Tourism, the envivonment and public infrastructure: the case of semi 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 semi public infrastructure that contains the 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, a stricter environmental regulation expands tourism sector. Domestic wage inequality narrows or widens, depending on the elasticity of substitution in each industry.

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

JEL Classification: D33, F18, Q38

1 Introduction

The tourism sector has become an important sector for both developed and developing countries as it creates employment opportunities and attracts foreign currency. The tourism sector requires a large amount of investment, for example, water supply, sewerage systems, ports, airports, parks, highways, and tourism promotion by authorities (e.g., Visit Japan, Incredible India, and Malaysia Truly Asia), which is rather difficult to be financed only by the private sector. Therefore, a national government needs to construct public infrastructure for the tourism industry. At the same time, the tourism sector causes environmental damage. For example, the concentration of people degrades the water quality in the local community, and

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traffic congestion pollutes the air by the emission of fumes.[1] To mitigate these negative effects, the government introduces an environmental regulation by issuing emission permits to control the amount of pollution.

At the same time, the productivity of tourism industry is largely affected by infrastructure, such as highway, airport, park. Such a infrastructure improves other industries as well as tourism industry. It also includes congestion effect, i.e., an increase in users decreases its efficiency.[2] Thus this paper constructs a model with semi public infrastructure that contributes all industries in the economy and contains congestion effect. Shimizu and Okamoto (2022) develops a small open economy model with infrastructure that contributes to only tourism industry and does not include congestion effect. Shimizu (2020) constructs a model with pure public infrastructure that contributes all industries but does not include congestion effect. Hence this paper complements the analyses of Shimizu and Okamoto (2022) and Shimizu (2020). The remainder of the paper is organized as follows. Section 2 sets up the model. In section 3, we analyze the effects of stricter environmental regulation and improvement in tourism terms of trade, taking only supply side of the economy into account. In section 4, we examine the effects of stricter environmental regulation, considering the change in tourism terms of trade. Some concluding remarks are made in section 5.

2 The model

We consider a small open economy consisting of two private sectors and one public sector. Two private sectors are manufacturing and tourism sectors. The manufacturing product is traded while tourism service is non-traded in the absence of international tourism. The manufacturing sector employs skilled labor S and capital K to produce manufacturing good. The tourism sector requires unskilled labor L and pollution permits Z. The public sector constructs public infrastructure using only capital. The public infrastructure improves the productivity of both private sectors.

Let X and T denote the outputs of manufacturing good and tourism service, respectively. The production functions of

[1] In Japan, especially in Kyoto, an excessive tourism boom has caused over-tourism, bringing serious damages to the local community. However, this congestion phenomenon was suddenly terminated with the outbreak of the COVID-19 pandemic. We hope that we will be able to overcome those negative effects of the COVID-19 pandemic after a period of time as in the case of the other pandemics in the past such as Spanish flu and Soviet flu. In fact, the number of infected persons is rapidly decreasing since the end of August, 2021. We also believe that there will be rapid growth in inbound tourism as a repercussion of immigration control. Thus, negative aspects of the tourism boom are still worth considering.

[2] The public intermediate good is divided into two types. The former, which is also called the pure public intermediate good, has no congestion effect, i.e., an increase in uses has no effect on efficiency of intermediate good. Examples are information and technology that contribute to economic activities. The latter, called the semi public intermediate good, contains congestion effect.

two private goods are given by[3]

$$X = M^{\xi_X} F(S, K_X), \tag{1}$$

$$T = M^{\xi_T} N(L, Z), \tag{2}$$

where M is the amount of public infrastructure and $\xi_j \in (0,1)$ is a parameter. S, K_j, L, and Z represent the endowment of skilled labor, the capital input devoted to the production of good j, the endowment of unskilled labor, and the amount of emission permits, respectively. F (resp. N) is a homogeneous function of degree $1 - \xi_X$ (resp. $1 - \xi_T$). Hence, X and T are homogeneous of degree one in primary factors of production and public infrastructure. The public infrastructure in this paper includes congestion effect: when the input of the primary factors of production doubles, the output becomes less than twice, keeping the amount of public infrastructure constant. Furthermore, we assume that X and T are strictly quasi-concave.

The production function of public infrastructure is

$$M = K_M / a_{KM},$$

where a_{ij} is the amount of factor j to produce one unit of good j. We assume a linear production technology and thus a_{KM} is constant.

The fee charged for using public infrastructure is determined by the Lindahl pricing, i.e., the price of public infrastructure is equal to the value of its marginal product. Thus the fee charged for firms in manufacturing sector is

$$t_X = p_X \frac{\partial X}{\partial M} = p_X \xi_X \frac{X}{M} = p_X \xi_X / a_{MX}, \tag{3}$$

where $a_{MX} = M/X$. Similarly, the fee charged for firms in tourism sector is

$$t_T = p_T \frac{\partial T}{\partial M} = p_T \xi_T \frac{T}{M} = p_T \xi_T / a_{MT}, \tag{4}$$

where $a_{MT} = M/T$.

Therefore, the price of public intermediate good p_M is given by

$$p_M = t_X + t_T. \tag{5}$$

The zero profit conditions are

$$a_{SX} w_S + a_{KX} q + a_{MX} t_X = p_X, \tag{6}$$

[3] Pi and Zhou (2014) considered a symmetric externality case (in our notation, $\xi_X = \xi_T = \xi$). We allow the extent of externality to differ across industries.

$$a_{LT}w_L + a_{ZT}r + a_{MT}t_T = p_T, \tag{7}$$

$$a_{KM}q = p_M, \tag{8}$$

where w_S, w_L, q, r, p_X, and p_T are the wage of skilled labor, the unskilled wage, the rental rate of capital, the price of emission permits, the price of manufacturing good, and the price of tourism service, respectively. Note that p_X is constant by the assumption of a small open economy.

The market clearing conditions are

$$a_{KX}X + a_{KM}M = K, \tag{9}$$

$$a_{SX}X = S, \tag{10}$$

$$a_{LT}T = L, \tag{11}$$

$$a_{ZT}T = Z, \tag{12}$$

where K, S, and L are the endowments of capital, skilled labor, and unskilled labor, respectively. Z is the amount of emission permits, which is a policy instrument of the government. Equations (3) - (12) include 10 unknowns: t_X, t_T, X, M, T, p_M, w_S, w_L, q, and r. Given p_T, the above 10 equations determine 10 unknowns.[4]

3 Comparative statics analysis: supply side

In this section we analyze the effects of stricter environmental policy (a decrease in Z) and improvement in tourism terms of trade (an increase in p_T), focusing only on the supply side of the economy.

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

$$\sigma_X = \frac{\widehat{a}_{KX} - \widehat{a}_{SX}}{\widehat{w}_S - \widehat{q}}, \tag{13}$$

$$\sigma_T = \frac{\widehat{a}_{ZT} - \widehat{a}_{LT}}{\widehat{w}_L - \widehat{r}}. \tag{14}$$

A hat over a variable denotes the rate of change: e.g., $\widehat{a}_{KX} \equiv da_{KX}/a_{KX}$.

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

Cost minimization in the manufacturing good sector requires

$$\theta_{SX}\widehat{a}_{SX} + \theta_{KX}\widehat{a}_{KX} + \theta_{MX}\widehat{a}_{MX} = 0, \tag{15}$$

where θ_{ij} denotes the cost share of factor i in sector j. Taking $\theta_{MX} = \xi_X$ from (3) and $a_{MX} = M/X$ into account, we can rewrite (15) as

$$\theta_{SX}\widehat{a}_{SX} + \theta_{KX}\widehat{a}_{KX} + \xi_X(\widehat{M} - \widehat{X}) = 0. \tag{16}$$

Similarly, cost minimization in the tourism sector requires

$$\theta_{LT}\widehat{a}_{LT} + \theta_{ZT}\widehat{a}_{ZT} + \theta_{MT}\widehat{a}_{MT} = 0. \tag{17}$$

Considering $\theta_{MT} = \xi_T$ from (4) and $a_{MT} = M/T$, (17) is rewritten as

$$\theta_{LT}\widehat{a}_{LT} + \theta_{ZT}\widehat{a}_{ZT} + \xi_T(\widehat{M} - \widehat{T}) = 0. \tag{18}$$

$\theta_{LT} \equiv w_L a_{LT}/p_T, \theta_{ZT} \equiv r a_{ZT}/p_T$

Diffretentiating (6) and considering (3) and (15), we obtain

$$\theta_{SX}\widehat{w}_S + \theta_{KX}\widehat{q} + \xi_X(\widehat{X} - \widehat{M}) = (1 - \xi_X)\widehat{p}_X. \tag{19}$$

Differentiating (7) and substituting (4) and (17), we obtain

$$\theta_{LT}\widehat{w}_L + \theta_{ZT}\widehat{r} + \xi_T(\widehat{T} - \widehat{M}) = (1 - \xi_T)\widehat{p}_T. \tag{20}$$

Solving (13) and (16), we obtain[5]

$$\widehat{a}_{SX} = \frac{-\theta_{KX}\sigma_X(\widehat{w}_S - \widehat{q}) + \xi_X(\widehat{X} - \widehat{M})}{1 - \xi_X}, \tag{21}$$

$$\widehat{a}_{KX} = \frac{\theta_{SX}\sigma_X(\widehat{w}_S - \widehat{q}) + \xi_X(\widehat{X} - \widehat{M})}{1 - \xi_X}. \tag{22}$$

Similarly, solving (14) and (18), we obtain

$$\widehat{a}_{LT} = \frac{-\theta_{ZT}\sigma_T(\widehat{w}_L - \widehat{r}) + \xi_T(\widehat{T} - \widehat{M})}{1 - \xi_T}, \tag{23}$$

$$\widehat{a}_{ZT} = \frac{\theta_{LT}\sigma_T(\widehat{w}_L - \widehat{r}) + \xi_T(\widehat{T} - \widehat{M})}{1 - \xi_T}. \tag{24}$$

[5]We have used $\theta_{SX} + \theta_{KX} + \xi_X = 1$.

Differentiating (9) and substituting (22), we obtain

$$\lambda_{KX}\widehat{X} + \lambda_{KX}\theta_{SX}\sigma_X(\widehat{w}_S - \widehat{q}) + (\lambda_{KM} - \xi_X)\widehat{M} = (1 - \xi_X)\widehat{K}, \tag{25}$$

where λ_{ij} is the share of factor i in the production of good j.

Differentiating (10) and substituting (21), we have

$$-\theta_{KX}\sigma_X(\widehat{w}_S - \widehat{q}) + \widehat{X} - \xi_X\widehat{M} = (1 - \xi_X)\widehat{S}. \tag{26}$$

Differentiating (11) and considering (23), we get

$$-\theta_{ZT}\sigma_T(\widehat{w}_L - \widehat{r}) + \widehat{T} - \xi_T\widehat{M} = (1 - \xi_T)\widehat{L}. \tag{27}$$

Differentiating (12) and substituting (24), we have

$$\theta_{LT}\sigma_T(\widehat{w}_L - \widehat{r}) + \widehat{T} - \xi_T\widehat{M} = (1 - \xi_T)\widehat{Z}. \tag{28}$$

Substituting (3), (4), and (5) into (8) and differentiating, we obtain

$$\widehat{M} - \mu_X\widehat{X} - \mu_T\widehat{T} + \widehat{q} = \mu_X\widehat{p}_X + \mu_T\widehat{p}_T, \tag{29}$$

where $\mu_X \equiv t_X/(t_X + t_T)$ and $\mu_T \equiv t_T/(t_X + t_T)$. By definition, $\mu_X + \mu_T = 1$.

From (27) and (28), we have

$$\sigma_T(\widehat{w}_L - \widehat{r}) = \widehat{Z}. \tag{30}$$

Substituting (30) back into (27) or (28) yields[6]

$$\widehat{T} = \theta_{ZT}\widehat{Z} + \xi_T\widehat{M}. \tag{31}$$

Then we substitute (31) into (29) to obtain

$$(1 - \mu_T\xi_T)\widehat{M} - \mu_X\widehat{X} + \widehat{q} = \mu_T(\widehat{p}_T + \theta_{ZT}\widehat{Z}) \tag{32}$$

(19), (25), (26), and (32) constitute a system of $\widehat{X}$, $\widehat{M}$, $\widehat{q}$, and $\widehat{w}_S$, which can be described in the matrix form as

$$\begin{pmatrix} \xi_X & -\xi_X & \theta_{KX} & \theta_{SX} \\ \lambda_{KX} & \lambda_{KM} - \xi_X & -\lambda_{KX}\theta_{SX}\sigma_X & \lambda_{KX}\theta_{SX}\sigma_X \\ 1 & -\xi_X & \theta_{KX}\sigma_X & -\theta_{KX}\sigma_X \\ -\mu_X & 1 - \mu_T\xi_T & 1 & 0 \end{pmatrix} \begin{pmatrix} \widehat{X} \\ \widehat{M} \\ \widehat{q} \\ \widehat{w}_S \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ \mu_T(\widehat{p}_T + \theta_{ZT}\widehat{Z}) \end{pmatrix}. \tag{33}$$

[6]This equation can also be obtained by differentiating the production function of the tourism service (2) and substituting the profit maximization condition ($p_T \frac{\partial T}{\partial Z} = r$).

3.1 Environmental regulation

Solving (33), we obtain[7] [8]

$$\begin{aligned}\frac{\widehat{X}}{\widehat{Z}} &= -\frac{\mu_T\theta_{ZT}(1-\xi_X)^2\sigma_X(\lambda_{KM}\theta_{KX}-\lambda_{KX}\xi_X)}{\Delta} \\ &= -\frac{\mu_T\theta_{ZT}(1-\xi_X)^2\sigma_X(1-\mu_X)\lambda_{KM}\theta_{KX}}{\Delta} < 0,\end{aligned} \tag{34}$$

$$\frac{\widehat{M}}{\widehat{Z}} = \frac{\mu_T\theta_{ZT}(1-\xi_X)^2\lambda_{KX}\sigma_X}{\Delta} > 0, \tag{35}$$

$$\frac{\widehat{q}}{\widehat{Z}} = \frac{(1-\xi_X)\mu_T\theta_{ZT}[\xi_X\sigma_X(\theta_{KX}+\lambda_{KX}\theta_{SX})+\lambda_{KM}\theta_{SX}]}{\Delta} > 0, \tag{36}$$

$$\begin{aligned}\frac{\widehat{w}_S}{\widehat{Z}} &= \frac{\mu_T\theta_{ZT}(1-\xi_X)[\xi_X\sigma_X(\theta_{KX}+\lambda_{KX}\theta_{SX})-\lambda_{KM}\theta_{KX}]}{\Delta} \\ &= \frac{\mu_T\theta_{ZT}(1-\xi_X)[\sigma_X(\mu_X+\mu_T\xi_X)-1]\lambda_{KM}\theta_{KX}}{\Delta},\end{aligned} \tag{37}$$

where $\Delta = (1-\xi_X)\{\sigma_X[\xi_X+\mu_X(1-\xi_X)](\theta_{KX}+\lambda_{KX}\theta_{SX})+\lambda_{KX}\sigma_X\mu_T(1-\xi_T)(1-\xi_X)+\theta_{SX}\lambda_{KM}\} > 0$.

From (31), we have $\widehat{T}/\widehat{Z} = \theta_{ZT}+\xi_T\widehat{M}/\widehat{Z} > 0$.

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[7] Substituting (5) and (8) into (3), we have

$$\xi_X = \frac{t_X}{p_X}\frac{M}{X} = \frac{t_X}{p_M}\frac{p_M M}{p_X X} = \mu_X\frac{p_M M}{p_X X} = \mu_X\frac{\theta_{KX}\lambda_{KM}}{\lambda_{KX}}.$$

Thus, we obtain

$$\begin{aligned}\lambda_{KM}\theta_{KX}-\lambda_{KX}\xi_X &= \lambda_{KM}\theta_{KX}-\mu_X\theta_{KX}\lambda_{KM} \\ &= (1-\mu_X)\lambda_{KM}\theta_{KX} > 0.\end{aligned}$$

[8] Note that the following relationship holds.

$$\begin{aligned}\xi_X(\theta_{KX}+\lambda_{KX}\theta_{SX}) &= \lambda_{KM}\theta_{KX}-(1-\xi_X)(\lambda_{KM}\theta_{KX}-\lambda_{KX}\xi_X) \\ &= \lambda_{KM}\theta_{KX}-(1-\xi_X)(1-\mu_X)\lambda_{KM}\theta_{KX} \\ &= [1-(1-\xi_X)(1-\mu_X)]\lambda_{KM}\theta_{KX} \\ &= [1-(1-\mu_X-\xi_X+\xi_X\mu_X)]\lambda_{KM}\theta_{KX} \\ &= (\mu_X+\xi_X-\xi_X\mu_X)\lambda_{KM}\theta_{KX} \\ &= (\mu_X+\mu_T\xi_X)\lambda_{KM}\theta_{KX},\end{aligned}$$

Substituting (30) and (31) into (20), we obtain

$$\frac{\widehat{r}}{\widehat{Z}} = \xi_T \frac{\widehat{M}}{\widehat{Z}} - \frac{\theta_{LT} + \sigma_T \xi_T \theta_{ZT}}{\sigma_T(1-\xi_T)}. \tag{38}$$

Substituting (35) into (38), we have

$$\frac{\widehat{r}}{\widehat{Z}} = \frac{\sigma_T \xi_T \theta_{ZT}[(1-\xi_T)\mu_T(1-\xi_X)^2 \lambda_{KX}\sigma_X - \Delta] - \theta_{LT}\Delta}{\sigma_T(1-\xi_T)\Delta} < 0.$$

Substituting (38) into (30),

$$\frac{\widehat{w}_L}{\widehat{Z}} = \frac{\widehat{r}}{\widehat{Z}} + \frac{1}{\sigma_T} = \xi_T \frac{\widehat{M}}{\widehat{Z}} + \frac{\theta_{ZT}(1-\sigma_T\xi_T)}{\sigma_T(1-\xi_T)} > 0 \quad \text{if } 1-\xi_T\sigma_T \geq 0. \tag{39}$$

From (3), (34), and (35), we have

$$\frac{\widehat{t}_X}{\widehat{Z}} = \frac{\widehat{X}}{\widehat{Z}} - \frac{\widehat{M}}{\widehat{Z}} < 0. \tag{40}$$

From (4), (31), and (35), we have

$$\frac{\widehat{t}_T}{\widehat{Z}} = \frac{\widehat{T}}{\widehat{Z}} - \frac{\widehat{M}}{\widehat{Z}} = \theta_{ZT} - (1-\xi_T)\frac{\widehat{M}}{\widehat{Z}} > 0. \tag{41}$$

	$\widehat{X}$	$\widehat{T}$	$\widehat{M}$	$\widehat{w}_S$	$\widehat{w}_L$	$\widehat{q}$	$\widehat{r}$	$\widehat{t}_X$	$\widehat{t}_T$
$Z\downarrow$	+	−	−	$\pm^a$	$\pm^b$	−	+	+	−

a: negative (positive) if and only if $\sigma_X > (<) 1/(\mu_T\xi_X + \mu_X)$

b: negative if $1-\xi_T\sigma_T \geq 0$

Table 1: stricter environmental policy

Proposition 1 *Suppose that the tourism terms of trade p_T are constant. A stricter environmental regulation contracts the tourism sector and public infrastructure sector while it expands traded good sector. The rental rate of capital falls while the price of pollution permits rises. If the elasticity of substitution in the tourism sector is not so large, the wage of unskilled labor declines. When the elasticity of substitution in the manufacturing sector is large (small), the wage of skilled labor falls (rises). The price of public infrastructure charged for firms in manufacturing sector rises while that for firms in tourism sector falls.*

The intuition is as follows. A stricter regulation on pollution, by reducing the amount of pollution permits, contracts the tourism industry and raises the price of pollution permits. Thus the demand for public infrastructure by the tourism sector declines, which decreases its price t_T. If the elasticity of substitution in the tourism sector is not so large, the demand and the wage of unskilled labor, which is a specific factor to that sector, decline. An inflow of capital into the traded good sector expands its production, leading to increase in demand for public infrastructure and its price t_X. If the elasticity of substitution in the traded good sector is large (small), the demand for skilled labor and its wage decrease (increase).

3.2 Tourism terms of trade

From (33), the effects of the change in p_T on X, M, q, and w_S are proportional to the effects of the change in Z:

$$\frac{\widehat{\Psi}}{\widehat{p_T}} = \frac{1}{\theta_{ZT}}\frac{\widehat{\Psi}}{\widehat{Z}}, \tag{42}$$

where $\Psi = X, M, q, w_S$. When Z is constant, (30) implies $\widehat{w}_L/\widehat{p}_T = \widehat{r}/\widehat{p}_T$ and from (31) we have

$$\widehat{T}/\widehat{p}_T = \xi_T\widehat{M}/\widehat{p}_T > 0. \tag{43}$$

Substituting $\widehat{w}_L = \widehat{r}$ and (43) into (20), we have

$$\widehat{r} - \xi_T\widehat{M} = \widehat{p}_T, \tag{44}$$

which implies that

$$\frac{\widehat{r}}{\widehat{p_T}} = 1 + \xi_T\frac{\widehat{M}}{\widehat{p_T}} = 1 + \frac{\widehat{T}}{\widehat{p_T}} > 1. \tag{45}$$

Differentiating (3), we can show that an improvement in tourism terms of trade decreases the public fee paid by firms in manufacturing sector:

$$\frac{\widehat{t_X}}{\widehat{p_T}} = \frac{\widehat{X}}{\widehat{p_T}} - \frac{\widehat{M}}{\widehat{p_T}} < 0. \tag{46}$$

From (4), (42), and (43), the improvement in tourism terms of trade raises the price of public infrastructure paid by firms in tourism sector:

$$\frac{\widehat{t_T}}{\widehat{p_T}} = 1 + \frac{\widehat{T}}{\widehat{p_T}} - \frac{\widehat{M}}{\widehat{p_T}} = 1 - (1-\xi_T)\frac{\widehat{M}}{\widehat{p_T}} = \frac{1}{\theta_{ZT}}\left[\theta_{ZT} - (1-\xi_T)\theta_{ZT}\frac{\widehat{M}}{\widehat{p_T}}\right] = \frac{1}{\theta_{ZT}}\left[\theta_{ZT} - (1-\xi_T)\frac{\widehat{M}}{\widehat{Z}}\right] > 0, \tag{47}$$

where the last inequality follows from (41).

Proposition 2 *An improvement in tourism terms of trade expands tourism and public infrastructure sectors and contracts manufacturing sector. The wage of unskilled labor, the rental rate of capital, and the price of pollution permits rise. If the elasticity of substitution in the manufacturing sector is large (small), the wage of skilled labor rises (falls).*

	$\widehat{X}$	$\widehat{T}$	$\widehat{M}$	$\widehat{w}_S$	$\widehat{w}_L$	$\widehat{q}$	$\widehat{r}$	$\widehat{t}_X$	$\widehat{t}_T$
$p_T \uparrow$	$-$	$+$	$+$	$\pm^c$	$+$	$+$	$+$	$-$	$+$

c: positive (negative) if and only if $\sigma_X > (<) 1/(\mu_T \xi_X + \mu_X)$

Table 2: an improvement in tourism terms of trade

The intuition is as follows. A rise in the price of tourism service increases the output of tourism service, which increases the price of emission permits, the price of public infrastructure charged for tourism sector, and the wage of unskilled labor. 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 previous 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 that 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 that 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 $E = up_X^a p_T^b Z^\rho/(a^a b^b)$. 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. Note that $E_{TZ} \equiv \partial^2 E/\partial Z \partial p_T = \partial C_T/\partial Z > 0$ since domestic residents increase the compensated demand as disutility from pollution rises.

Suppose that 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, the demand function for domestic tourism service is derived as $D_T = \beta Y^*/p_T$.

The revenue function is given by

$$R(p_T, Z) \equiv \max[p_X X + p_T T | K_X + K_M = K, X = (K_M/a_{KM})^{\xi_X} F(S, K_X), T = (K_M/a_{KM})^{\xi_T} N(L, Z)].$$

Applying the envelope theorem, we have $R_T \equiv \partial R/\partial p_T = T$ and $R_Z \equiv \partial R/\partial Z = r$.[9] 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

$$E(p_T, Z, u) = R(p_T, Z), \tag{48}$$

which requires that total expenditure equals total revenue.

The market clearing condition for domestic tourism service is given by

$$E_T(p_T, Z, u) + D_T(p_T) = R_T(p_T, Z) \tag{49}$$

The left-hand side represents demand for domestic tourism service, while the right-hand side its supply by domestic firms.

The above two equations simultaneously determine the tourism terms of trade p_T and the domestic residents' welfare u. Differentiating (48) and (49), we obtain

$$\begin{bmatrix} -D_T & E_u \\ -S_T & E_{Tu} \end{bmatrix} \begin{bmatrix} dp_T \\ du \end{bmatrix} = \begin{bmatrix} r - E_Z \\ R_{TZ} - E_{TZ} \end{bmatrix} dZ, \tag{50}$$

where $S_T \equiv R_{TT} - E_{TT} - \frac{\partial D_T^*}{\partial p_T} > 0$ denotes the slope of excess supply function of domestic tourism service. Solving the above equation, we obtain

$$\frac{dp_T}{dZ} = \frac{\frac{rE_u}{p_T}\left(\frac{p_T E_{Tu}}{E_u} - \frac{p_T}{r}\frac{\partial r}{\partial p_T}\right)}{\Delta^*}, \tag{51}$$

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

$$\frac{du}{dZ} = -\frac{D_T(R_{TZ} - E_{TZ}) + S_T(E_Z - r)}{\Delta^*}. \tag{52}$$

The stability condition requires $\Delta^* > 0$[10]. $p_T E_{Tu}/E_u = b \in (0, 1)$ is the marginal propensity of domestic residents to consume tourism service. Since the elasticity of permits price with respect to the tourism terms of trade $\frac{p_T}{r}\frac{\partial r}{\partial p_T}$ is greater than unity (see (45)), a stricter environmental regulation unambiguously improves the tourism terms of trade ($dp_T/dZ < 0$). The stricter environmental regulation improves welfare if and only if emission reduction decreases the excess supply of tourism service ($\frac{\partial}{\partial Z}(R_T - E_T - D_T) = R_{TZ} - E_{TZ} > 0$) and the marginal damage of pollution to domestic residents is greater than the marginal cost of pollution emission ($E_Z > r$).

Differentiating (48) and substituting (49), we obtain

$$E_u du = D_T dp_T - (E_Z - r)dZ. \tag{53}$$

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 each endogenous variable is given by

$$\frac{d\Theta}{dZ} = \frac{\partial\Theta}{\partial Z} + \frac{\partial\Theta}{\partial p_T}\frac{dp_T}{dZ} \tag{54}$$

or

$$\frac{Z}{\Theta}\frac{d\Theta}{dZ} = \frac{Z}{\Theta}\frac{\partial\Theta}{\partial Z} + \frac{p_T}{\Theta}\frac{\partial\Theta}{\partial p_T}\frac{Z}{p_T}\frac{dp_T}{dZ}, \tag{55}$$

where $\Theta = X, T, M, w_S, w_L, q, r$. 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.

Therefore, utilizing (42) and (55) for $\Theta = \Psi = X, M, q, w_S$, the total effect on each endogenous variable ($\Psi = X, M, q, w_S$) is written as

$$\frac{Z}{\Psi}\frac{d\Psi}{dZ} = \frac{p_T}{\Psi}\frac{\partial\Psi}{\partial p_T}\left(\theta_{ZT} + \frac{Z}{p_T}\frac{dp_T}{dZ}\right), \quad \Psi = X, M, q, w_S. \tag{56}$$

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

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

[10] Let $\Omega \equiv E_T + D_T - R_T$ be the domestic excess demand for tourism service. From (48) and (49), we obtain $dp_T/d\Omega = -E_u/\Delta$. Hence, the stability of tourism service market requires $\Delta > 0$.

If the indirect effect is sufficiently large, stricter environmental policy expands tourism sector.

From (55) for $\Theta = T$, the necessary and sufficient condition for stricter environmental regulation to decrease the output of tourism service ($\frac{dT}{dZ} > 0$) is

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

we have used (31), (42), and (43). It is straightforward to show that $A < -\theta_{ZT}$.

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

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

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

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

If $\partial w_S/\partial p_T > (<)0$ (i.e., $\sigma_X > (<)1/[\xi_X + \mu_X(1-\xi_X)] = 1/(\mu_T\xi_X + \mu_X)$), the necessary and sufficient condition for stricter environmental policy to decrease the wage of unskilled labor is

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

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

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

From (55) for $\Theta = w_L$, the necessary and sufficient condition for stricter environmental regulation to decrease the wage of unskilled labor is

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

where we have used $\widehat{w}_L/\widehat{p}_T = \widehat{r}/\widehat{p}_T$, (39), (42), and (45). It is straightforward to show that $\sigma_T \gtreqless 1 \leftrightarrow B \gtreqless -\theta_{ZT}$.

From (54) for $\Theta = r$, the total effect of stricter environmental regulation on the price of emission permits is unambiguously positive:

$$
\frac{dr}{dZ} = \underset{(-)}{\frac{\partial r}{\partial Z}} + \underset{(+)}{\frac{\partial r}{\partial p_T}}\underset{(-)}{\frac{dp_T}{dZ}} < 0.
$$

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

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

since the numerator is

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

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

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

Table 3: $\sigma_T > 1$ and $\sigma_X < 1/(\mu_T\xi_X + \mu_X)$

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

Table 4: $\sigma_T > 1$ and $\sigma_X > 1/(\mu_T\xi_X + \mu_X)$

Proposition 3 *Assume $\sigma_T \geq 1/(2-\xi_T)$. When $\frac{Z}{p_T}\frac{dp_T}{dZ} < A$, a stricter environmental regulation expands the tourism and public infrastructure sectors while it contracts the manufacturing sector. The wage of unskilled labor and the rental rate of capital rise. If $\frac{Z}{p_T}\frac{dp_T}{dZ} > \max(B, -\theta_{ZT})$, all the above results are reversed.*

Focusing on the total effect on the domestic wage inequality, we have the following proposition.

Proposition 4 *When $\sigma_X < 1/(\mu_T\xi_X + \mu_X)$, a stricter environmental policy narrows or widens wage inequality for a large tourism terms of trade effect. That is, the stricter environmental regulation narrows (resp. widens) domestic wage inequality for $\frac{Z}{p_T}\frac{dp_T}{dZ} \leq \min(B, -\theta_{ZT})$ (resp. $\frac{Z}{p_T}\frac{dp_T}{dZ} \geq \max(B, -\theta_{ZT})$). When $\sigma_X > 1/(\mu_T\xi_X + \mu_X)$, the stricter environmental policy narrows or widens wage inequality for a moderate tourism terms of trade effect (between B and $-\theta_{ZT}$). That is, the stricter environmental regulation narrows (resp. widens) domestic wage inequality for $\sigma_T > 1$ (resp. $1/(2-\xi_T) \leq \sigma_T < 1$).*

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

Table 5: $1/(2-\xi_T) \leq \sigma_T < 1$ and $\sigma_X < 1/(\mu_T\xi_X + \mu_X)$

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

Table 6: $1/(2-\xi_T) \leq \sigma_T < 1$ and $\sigma_X > 1/(\mu_T\xi_X + \mu_X)$

When $\sigma_X < 1/(\mu_T\xi_X + \mu_X)$ (i.e., $\partial w_S/\partial p_T < 0$), indirect effect working through the change in tourism terms of trade goes 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 $\sigma_X > 1/(\mu_T\xi_X + \mu_X)$ (i.e., $\partial w_S/\partial p_T > 0$), the indirect effect goes 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 Tables 4 and 6). If $\sigma_T > 1$, stricter environmental regulation narrows domestic wage inequality. While if $1/(2-\xi_T) \leq \sigma_T < 1$, stricter environmental policy leads to widening domestic wage inequality.

5 Conclusions

We have developed a polluted small open economy model with tourism and public infrastructure which includes congestion effect. Pollution is emitted by the tourism sector. By reducing the amount of pollution, a stricter environmental regulation expands the tourism sector if the tourism terms-of-trade is sufficiently 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, pollution is treated as an input and the environmental regulation decreases the amount of pollution permits. One can consider the effect of pollution tax rate as in Yanase (2017). Alternatively, pollution may be emitted as a by-product as in Beladi et al. (2009) and Chao et al. (2008).

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