{9}$$

According to Lindahl pricing, the price of public infrastructure is determined by the sum of marginal value products of public infrastructure in both industries: $p_M = p_X \frac{\partial X}{\partial M} + p_T \frac{\partial T}{\partial M}$. Thus we have

$$p_M M = \xi_X(M) p_X X + \xi_T(M) p_T T, \tag{10}$$

where $\xi_j = \frac{dj}{dM}\frac{M}{j} = \frac{dg_j}{dM}\frac{M}{g_j}$, $(j = X, T)$ denote productivity improvement rate of industry j by additional public infrastructure. Pi and Zhou (2014) considers the symmetry case of $\xi_X = \xi_T$.

The national government finances the cost of public infrastructure by taxing income of domestic residents. Then budget constraint of national government satisfies

$$t(w_L L + w_S S + qK + rZ) = p_M M, \tag{11}$$

[3]Since cost minimization is required in public sector, cost equals revenue.

where t is income tax rate.[4]

Given p_T, (3) - (10) determine X, T, M, w_S, w_L, q, r and p_M.[5] Then, t is determined by (11).

3 Comparative statics: supply side analysis

The supply side of the economy ((3) - (10)) determines outputs and factor prices (and therefore factor demands). In this section, we examine the effects of a stricter environmental regulation and an improvement in the tourism terms-of-trade p_T. A stricter environmental regulation means a reduction in emission permits ($dZ < 0$).

The cost minimization in each industry requires

$$\theta_{SX}\hat{a}_{SX} + \theta_{KX}\hat{a}_{KX} = -\hat{g}_X, \tag{12}$$

$$\theta_{LT}\hat{a}_{LT} + \theta_{ZT}\hat{a}_{ZT} = -\hat{g}_T. \tag{13}$$

To facilitate the following analysis, we define the elasticity of substitution in each sector,

$$\sigma_X = \frac{\hat{a}_{KX} - \hat{a}_{SX}}{\hat{w}_S - \hat{q}}, \tag{14}$$

$$\sigma_T = \frac{\hat{a}_{ZT} - \hat{a}_{LT}}{\hat{w}_L - \hat{r}}. \tag{15}$$

Solving (12) and (14) for a_{iX}, we have

$$\hat{a}_{SX} = -\theta_{KX}\sigma_X(\hat{w}_S - \hat{q}) - \hat{g}_X, \tag{16}$$

$$\hat{a}_{KX} = \theta_{SX}\sigma_X(\hat{w}_S - \hat{q}) - \hat{g}_X. \tag{17}$$

Solving (13) and (15) for a_{iT}, we obtain

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[4](11) is rewritten as

$$t = \frac{qK_M}{w_L L + w_S S + qK + rZ},$$

where we have used (2) and (5). Then the national income is given by

$$R = (1 - t)(w_L L + w_S S + qK + rZ) = w_L L + w_S S + qK_X + rZ = p_X X + p_T T,$$

where (3) and (4) is used.

[5]The price of tourism service p_T is to be determined by demand and supply of domestic tourism service. See section 4.

$$\hat{a}_{LT} = -\theta_{ZT}\sigma_T(\hat{w}_L - \hat{r}) - \hat{g}_T, \tag{18}$$

$$\hat{a}_{ZT} = \theta_{LT}\sigma_T(\hat{w}_L - \hat{r}) - \hat{g}_T. \tag{19}$$

Differentiatitng (3) and considering (12), we obtain

$$\theta_{SX}\hat{w}_S + \theta_{KX}\hat{q} - \xi_X\hat{M} = \hat{p}_X. \tag{20}$$

Differentiating (4) and taking into account (13), we have

$$\theta_{LT}\hat{w}_L + \theta_{ZT}\hat{r} - \xi_T\hat{M} = \hat{p}_T. \tag{21}$$

Since a_{KM} is constant, (5) implies

$$\hat{q} = \hat{p}_M. \tag{22}$$

Differentiating (6) and considering (17), we obtain

$$\lambda_{KX}\hat{X} + \lambda_{KX}\theta_{SX}\sigma_X(\hat{w}_S - \hat{q}) + (\lambda_{KM} - \lambda_{KX}\xi_X)\hat{M} = \hat{K}. \tag{23}$$

Differentiating (7) and taking into account (16), we have

$$-\theta_{KX}\sigma_X(\hat{w}_S - \hat{q}) - \xi_X\hat{M} + \hat{X} = \hat{S}. \tag{24}$$

Differentiating (8) and substituting (18), we have

$$-\theta_{ZT}\sigma_T(\hat{w}_L - \hat{r}) - \xi_T\hat{M} + \hat{T} = \hat{L}. \tag{25}$$

Differentiating (9) and considering (19), we have

$$\theta_{LT}\sigma_T(\hat{w}_L - \hat{r}) - \xi_T\hat{M} + \hat{T} = \hat{Z}. \tag{26}$$

Differentiating (10), we have

$$\hat{p}_M + \hat{M} = \delta_X(\hat{p}_X + \hat{X}) + \delta_T(\hat{p}_T + \hat{T}) + \delta_X\hat{\xi}_X + \delta_T\hat{\xi}_T,$$

where $\delta_X \equiv \xi_X p_X X/p_M M$ and $\delta_T \equiv \xi_T p_T T/p_M M$. Define $\epsilon_j = \frac{M}{\xi_j}\frac{d\xi_j}{dM}$. Taking into account (22), we have

$$\hat{q} + \tau\hat{M} - \delta_X\hat{X} - \delta_T\hat{T} = \delta_X\hat{p}_X + \delta_T\hat{p}_T, \tag{27}$$

where $\tau \equiv 1-\delta_X\epsilon_X-\delta_T\epsilon_T = \delta_X+\delta_T-\delta_X\epsilon_X-\delta_T\epsilon_T = \delta_X(1-\epsilon_X)+\delta_T(1-\epsilon_T) > 0$ since $1-\epsilon_j = \xi_j - g_j''M/g_j' > 0$.[6]

From (25) and (26), we have[7]

$$\sigma_T(\hat{w}_L - \hat{r}) = \hat{Z}, \tag{28}$$

which implies that if the amount of pollution permits is constant, $\hat{w}_L = \hat{r}$ holds.

Substituting (28) into (25), we have

$$\hat{T} = \theta_{ZT}\hat{Z} + \xi_T\hat{M}. \tag{29}$$

Substituting (29) into (27), we have[8]

$$\hat{q} + (\tau - \delta_T\xi_T)\hat{M} - \delta_X\hat{X} = \delta_T(\hat{p}_T + \theta_{ZT}\hat{Z}). \tag{30}$$

$\hat{X}$, $\hat{M}$,$\hat{q}$, and $\hat{w}_S$ are determined by (20), (23), (24), and (30). Rewrite (20), (23), (24), and (30) into the matrix form:

$$\begin{pmatrix} 0 & -\xi_X & \theta_{KX} & \theta_{SX} \\ \lambda_{KX} & \lambda_{KM} - \lambda_{KX}\xi_X & -\lambda_{KX}\theta_{SX}\sigma_X & \lambda_{KX}\theta_{SX}\sigma_X \\ 1 & -\xi_X & \theta_{KX}\sigma_X & -\theta_{KX}\sigma_X \\ -\delta_X & \tau - \delta_T\xi_T & 1 & 0 \end{pmatrix} \begin{pmatrix} \hat{X} \\ \hat{M} \\ \hat{q} \\ \hat{w}_S \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ \delta_T(\hat{p}_T + \theta_{ZT}\hat{Z}) \end{pmatrix}. \tag{31}$$

We utilize (31) to analyze the effects of stricter environmental regulation and improvement in tourism terms-of-trade.

3.1 Environmental regulation

First we analyze the effects of a stricter environmental regulation.

[6]Differentiating $\xi_j = g_j' \frac{M}{g_j}$, we have

$$\hat{\xi}_j = \frac{g_j''M}{g_j'}\hat{M} + \hat{M} - \xi_j\hat{M}.$$

Dividing both sides by $\hat{M}$ yields

$$1 - \epsilon_j = \xi_j - \frac{g_j''M}{g_j'} > 0.$$

[7]Note that since we consider only the effect of stricter environmental regulation (a decrease in Z), L is treated as constant.

[8]Note that p_X is constant by the assumption of a small open economy.

Solving (31), we obtain[9]

$$\begin{aligned}\frac{\hat{X}}{\hat{Z}} &= -\frac{\sigma_X\delta_T\theta_{ZT}(\lambda_{KM}\theta_{KX}-\lambda_{KX}\xi_X)}{\Delta_1}\\ &= -\frac{\sigma_X\delta_T\theta_{ZT}(1-\delta_X)\lambda_{KM}\theta_{KX}}{\Delta_1} < 0,\end{aligned} \tag{32}$$

$$\frac{\hat{M}}{\hat{Z}} = \frac{\sigma_X\lambda_{KX}\delta_T\theta_{ZT}}{\Delta_1} > 0, \tag{33}$$

$$\frac{\hat{q}}{\hat{Z}} = \frac{\delta_T\theta_{ZT}(\xi_X\lambda_{KX}\sigma_X+\theta_{SX}\lambda_{KM})}{\Delta_1} > 0, \tag{34}$$

$$\begin{aligned}\frac{\hat{w}_S}{\hat{Z}} &= \frac{\delta_T\theta_{ZT}(\xi_X\lambda_{KX}\sigma_X-\theta_{KX}\lambda_{KM})}{\Delta_1}\\ &= \frac{\delta_T\theta_{ZT}\theta_{KX}\lambda_{KM}(\delta_X\sigma_X-1)}{\Delta_1},\end{aligned} \tag{35}$$

where

$$\Delta_1 = \lambda_{KM}(\theta_{SX}+\delta_X\theta_{KX}\sigma_X)+\lambda_{KX}\sigma_X(\tau-\delta_T\xi_T-\delta_X\xi_X+\xi_X) > 0. \tag{36}$$

The second term is positive since

$$\begin{aligned}\tau-\delta_X\xi_X-\delta_T\xi_T &= \delta_X(1-\epsilon_X)+\delta_T(1-\epsilon_T)-\delta_X\xi_X-\delta_T\xi_T\\ &= \delta_X(\xi_X-\frac{g''_X M}{g'_X})+\delta_T(\xi_T-\frac{g''_T M}{g'_T})-\delta_X\xi_X-\delta_T\xi_T\\ &= -\delta_X\frac{g''_X M}{g'_X}-\delta_T\frac{g''_T M}{g'_T} > 0.\end{aligned}$$

From (29), we have

$$\frac{\hat{T}}{\hat{Z}} = \theta_{ZT}+\xi_T\frac{\hat{M}}{\hat{Z}} > 0.$$

Next, we consider the effects of the change in tourism terms-of-trade. When p_T is constant, (21) implies

$$\hat{w}_L = \theta_{ZT}(\hat{w}_L-\hat{r})+\xi_T\hat{M}.$$

Substituting (28) into the above equation, we obtain

$$\frac{\hat{w}_L}{\hat{Z}} = \frac{\theta_{ZT}}{\sigma_T}+\xi_T\frac{\hat{M}}{\hat{Z}} > 0. \tag{37}$$

[9]Using $\delta_X = \xi_X p_X X/p_M M$, we have $\xi_X = \delta_X\frac{p_M M}{p_X X} = \delta_X\frac{\theta_{KX}\lambda_{KM}}{\lambda_{KX}}$.

From (28), we have

$$\begin{aligned}\frac{\hat{r}}{\hat{Z}} &= \frac{\hat{w}_L}{\hat{Z}} - \frac{1}{\sigma_T} \\ &= \frac{\theta_{ZT}}{\sigma_T} + \xi_T \frac{\hat{M}}{\hat{Z}} - \frac{1}{\sigma_T} \\ &= -\frac{\theta_{LT}}{\sigma_T} + \xi_T \frac{\sigma_X \lambda_{KX} \delta_T \theta_{ZT}}{\Delta_1} \\ &= \frac{\xi_T \sigma_X \lambda_{KX} \delta_T \theta_{ZT} \sigma_T - \theta_{LT} \Delta_1}{\sigma_T \Delta_1} < 0 \quad \text{if and only if } \sigma_T < \sigma_T^* \equiv \frac{\theta_{LT} \Delta_1}{\xi_T \lambda_{KX} \sigma_X \delta_T \theta_{ZT}}.\end{aligned}$$

The above results are summarized by Table 3.1.

	$\hat{X}$	$\hat{T}$	$\hat{M}$	$\hat{w}_S$	$\hat{w}_L$	$\hat{q}$	$\hat{r}$
$Z \downarrow$	$+$	$-$	$-$	$\pm^a$	$-$	$-$	$\pm^b$

a: negative if $\sigma_X > 1/\delta_X$, and positive if $\sigma_X < 1/\delta_X$.

b: positive if $\sigma_T < \sigma_T^*$, and negative if $\sigma > \sigma_T^*$.

Table 1: Effects of stricter environmental regulation

Thus we have the following proposition.

Proposition 1 *Suppose that the tourism terms-of-trade p_T is constant. A stricter environmental regulation contracts tourism sector and tourism infrastructure sector while it expands manufacturing sector. It decreases the wage of unskilled labor and the rental rate of capital. If the elasticity of substitution in the manufacturing sector is small (large), the wage of skilled labor rises (falls). If the elasticity of substitution in the tourism sector is small (large), the price of emission permits rises (falls).*

An economic intuition of the above results are as follows. Stricter environmental regulation decreases total income ($R_Z = r > 0$). Given the tax rate t, tax revenue declines, leading to decrease in the output of public infrastructure M. Therefore, stricter environmental regulation lowers the output of tourism service and the wage of unskilled labor which is a specific factor to tourism service. There are conflicting effects on the output of trade good. On the one hand, inflow of capital from public infrastructure sector expands traded good sector. On the other hand, contraction of public infrastructure sector decreases productivity of traded good sector. The former effect outweighs the latter since the public infrastructure has diminishing effect on the tourism sector (see the third condition of (1)). When the elasticity of substitution in the trade good sector is large (small), inflow of capital decreases (increases) demand for skilled labor and the wage of skilled labor. The rental rate of capital falls due to decreased demand for capital in public infrastructure sector. If the elasticity of substitution in tourism sector is small (large), decreased emission permits increases (decreases) the demand for emission permits and its price.

We next consider the effect on relative wage or wage gap between skilled labor and unskilled labor. From (33), (35), and (37), the change in wage gap is given by

$$\begin{aligned}\frac{\hat{w}_S}{\hat{Z}} - \frac{\hat{w}_L}{\hat{Z}} &= \frac{\delta_T\theta_{ZT}(\xi_X\lambda_{KX}\sigma_X - \theta_{KX}\lambda_{KM})}{\Delta_1} - \frac{\theta_{ZT}}{\sigma_T} - \xi_T\frac{\hat{M}}{\hat{Z}} \\ &= \frac{\delta_T\theta_{ZT}(\xi_X\lambda_{KX}\sigma_X - \theta_{KX}\lambda_{KM})}{\Delta_1} - \frac{\theta_{ZT}}{\sigma_T} - \xi_T\frac{\sigma_X\lambda_{KX}\delta_T\theta_{ZT}}{\Delta_1} \\ &= \frac{(\xi_X - \xi_T)\delta_T\theta_{ZT}\lambda_{KX}\sigma_X - \delta_T\theta_{ZT}\theta_{KX}\lambda_{KM}}{\Delta_1} - \frac{\theta_{ZT}}{\sigma_T}.\end{aligned}$$

Thus $\hat{w}_S/\hat{Z} - \hat{w}_L/\hat{Z} < 0$ if $\xi_T \geq \xi_X$. Taking into account that $\hat{w}_L/\hat{Z}$ is always positive and $\hat{w}_S/\hat{Z} < 0$ if and only if $\sigma_X < 1/\delta_X$, $\hat{w}_S/\hat{Z} - \hat{w}_L/\hat{Z} < 0$ if $\sigma_X < 1/\delta_X$. It follows that $\hat{w}_S/\hat{Z} - \hat{w}_L/\hat{Z} < 0$ if $\xi_T \geq \xi_X$ or $\sigma_X < 1/\delta_X$. We then have the following corollary.

Corollary 1 *Suppose that the tourism terms-of-trade p_T is constant. If $\xi_T \geq \xi_X$ or $\sigma_X < 1/\delta_X$, stricter environmental regulation widens domestic wage inequality.*

If ξ_T is sufficiently large, decrease in unskilled wage due to decreased tourism infrastructure is large. Therefore, even if skilled wage decreases, decrease in unskilled wage is larger than that of skilled wage.

3.2 Improvement in tourism terms-of-trade

Next we consider the effects of an improvement in tourism terms-of-trade ($dp_T > 0$).

From (31), the effects of the change in p_T on X, M, q, w_S are proportional to the effects of the change in Z:

$$\frac{\hat{X}}{\hat{p}_T} = \frac{1}{\theta_{ZT}}\frac{\hat{X}}{\hat{Z}}, \quad \frac{\hat{M}}{\hat{p}_T} = \frac{1}{\theta_{ZT}}\frac{\hat{M}}{\hat{Z}}, \quad \frac{\hat{q}}{\hat{p}_T} = \frac{1}{\theta_{ZT}}\frac{\hat{q}}{\hat{Z}}, \quad \frac{\hat{w}_S}{\hat{p}_T} = \frac{1}{\theta_{ZT}}\frac{\hat{w}_S}{\hat{Z}}.$$

When Z is unchanged, (28) implies $\hat{w}_L = \hat{r}$. Then (25) implies $\hat{T} = \xi_T\hat{M} > 0$. Also, from (21), we have

$$\hat{r} = \hat{p}_T + \hat{T} > 0. \tag{38}$$

The effects of improvement in tourism terms-of-trade are summarized by the following table.

	$\hat{X}$	$\hat{T}$	$\hat{M}$	$\hat{w}_S$	$\hat{w}_L$	$\hat{q}$	$\hat{r}$
$p_T \uparrow$	−	+	+	$\pm^a$	+	+	+

a: positive if $\sigma_X > 1/\delta_X$, negative if $\sigma_X < 1/\delta_X$

Table 2: Effects of an improvement in tourism terms-of-trade

Thus we can establish the following proposition.

Proposition 2 *An improvement in the tourism terms-of-trade expands tourism sector and tourism infrastructure sector while it contracts manufacturing sector. It raises the wage of unskilled labor, the rentala rate of capital, and the price of emission permits. If the elasticity of substitution in the manufacturing sector is small (large), the wage of skilled labor falls (rises).*

An improvement in the tourism terms-of-trade p_T raises national income ($R_T = T > 0$). Given t, tax revenue increases, leading to increase in the output of public infrastructure. It follows that the output of tourism service and the wage of unskilled labor rise. There are conflicting effects on the output of traded good. On the one hand, the expansion of public infrastructure sector extract capital from traded good sector. On the other hand, the increase in public infrastructures enhances the productivity of trade good sector. The former effect dominates the latter, the output of traded good declines. When the elasticity of substitution in the traded good sector is large (small), outflow of capital increases (decreases) the demand for skilled labor and the wage of skilled labor. The expansion of tourism service sector raises the price of emission permits while the increase in public infrastructure pushes up the rental rate of capital.

4 The toral effect

4.1 Tourism terms-of-trade and welfare

The above sections have treated the tourism terms-of-trade p_T as constant. However, p_T is eventually determined by the market equilibrium condition of the domestic tourism service. In this section, we consider the effects of stricter environmental regulation, taking into account the p_T is determined endogenously.

To determine the price of tourism service, we need to introduce the demand side of the economy. Suppose that both domestic residents and foreign tourists consume manufacturing good and domestic tourism service. The demand side of the economy is represented by the expenditure function of domestic residents and the demand function of foreign tourists. The expenditure function is defined as

$$E(p_T, Z, u) \equiv \min[p_X C_X + p_T C_T | u = C_X^a C_T^b Z^{-\rho}],$$

where C_X is the consumption of manufacturing good and C_T the consumption of domestic tourism service by domestic residents. u is the level of the utility. a and b are parameters and satisfy $a + b = 1$. $\rho \geq 0$ represents the magnitude of disutility from pollution. Since the utility function is specified as the Cobb-Douglas form, the expenditure function is derived as $E = u p_X^a p_T^b Z^\rho / (a^a b^b)$. By the envelope theorem, we have $E_T \equiv \partial E / \partial p_T = bE/p_T = C_T$. The negatively sloped demand function implies $E_{TT} \equiv \partial^2 E / \partial p_T^2 < 0$. $E_Z \equiv \partial E / \partial Z > 0$ denotes the marginal environmental damage perceived by domestic residents and $E_u \equiv \partial E / \partial u > 0$ the inverse of marginal utility of income. $E_{TZ} \equiv \partial^2 E / \partial Z \partial p_T = \partial C_T / \partial Z > 0$ since domestic residents increase the compensated demand as disutility from pollution rises.

The utility function of foreign tourists is given by $u^* = D_X^\alpha D_T^\beta Z^{-\gamma}$, where $\alpha + \beta = 1$ and $\gamma \geq 0$. Given the budget Y^* of foreign tourists, demand function for domestic tourism service is derived as $D_T = \beta Y^* / p_T$.

The revenue function of the domestic residents is given by

$$R(p_T, Z) \equiv \max[p_X X + p_T T | K_X + K_M = K].$$

Applying the envelope theorem, we have $R_T \equiv \partial R / \partial p_T = T$ and $R_Z \equiv \partial R / \partial Z = r$.[10] The positively sloped supply function implies $R_{TT} \equiv \partial^2 R / \partial p_T^2 > 0$. Note that $R_{TZ} \equiv \partial^2 R / \partial Z \partial p_T = \partial T / \partial Z > 0$ from the above analysis.

The budget constraint of the economy is

$$E(p_T, Z, u) = R(p_T, Z), \tag{39}$$

which requires that the total expenditure is equal to the total revenue.

The market clearing condition for tourism service is

$$E_T(p_T, Z, u) + D_T(p_T) = R_T(p_T, Z), \tag{40}$$

[10]Since Lindahl pricing is assumed, the usual envelope theorem holds. See Okamoto (1985).

where the left hand side denotes the demand for tourism service while the right hand side denotes its supply. The above two equations determine p_T and u. Differentiating (39) and (40), we obtain

$$\begin{bmatrix} -D_T & E_u \\ -S_T & E_{Tu} \end{bmatrix} \begin{bmatrix} dp_T \\ du \end{bmatrix} = \begin{bmatrix} -(E_Z - r) \\ R_{TZ} - E_{TZ} \end{bmatrix} dZ, \tag{41}$$

where $S_T \equiv R_{TT} - E_{TT} - \frac{\partial D_T}{\partial p_T} > 0$ represents the slope of the excess supply function of the tourism service. Let Δ^* be the determinant of the 2×2 matrix on the LHS of (41). Then stability condition requires $\Delta^* > 0$.[11] Solving (41), we obtain

$$\frac{dp_T}{dZ} = -\frac{E_{Tu}(E_Z - r) + E_u(R_{TZ} - E_{TZ})}{\Delta^*}, \tag{42}$$

$$\frac{du}{dZ} = -\frac{D_T(R_{TZ} - E_{TZ}) + S_T(E_Z - r)}{\Delta^*}. \tag{43}$$

As pointed out by Beladi et al. (2009) and Yanase (2017), stricter environmental regulation affects the tourism terms-of-trade and domestic welfare through two conventional channels. On the one hand, if a pollution reduction decreases domestic excess supply of tourism service ($R_{TZ} - E_{TZ} = \frac{\partial}{\partial Z}(R_T - E_T) = \frac{\partial}{\partial Z}(T - C_T) > 0$), the price of tourism service rises. This positive terms-of-trade effect improves the domestic welfare. On the other hand, if the marginal damage of pollution to domestic residents is large than the marginal cost of pollution emission ($E_Z > r$), the pollution reduction pushes up the real income of domestic residents. This positive income effect raises the tourism terms-of-trade.

Since $E_{Tu}E_Z = E_u E_{TZ}$, we can rewrite the effect of stricter environmental regulation on tourism terms-of-trade (42) as

$$\frac{dp_T}{dZ} = -\frac{\frac{rE_u}{p_T}\left(\frac{p_T}{r}\frac{\partial r}{\partial p_T} - \frac{p_T E_{Tu}}{E_u}\right)}{\Delta^*}, \tag{44}$$

where $p_T E_{Tu}/E_u = b$ is the domestic resident's marginal propensity to consume tourism service. Since the elasticity of the price of emission permits with respect to tourism terms-of-trade ($\frac{p_T}{r}\frac{\partial r}{\partial p_T}$) is greater than unity (see (38)), a decrease in emission permits unambiguously improves the tourism terms-of-trade. That is, stricter environmental regulation unambiguously yields positive terms-of-trade effect.

Differentiating (39) and substituting (40), we obtain

$$E_u du = D_T dp_T - (E_Z - r)dZ. \tag{45}$$

[11] Let $\Omega \equiv E_T + D_T - T$ be the domestic excess demand for tourism service. From equations (39) and (40), we have $dp_T/d\Omega = -E_u/\Delta^*$. Hence, stability of tourism service market requires $\Delta^* > 0$.

It follows that a sufficient condition for stricter environmental regulation to improve domestic welfare is $E_Z > r$.

4.2 Effects on outputs and factor prices

The total effect (including the change in tourism terms-of-trade) of stricter environmental regulation on the output of manufacturing good is given by

$$\frac{dX}{dZ} = \frac{\partial X}{\partial Z} + \frac{\partial X}{\partial p_T}\frac{dp_T}{dZ} \tag{46}$$

or

$$\frac{Z}{X}\frac{dX}{dZ} = \frac{Z}{X}\frac{\partial X}{\partial Z} + \frac{p_T}{X}\frac{\partial X}{\partial p_T}\frac{Z}{p_T}\frac{dp_T}{dZ}. \tag{47}$$

The first term represents the direct effect of the environmental regulation while the second term the indirect effect that works through the change in the tourism terms-of-trade.

From (31), we have $\frac{Z}{X}\frac{\partial X}{\partial Z} = \theta_{ZT}\frac{p_T}{X}\frac{\partial X}{\partial p_T}$. Therefore, the total effect is rewritten as

$$\begin{aligned}\frac{Z}{X}\frac{dX}{dZ} &= \theta_{ZT}\frac{p_T}{X}\frac{\partial X}{\partial p_T} + \frac{p_T}{X}\frac{\partial X}{\partial p_T}\frac{Z}{p_T}\frac{dp_T}{dZ}\\ &= \frac{p_T}{X}\frac{\partial X}{\partial p_T}\left(\theta_{ZT} + \frac{Z}{p_T}\frac{dp_T}{dZ}\right).\end{aligned}$$

Since $\partial X/\partial p_T < 0$, the necessary and sufficient condition for the pollution reduction to decrease the output of traded good ($dX/dZ > 0$) is

$$\frac{Z}{p_T}\frac{dp_T}{dZ} < -\theta_{ZT}.$$

Similarly, the total effect of stricter environmental regulation on the output of public infrastructure is

$$\frac{Z}{M}\frac{dM}{dZ} = \frac{p_T}{M}\frac{\partial M}{\partial p_T}(\theta_{ZT} + \frac{Z}{p_T}\frac{dp_T}{dZ}). \tag{48}$$

Since $\partial M/\partial p_T > 0$, stricter environmental regulation decreases the output of public infrastructure if and only if

$$\frac{Z}{p_T}\frac{dp_T}{dZ} > -\theta_{ZT}.$$

The total effect of stricter environmental regulation on the wage of skilled labor is

$$\frac{Z}{w_S}\frac{dw_S}{dZ} = \frac{p_T}{w_S}\frac{\partial w_S}{\partial p_T}\left(\theta_{ZT} + \frac{Z}{p_T}\frac{dp_T}{dZ}\right).$$

If $\partial w_S/\partial p_T > (<) 0$ (i.e., $\sigma_X > (<) 1/\delta_X$), the necessary and sufficient condition for stricter environmental policy to decrease the wage of unskilled labor is

$$\frac{Z}{p_T}\frac{dp_T}{dZ} > (<) - \theta_{ZT}.$$

The total effect of stricter environmental regulation on the rental rate of capital is

$$\frac{Z}{q}\frac{dq}{dZ} = \frac{p_T}{q}\frac{\partial q}{\partial p_T}\left(\theta_{ZT} + \frac{Z}{p_T}\frac{dp_T}{dZ}\right).$$

Since $\partial q/\partial p_T > 0$, the amount of pollution and the rental rate of capital move the same direction if and only if

$$\frac{Z}{p_T}\frac{dp_T}{dZ} > -\theta_{ZT}.$$

The total effect of stricter environmental regulation on the output of tourism service is

$$\frac{Z}{T}\frac{dT}{dZ} = \frac{Z}{T}\frac{\partial T}{\partial Z} + \frac{p_T}{T}\frac{\partial T}{\partial p_T}\frac{Z}{p_T}\frac{dp_T}{dZ}.$$

Since $\partial T/\partial p_T > 0$, the necessary and sufficient condition for stricter environmental regulation to decrease the output of tourism service is

$$\begin{aligned}\frac{dT}{dZ} > 0 \leftrightarrow \frac{Z}{p_T}\frac{dp_T}{dZ} &> -\frac{\frac{Z}{T}\frac{\partial T}{\partial Z}}{\frac{p_T}{T}\frac{\partial T}{\partial p_T}} \\ &= -\frac{\theta_{ZT} + \xi_T\frac{\partial M}{\partial Z}\frac{Z}{M}}{\xi_T\frac{\partial M}{\partial p_T}\frac{p_T}{M}} \\ &= -\frac{\theta_{ZT} + \xi_T\theta_{ZT}\frac{\partial M}{\partial p_T}\frac{p_T}{M}}{\xi_T\frac{\partial M}{\partial p_T}\frac{p_T}{M}} \\ &= -\theta_{ZT}\frac{1 + \xi_T\frac{\partial M}{\partial p_T}\frac{p_T}{M}}{\xi_T\frac{\partial M}{\partial p_T}\frac{p_T}{M}} \equiv A.\end{aligned}$$

It is straightforward to show that $A < -\theta_{ZT}$.

The total effect of stricter environmental regulation on the wage of unskilled labor is

$$\frac{Z}{w_L}\frac{dw_L}{dZ} = \frac{Z}{w_L}\frac{\partial w_L}{\partial Z} + \frac{p_T}{w_L}\frac{\partial w_L}{\partial p_T}\frac{Z}{p_T}\frac{dp_T}{dZ}.$$

Since $\partial w_L/\partial p_T > 0$, the necessary and sufficient condition for stricter environmental regulation to decrease the wage of unskilled labor is

$$
\begin{aligned}
\frac{dw_L}{dZ} > 0 \leftrightarrow \frac{Z}{p_T}\frac{dp_T}{dZ} &> -\frac{\frac{Z}{w_L}\frac{\partial w_L}{\partial Z}}{\frac{p_T}{w_L}\frac{\partial w_L}{\partial p_T}} \\
&= -\frac{\frac{\theta_{ZT}}{\sigma_T} + \xi_T \frac{\partial M}{\partial Z}\frac{Z}{M}}{\frac{p_T}{r}\frac{\partial r}{\partial p_T}} \\
&= -\frac{\frac{\theta_{ZT}}{\sigma_T} + \xi_T \frac{\partial M}{\partial Z}\frac{Z}{M}}{1 + \xi_T \frac{\partial M}{\partial p_T}\frac{p_T}{M}} \\
&= -\frac{\frac{\theta_{ZT}}{\sigma_T} + \xi_T \theta_{ZT} \frac{\partial M}{\partial p_T}\frac{p_T}{M}}{1 + \xi_T \frac{\partial M}{\partial p_T}\frac{p_T}{M}} \\
&= -\theta_{ZT}\frac{\frac{1}{\sigma_T} + \xi_T \frac{\partial M}{\partial p_T}\frac{p_T}{M}}{1 + \xi_T \frac{\partial M}{\partial p_T}\frac{p_T}{M}} \equiv B.
\end{aligned}
$$

It follows that $\sigma_T \gtreqless 1 \leftrightarrow B \gtreqless -\theta_{ZT}$.

The total effect of stricter environmental regulation on the price of emission permits is

$$
\frac{Z}{r}\frac{dr}{dZ} = \frac{Z}{r}\frac{\partial r}{\partial Z} + \frac{p_T}{r}\frac{\partial r}{\partial p_T}\frac{Z}{p_T}\frac{dp_T}{dZ}.
$$

Since $\partial r / \partial p_T > 0$, stricter environmental regulation decreases the price of emission permits if and only if

$$
\frac{dr}{dZ} > 0 \leftrightarrow \frac{Z}{p_T}\frac{dp_T}{dZ} > -\frac{\frac{Z}{r}\frac{\partial r}{\partial Z}}{\frac{p_T}{r}\frac{\partial r}{\partial p_T}} \equiv C.
$$

Since $\hat{w}_L / \hat{p}_T = \hat{r} / \hat{p}_T$ and $(\hat{w}_L - \hat{r}) / \hat{Z} = 1/\sigma_T > 0$, we have $B < C$.

$$
\begin{aligned}
C &= -\frac{\frac{Z}{r}\frac{\partial r}{\partial Z}}{\frac{p_T}{r}\frac{\partial r}{\partial p_T}} \\
&= -\frac{-\frac{\theta_{LT}}{\sigma_T} + \xi_T \frac{\partial M}{\partial Z}\frac{Z}{M}}{1 + \xi_T \frac{\partial M}{\partial p_T}\frac{p_T}{M}} \\
&= -\frac{-\frac{\theta_{LT}}{\sigma_T} + \xi_T \theta_{ZT} \frac{\partial M}{\partial p_T}\frac{p_T}{M}}{1 + \xi_T \frac{\partial M}{\partial p_T}\frac{p_T}{M}} \\
&= -\theta_{ZT}\frac{-\frac{\theta_{LT}}{\theta_{ZT}\sigma_T} + \xi_T \frac{\partial M}{\partial p_T}\frac{p_T}{M}}{1 + \xi_T \frac{\partial M}{\partial p_T}\frac{p_T}{M}}.
\end{aligned}
$$

It is straightforward to show that $C > -\theta_{ZT}$.

We can show that $B > A$ if $\sigma_T \geq 1/2$:

$$\begin{aligned}
B - A &= -\theta_{ZT} \frac{\frac{1}{\sigma_T} + \xi_T \frac{\partial M}{\partial p_T} \frac{p_T}{M}}{1 + \xi_T \frac{\partial M}{\partial p_T} \frac{p_T}{M}} + \theta_{ZT} \frac{1 + \xi_T \frac{\partial M}{\partial p_T} \frac{p_T}{M}}{\xi_T \frac{\partial M}{\partial p_T} \frac{p_T}{M}} \\
&= \theta_{ZT} \left(\frac{1 + \xi_T \frac{\partial M}{\partial p_T} \frac{p_T}{M}}{\xi_T \frac{\partial M}{\partial p_T} \frac{p_T}{M}} - \frac{\frac{1}{\sigma_T} + \xi_T \frac{\partial M}{\partial p_T} \frac{p_T}{M}}{1 + \xi_T \frac{\partial M}{\partial p_T} \frac{p_T}{M}} \right) \\
&= \theta_{ZT} \frac{\left(1 + \xi_T \frac{\partial M}{\partial p_T} \frac{p_T}{M}\right)^2 - \xi_T \frac{\partial M}{\partial p_T} \frac{p_T}{M} \left(\frac{1}{\sigma_T} + \xi_T \frac{\partial M}{\partial p_T} \frac{p_T}{M}\right)}{(\xi_T \frac{\partial M}{\partial p_T} \frac{p_T}{M})(1 + \xi_T \frac{\partial M}{\partial p_T} \frac{p_T}{M})} \geq 0 \quad \text{if } \sigma_T > 1/2,
\end{aligned}$$

since the numerator is

$$\begin{aligned}
&\left(1 + \xi_T \frac{\partial M}{\partial p_T} \frac{p_T}{M}\right)^2 - \xi_T \frac{\partial M}{\partial p_T} \frac{p_T}{M} \left(\frac{1}{\sigma_T} + \xi_T \frac{\partial M}{\partial p_T} \frac{p_T}{M}\right) \\
&= 1 + 2\xi_T \frac{\partial M}{\partial p_T} \frac{p_T}{M} + \left(\xi_T \frac{\partial M}{\partial p_T} \frac{p_T}{M}\right)^2 - \frac{\xi_T}{\sigma_T} \frac{\partial M}{\partial p_T} \frac{p_T}{M} - \left(\xi_T \frac{\partial M}{\partial p_T} \frac{p_T}{M}\right)^2 \\
&= 1 + \left(2 - \frac{1}{\sigma_T}\right) \xi_T \frac{\partial M}{\partial p_T} \frac{p_T}{M} > 0 \quad \text{if } \sigma_T > 1/2.
\end{aligned}$$

Therefore, if $\sigma_T > 1$, $A < -\theta_{ZT} < B < C$. While if $1/2 < \sigma_T < 1$, $A < B < -\theta_{ZT} < C$. The above results are summarized by Table 3 - 6 and Proposition 3.

$\frac{Z}{p_T}\frac{dp_T}{dZ}$	$\cdots$	A	$\cdots$	$-\theta_{ZT}$	$\cdots$	B	$\cdots$	C	$\cdots$
dX/dZ	+	+	+	0	−	−	−	−	−
dT/dZ	−	0	+	+	+	+	+	+	+
dM/dZ	−	−	−	0	+	+	+	+	+
dw_S/dZ	+	+	+	0	−	−	−	−	−
dw_L/dZ	−	−	−	−	−	0	+	+	+
dq/dZ	−	−	−	0	+	+	+	+	+
dr/dZ	−	−	−	−	−	−	−	0	+

Table 3: $\sigma_T > 1$ and $\sigma_X < 1/\delta_X$

Proposition 3 *A stricter environmental regulation expands the tourism sector if and only if $\hat{p}_T/\hat{Z} < A$. When $\sigma_X < 1/\delta_X$, stricter environmental regulation narrows domestic wage inequality if $\frac{Z}{p_Z}\frac{dp_T}{dZ} < \min(-\theta_{ZT}, B)$, or widens domestic wage*

$\frac{Z}{p_T}\frac{dp_T}{dZ}$	$\cdots$	A	$\cdots$	$-\theta_{ZT}$	$\cdots$	B	$\cdots$	C	$\cdots$
dX/dZ	+	+	+	0	−	−	−	−	−
dT/dZ	−	0	+	+	+	+	+	+	+
dM/dZ	−	−	−	0	+	+	+	+	+
dw_S/dZ	−	−	−	0	+	+	+	+	+
dw_L/dZ	−	−	−	−	−	0	+	+	+
dq/dZ	−	−	−	0	+	+	+	+	+
dr/dZ	−	−	−	−	−	−	−	0	+

Table 4: $\sigma_T > 1$ and $\sigma_X > 1/\delta_X$

inequality if $\frac{Z}{p_Z}\frac{dp_T}{dZ} > \max(-\theta_{ZT}, B)$. *When* $\sigma_X > 1/\delta_X$, *stricter environmental regulation narrows domestic wage inequality if* $\frac{Z}{p_Z}\frac{dp_T}{dZ} \in (-\theta_{ZT}, B)$ *and* $\sigma_T > 1$, *or widens domestic wage inequality if* $\frac{Z}{p_Z}\frac{dp_T}{dZ} \in (B, -\theta_{ZT})$ *and* $\sigma_T < 1$.

A stricter environmental regulation expands the tourism sector if and only if $\hat{p}_T/\hat{Z} < A$, i.e., positive terms-of-trade effect is sufficiently large.

Next we consider the effect on skilled-unskilled wage gap. When $\sigma_X < 1/\delta_X$ (i.e., $\partial w_S/\partial p_T < 0$), both the direct and indirect effects work the opposite direction for the skilled wage and the unskilled wage. In this case, if the terms-of-trade effect is sufficiently large, stricter environmental regulation leads to lower skilled wage and higher unskilled wage, narrowing domestic wage inequality. While if the tourism terms-of-trade effects is sufficiently small, stricter environmental regulation widens domestic wage gap (see Tables 3 and 5).

When $\sigma_X > 1/\delta_X$ (i.e., $\partial w_S/\partial p_T > 0$), both the direct and indirect effects work to the same direction for the skilled wage and the unskilled wage. In this case, if the terms-of-trade effect is moderate, the total effects on the skilled wage and unskilled wage work to the opposite direction (see Table 4). If $\sigma_T > 1$, stricter environmental regulation narrows domestic wage inequality. While if $1/2 \leq \sigma_T < 1$, stricter environmental policy leads to widening domestic wage inequality (see Table 6).

$\frac{Z}{p_T}\frac{dp_T}{dZ}$	$\cdots$	A	$\cdots$	B	$\cdots$	$-\theta_{ZT}$	$\cdots$	C	$\cdots$
dX/dZ	+	+	+	+	+	0	−	−	−
dT/dZ	−	0	+	+	+	+	+	+	+
dM/dZ	−	−	−	−	−	0	+	+	+
dw_S/dZ	+	+	+	+	+	0	−	−	−
dw_L/dZ	−	−	−	0	+	+	+	+	+
dq/dZ	−	−	−	−	−	0	+	+	+
dr/dZ	−	−	−	−	−	−	−	0	+

Table 5: $1/2 \leq \sigma_T < 1$ and $\sigma_X < 1/\delta_X$

5 Conclusions

This paper constructs a polluted small open economy model with tourism and public infrastructure. Pollution is emitted by the tourism sector. By reducing the amount of pollution, a stricter environmental regulation expands the tourism sector if and only if the tourism terms-of-trade is large. In addition, the stricter environmental regulation can narrow or widen the domestic wage inequality, depending on the elasticity of substitution in the tourism and manufacturing sectors. When the elasticity of substitution in the manufacturing sector is small, stricter environmental regulation narrows (widens) domestic wage inequality for a large (small) terms of trade effect. When the elasticity of substitution in the manufacturing sector is large, stricter environmental regulation narrows or widens domestic wage gap for moderate terms-of-trade effect, depending on the elasticity of substitution in the tourism sector.

In this paper, we have considered that the public infrastructure is the creation of atmosphere type that has no congestion effect. However, some infrastructure, such as highway, park, airport has congestion effect. This type of public infrastructure is called the unpaid factor type, or semi public intermediate good. The analysis of unpaid factor type of public infrastructure is one of the topics for future research.

$\frac{Z}{p_T}\frac{dp_T}{dZ}$	$\cdots$	A	$\cdots$	B	$\cdots$	$-\theta_{ZT}$	$\cdots$	C	$\cdots$
dX/dZ	+	+	+	+	+	0	−	−	−
dT/dZ	−	0	+	+	+	+	+	+	+
dM/dZ	−	−	−	−	−	0	+	+	+
dw_S/dZ	−	−	−	−	−	0	+	+	+
dw_L/dZ	−	−	−	0	+	+	+	+	+
dq/dZ	−	−	−	−	−	0	+	+	+
dr/dZ	−	−	−	−	−	−	−	0	+

Table 6: $1/2 \leq \sigma_T < 1$ and $\sigma_X > 1/\delta_X$

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