Tourism infrastructure and the environment: How does environmental regulation affect welfare, tourism industry, and domestic wage inequality?

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Abstract

This paper presents a general equilibrium model of small open developing economy with pollution generated by the tourism industry. The national government issues emission permits and constructs tourism infrastructure for the tourism sector. We examine the effects of stricter environmental regulation on welfare, production, and income distribution. If the elasticity of substitution in the tourism sector is sufficiently small, a stricter environmental regulation paradoxically expands the tourism sector and narrows domestic wage inequality even under constant tourism terms of trade. The tourism infrastructure enhances the possibility of welfare-improving environmental regulation under some conditions.
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Date sharing statement

The data that support the findings of current study are available in the website of Japan Fair Trade Commission. See Japan Fair Trade Commission (2016).

1. Introduction

For both developed and developing countries, tourism industry has become important since it creates employment opportunity and attracts foreign currency. The tourism industry requires a large amount of investment, for example, water supply, sewerage system, port, airport, park, highway, and tourism promotion by authorities (e.g., Visit Japan, Incredible India, and Malaysia Truly Asia) which is rather difficult to be financed by only private sector. Therefore, a national government needs to construct public infrastructure for the tourism industry, which we call hereafter tourism infrastructure. At the same time, tourism industry causes environmental damages. 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, the government introduces environmental regulation by issuing emission permits and controlling the amount of pollution. The government can use the revenue from selling pollution permits to construct tourism infrastructure. In general, by reducing emission permits, a stricter environmental regulation tends to discourage tourism sector, while formation of tourism infrastructure encourages the sector. The stricter environmental regulation directly improves welfare by reducing the disutility from pollution and at the same time, the price of tourism service affects consumption pattern and income level. Thus it is important to consider the welfare effect of stricter environmental regulation.

According to ILO (2018, pp. 16-17), the extent of wage inequality, measured by the Gini coefficient, is higher in low- and middle-income countries than in high-income countries. Therefore, rising wage inequality is a serious problem for many developing countries.[1] It is important for developing countries to find out the policy that mitigates domestic wage inequality.

There are many theoretical studies on the analysis of international tourism. A seminal contribution is made by Copeland (1991). Although he analyzes the effect of tourism boom (an increase in demand for tourism service by foreign tourists) on the tourism terms of trade (the price of tourism service which is exported through international tourism) and welfare, he does not consider the environmental pollution problem. In recent years, there are many studies of tourism and the environment, which include Beladi et al. (2009), Chao et al. (2008), Chao et al. (2012), Gupta and Dutta (2018), Nakai et al. (2018), Yabuuchi (2013, 2015, 2018), and Yanase (2017). Beladi et al. (2009) construct a two-good (one traded good and one tourism service) model where pollution is emitted as a by-product of the tourism service and derive the optimal pollution tax rate that maximizes the social welfare. They find that the optimal pollution tax rate does not coincide with the Pigouvian level, that is, the marginal environmental damage to domestic residents.[2] Chao et al. (2008) consider a three-good (two traded goods and one tourism service) model where pollution is generated by a manufacturing industry and derive the combination of optimal pollution tax and import tariff. They find that the optimal import tariff rate is positive. By constructing a three-good model where tourism industry requires pollution emission as an input, Yanase (2017) shows that if the excess supply of tourism service rises with pollution tax, the optimal pollution tax level is smaller than the Pigouvian level. By constructing a two good model where manufacturing industry is under perfect competition while tourism industry is under oligopoly and both tourism and manufacturing industries require pollution permits as an input, Chao et al. (2012) find that if factor cost share of emission permits in the tourism industry is smaller than in the manufacturing industry, stricter environmental regulation narrows wage inequality. They also show that if stricter environmental regulation improves tourism terms of trade greatly, then domestic welfare improves. In a two-good model where both tourism and manufacturing industries are under perfect competition, Nakai et al. (2018) shows that an improvement in tourism terms of trade narrows domestic wage inequality.

In a three-good Harris-Todaro model where agriculture and tourism industries are located in the rural area and manufacturing industry is located in the urban area, Yabuuchi (2013) finds that a tourism boom (pollution tax) reduces (increases) the urban unemployment rate, which positively (negatively) affects the domestic welfare[3]. By considering negative production externality from tourism industry to agriculture, Yabuuchi (2015) shows that a tourism boom (pollution tax) increases (decreases) urban unemployment rate. On the other hand, Yabuuchi (2018) introduces a subsidy to agriculture financed by pollution tax, and shows that a tourism boom can reduce the urban unemployment rate if the subsidy rate is sufficiently large relative to the negative externality from tourism industry.

In a dynamic model of tourism and the environment, Gupta and Dutta (2018) shows that the tourism boom expands tourism sector in the short run while contracts the sector in the long run. Meanwhile, the role of infrastructure on tourism industry is analyzed by Yanase (2015) in a dynamic setting. He shows that if the economy specializes in the production of tourism service, a tourism boom improves the tourism terms of trade and makes the economy better off. However, he does not take into account the environmental problem.

In summary, there is no study that examines the effects of environmental policy on domestic welfare and wage gap in the presence of tourism infrastructure. Then the research question in this paper is: Does the stricter environmental regulation improve domestic welfare or narrow domestic wage inequality in an economy with tourism infrastructure?

To answer the above question, we present a polluted small open developing economy model with infrastructure in tourism sector and examines the effects of environmental regulation on output, income distribution, and welfare. In this paper pollution is an input to tourism service.[4] If the elasticity of substitution in tourism sector is sufficiently small, a stricter environmental regulation paradoxically expands the tourism industry. In that case domestic wage inequality narrows as the result of stricter environmental regulation.

In this paper we analyzes a two-final goods model with tourism infrastructure that improves the productivity of tourism sector. To finance the cost of infrastructure, Lindahl pricing mechanism (the price of public intermediate good is equal to its marginal value product) is traditionally adopted (see Okamoto (1985)). However, this paper does not assume Lindahl pricing mechanism. Thus neither tangency property with respect to the production possibility curve, envelope theorem with respect to the revenue function, nor the reciprocity relations (the Stolper-Samuelson effect is equal to the Rybczynski effect) hold.[5] Because of this, we obtain an interesting result that a stricter environmental regulation may expand tourism industry. This result did not appear in the previous literature on tourism and the environment.

The remainder of this paper is organized as follows. In section 2, we set up the model. Section 3 conducts the comparative statics analysis of supply side of the economy. In section 4 we examine the effects of stricter environmental regulation by taking into account both supply and demand sides of the economy. Concluding remarks are made in section 5.

2. The model

Consider a small open developing economy that produces a manufacturing good X and a service T. The manufacturing good is traded while the service is non-traded in the absence of foreign tourists. The service is exported through international tourism and thus manufacturing good is imported. We call service T as tourism service and its price as the tourism terms of trade. Suppose that production of manufacturing good requires capital K and skilled labor S while production of tourism service requires unskilled labor L and pollution emission Z. The domestic government collects revenue from selling emission permits. The government uses this revenue to construct tourism infrastructure. For simplicity, suppose that tourism infrastructure requires only capital input,[6] and further assume that formation of tourism infrastructure enhances only the productivity of tourism industry.[7] Therefore, the cost of tourism infrastructure is financed by the user-pay principle. That is, firms in the tourism industry, the beneficiaries of tourism infrastructure, bear the cost of it through the payment for pollution permits.

The production function for the manufacturing good (or traded good) X is given by

$$X = X(K_X, S),$$

where K_j denotes capital input in good j and S the endowment of skilled labor. The function X is assumed to be the neo-classical type of production function that exhibits homogeneous of degree one and quasi-concave.

The production function for tourism service is given by

$$T = g(M)N(L, Z).$$

The function N has the same properties as the function X, i.e., the neo-classical properties. On the other hand, the function g represents the positive externality of the infrastructure, M the amount of tourism infrastructure devoted to only tourism industry, L the endowment of unskilled labor, and Z the amount of pollution. Keeping M unchanged and doubling L and Z, the output of tourism service T becomes twice. This implies that tourism infrastructure has no congestion effect. That is, tourism infrastructure in this paper is the creation of atmosphere type in Meade's (1952) terminology. We assume g is twice continuously differentiable and has the following properties:

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

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

The production function of tourism infrastructure is

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

where a_{ij} is the amount of factor $i(= L, S, K, Z)$ to produce one unit of good $j(= X, T, M)$. We assume linear production function for tourism infrastructure, and thus a_{KM} is constant.

We now turn to examine the equilibrium conditions for the supply side of the economy. Assume that perfect competition prevails in manufacturing and tourism industries. The zero profit condition (the price of the good is equal to its marginal cost) for traded good industry is

$$a_{SX} w_S + a_{KX} q = p_X, \tag{1}$$

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.

The zero profit condition for tourism service industry is

$$a_{LT} w_L + a_{ZT} r = p_T, \tag{2}$$

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 sector is[8]

$$a_{KM} q = p_M, \tag{3}$$

where p_M is the (shadow) price of tourism infrastructure.

Next we consider factor market equilibrium conditions. Factor endowments are exogenously given. The full employment condition of capital is

$$a_{KX}X + a_{KM}M = K. \tag{4}$$

The demand-supply equality of skilled labor requires

$$a_{SX}X = S. \tag{5}$$

The market equilibrium condition of unskilled labor requires

$$a_{LT}T = L. \tag{6}$$

The amount of pollution is given by

$$a_{ZT}T = Z. \tag{7}$$

Finally, the budget constraint of the government is

$$rZ = p_M M, \tag{8}$$

where the LHS (left-hand side) denotes the revenue from selling emission permits and the RHS (right-hand side) the cost of constructing tourism infrastructure. Equations (1) - (8) include 8 unknowns: X, T, w_L, w_S, q, r, p_M, and M. Given p_T, the above 8 equations determine 8 unknowns.[9] Note that the price of tourism infrastructure p_M is determined to satisfy the budget constraint of the government (8). It follows that traditional Lindahl pricing does not necessary hold and thus we will obtain different properties from the standard trade theory.

To facilitate the following analysis, we introduce the elasticity of factor substitution. The elasticity of substitution in each sector σ_j is defined as

$$\sigma_X = \frac{\hat{a}_{KX} - \hat{a}_{SX}}{\hat{w}_S - \hat{q}}, \tag{9}$$

$$\sigma_T = \frac{\hat{a}_{ZT} - \hat{a}_{LT}}{\hat{w}_L - \hat{r}}. \tag{10}$$

A hat over a variable implies the rate of change: e.g., $\hat{w}_S \equiv dw_S/w_S$.

The cost minimization in each industry requires[10]

$$\theta_{SX}\hat{a}_{SX} + \theta_{KX}\hat{a}_{KX} = 0, \tag{11}$$

$$\theta_{LT}\hat{a}_{LT} + \theta_{ZT}\hat{a}_{ZT} = -\hat{g}, \quad (12)$$

where θ_{ij} represents the cost share of factor i in sector j.

Solving equations (9) and (11), we obtain

$$\hat{a}_{SX} = -\theta_{KX}\sigma_X(\widehat{w}_S - \hat{q}), \quad (13)$$

$$\hat{a}_{KX} = \theta_{SX}\sigma_X(\widehat{w}_S - \hat{q}). \quad (14)$$

Similarly, solving equations (10) and (12), we have

$$\hat{a}_{LT} = -\theta_{ZT}\sigma_T(\widehat{w}_L - \hat{r}) - \hat{g}, \quad (15)$$

$$\hat{a}_{ZT} = \theta_{LT}\sigma_T(\widehat{w}_L - \hat{r}) - \hat{g}. \quad (16)$$

Differentiating equation (1) totally and taking into account equation (11), we obtain

$$\theta_{SX}\widehat{w}_S + \theta_{KX}\hat{q} = \hat{p}_X. \quad (17)$$

Differentiating equation (2) totally and considering equation (12), we obtain

$$\theta_{LT}\widehat{w}_L + \theta_{ZT}\hat{r} - \xi\widehat{M} = \hat{p}_T, \quad (18)$$

where $\xi \equiv \frac{g'M}{g} > 0$ denotes the elasticity of g with respect to M, or the productivity improvement rate of tourism industry by additional tourism infrastructure. By definition, $\hat{g} = \xi\widehat{M}$ holds.

Since a_{KM} is constant, equation (3) implies

$$\hat{p}_M = \hat{q}. \quad (19)$$

Differentiating equation (4) and substituting equation (14), we obtain

$$\lambda_{KX}\hat{X} + \lambda_{KX}\theta_{SX}\sigma_X(\widehat{w}_S - \hat{q}) + \lambda_{KM}\widehat{M} = \widehat{K}, \quad (20)$$

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

Differentiating equation (5) and substituting equation (13), we obtain

$$-\theta_{KX}\sigma_X(\widehat{w}_S - \hat{q}) + \hat{X} = \hat{S}. \quad (21)$$

Differentiating equation (6) and using equation (15), we have

$$-\theta_{ZT}\sigma_T(\widehat{w}_L - \hat{r}) - \xi\widehat{M} + \hat{T} = \hat{L}. \quad (22)$$

Differentiating equation (7) and substituting equation (16), we obtain

$$\theta_{LT}\sigma_T(\widehat{w}_L - \hat{r}) - \xi\widehat{M} + \hat{T} = \hat{Z}. \quad (23)$$

Differentiating equation (8) and considering equation (19), we obtain

$$\hat{q} + \widehat{M} - \hat{r} = \hat{Z}. \quad (24)$$

Equations (17), (18), (20) - (24) are expressed in the matrix form as

$$\begin{pmatrix} 0 & 0 & 0 & \theta_{SX} & 0 & \theta_{KX} & 0 \\ 0 & 0 & -\xi & 0 & \theta_{LT} & 0 & \theta_{ZT} \\ \lambda_{KX} & 0 & \lambda_{KM} & \lambda_{KX}\theta_{SX}\sigma_X & 0 & -\lambda_{KX}\theta_{SX}\sigma_X & 0 \\ 1 & 0 & 0 & -\theta_{KX}\sigma_X & 0 & \theta_{KX}\sigma_X & 0 \\ 0 & 1 & -\xi & 0 & -\theta_{ZT}\sigma_T & 0 & \theta_{ZT}\sigma_T \\ 0 & 1 & -\xi & 0 & \theta_{LT}\sigma_T & 0 & -\theta_{LT}\sigma_T \\ 0 & 0 & 1 & 0 & 0 & 1 & -1 \end{pmatrix} \begin{pmatrix} \hat{X} \\ \hat{T} \\ \hat{M} \\ \hat{w}_S \\ \hat{w}_L \\ \hat{q} \\ \hat{r} \end{pmatrix} = \begin{pmatrix} \hat{p}_X \\ \hat{p}_T \\ \hat{K} \\ \hat{S} \\ \hat{L} \\ \hat{Z} \\ \hat{Z} \end{pmatrix}, \tag{25}$$

which is the system of the equations describing the supply side of the economy.

3. Comparative statics: supply side analysis

The supply side of the economy (equations (1) - (8)) determines outputs and factor prices (and therefore factor demands). In this section, utilizing equation (25), we examine the effects of a stricter environmental regulation and an improvement in tourism terms of trade on outputs and factor prices.

Environmental regulation

In this section, we consider the effects of a stricter environmental regulation. A stricter environmental regulation means a reduction in emission permits ($dZ < 0$).

From equation (17), we have

$$\hat{q} = -\frac{\theta_{SX}}{\theta_{KX}}\hat{w}_S. \tag{26}$$

Since p_X is unchanged, an increase in the skilled wage is balanced by a decrease in the rental rate of capital. Equation (26) implies $\hat{w}_S - \hat{q} = \hat{w}_S/\theta_{KX}$. From equation (21), we have

$$\hat{X} = \theta_{KX}\sigma_X(\hat{w}_S - \hat{q}) = \sigma_X\hat{w}_S. \tag{27}$$

That is, an increase in the output of traded good X pushes up the wage of unskilled labor which is a specific input to that industry.

Substituting equations (26) and (27) into equation (20), we obtain

$$\widehat{M} = -\frac{\lambda_{KX}\sigma_X}{\lambda_{KM}\theta_{KX}}\widehat{w}_S = -\frac{\lambda_{KX}}{\lambda_{KM}\theta_{KX}}\widehat{X}, \tag{28}$$

which states that an increase in the output of traded good reduces the output of tourism infrastructure by extracting capital input from that industry. Equations (26)-(28) show that $\hat{q}$, $\widehat{X}$, and $\widehat{M}$ are proportional to $\widehat{w}_S$.

From equations (22) and (23), we have

$$\widehat{w}_L - \hat{r} = \frac{\hat{Z}}{\sigma_T}, \tag{29}$$

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

Solving equation (25), we obtain (see Appendix A)

$$\frac{\widehat{T}}{\hat{Z}} = \frac{\sigma_T[(\theta_{ZT} + \xi\theta_{LT})\lambda_{KX}\sigma_X + \theta_{SX}\theta_{ZT}\lambda_{KM}] - \xi\theta_{LT}\lambda_{KX}\sigma_X}{\Delta}, \tag{30}$$

$$\frac{\widehat{w}_S}{\hat{Z}} = \frac{\theta_{KX}\lambda_{KM}(\theta_{LT} - \sigma_T)}{\Delta}, \tag{31}$$

$$\frac{\widehat{w}_L}{\hat{Z}} = \frac{\lambda_{KX}\sigma_X[\theta_{ZT} + \xi(\sigma_T - 1)] + \lambda_{KM}\theta_{SX}\theta_{ZT}}{\Delta}, \tag{32}$$

$$\begin{aligned}\frac{\hat{r}}{\hat{Z}} &= \frac{\xi\sigma_T\lambda_{KX}\sigma_X - \theta_{LT}\lambda_{KM}\theta_{SX} - \lambda_{KX}\sigma_X\theta_{LT}}{\Delta} \\ &= \frac{\lambda_{KX}\sigma_X(\xi\sigma_T - \theta_{LT}) - \theta_{LT}\lambda_{KM}\theta_{SX}}{\Delta},\end{aligned} \tag{33}$$

where $\Delta \equiv \sigma_T[\lambda_{KX}\sigma_X(1-\xi) + \lambda_{KM}\theta_{SX}] > 0.$[11]

The qualitative effects of a reduction in emission are ambiguous and depend on the elasticity of substitution in the tourism sector σ_T. From equation (30), a reduction of emission decreases the production of tourism service if and only if

$$\sigma_T > \frac{\xi\lambda_{KX}\sigma_X\theta_{LT}}{\lambda_{KX}\sigma_X\theta_{ZT} + \xi\lambda_{KX}\sigma_X\theta_{LT} + \lambda_{KM}\theta_{SX}\theta_{ZT}} \equiv A.$$

We can immediately show that $A < \theta_{LT}$.

From equation (32), the necessary and sufficient condition for a reduction in emission to decrease the wage of unskilled labor is

$$\sigma_T > 1 - \frac{\theta_{ZT}}{\xi} - \frac{\lambda_{KM}\theta_{SX}\theta_{ZT}}{\lambda_{KX}\sigma_X\xi} \equiv B.$$

Using equation (33), a reduction in emission decreases the price of emission permits if and only if

$$\sigma_T > \frac{\theta_{LT}}{\xi} + \frac{\lambda_{KM}\theta_{SX}\theta_{LT}}{\lambda_{KX}\sigma_X\xi} \equiv C.$$

Since $\xi < 1$, $C > \theta_{LT}$ holds.

It is straightforward to show that $A > B$ since

$$A - B = \frac{\xi\theta_{LT}}{\theta_{ZT} + \xi\theta_{LT} + m} - 1 + \frac{\theta_{ZT}}{\xi} + \frac{m}{\xi} = \frac{(\theta_{ZT} + m)[(1-\xi)\theta_{ZT} + m]}{\xi(\theta_{ZT} + \xi\theta_{LT} + m)} > 0,$$

where $m \equiv \frac{\lambda_{KM}\theta_{SX}\theta_{ZT}}{\lambda_{KX}\sigma_X} > 0$.

Therefore we have the following magnitude relationships:

$$B < A < \theta_{LT} < C.$$

The above results are summarized by Table 1 which shows how σ_T changes qualitative effects of a reduction in Z.

σ_T	---	B	---	A	---	θ_{LT}	---	C	---
$\hat{X}$	$-$	$-$	$-$	$-$	$-$	0	$+$	$+$	$+$
$\hat{T}$	$+$	$+$	$+$	0	$-$	$-$	$-$	$-$	$-$
$\hat{M}$	$+$	$+$	$+$	$+$	$+$	0	$-$	$-$	$-$
$\hat{w}_S$	$-$	$-$	$-$	$-$	$-$	0	$+$	$+$	$+$
$\hat{w}_L$	$+$	0	$-$	$-$	$-$	$-$	$-$	$-$	$-$
$\hat{q}$	$+$	$+$	$+$	$+$	$+$	0	$-$	$-$	$-$
$\hat{r}$	$+$	$+$	$+$	$+$	$+$	$+$	$+$	0	$-$

Table 1. The effects of a reduction in Z

An intuition for the above results are as follows. When the elasticity of substitution in tourism sector σ_T is sufficiently small, a decrease in emission permits Z raises its price r largely since pollution is hardly substituted by unskilled labor. Therefore, the revenue from selling emission permits rZ and the output of tourism infrastructure M go up (see equation (8)).[12] If an increase in M is large, the output of tourism industry T rises despite the reduction in emission permits Z. Consequently, the wage of unskilled labor, which is a specific factor to tourism sector, goes up. At the same time, capital flows from manufacturing industry, leading to a decrease in output of manufacturing good X. The decrease in output of manufacturing good pushes down the wage of skilled labor, which is a specific factor to that industry. Since the price of manufacturing good is constant, the decrease in the wage of skilled labor is balanced by the increase in the rental rate of capital.

When σ_T is sufficiently large, the stricter environmental regulation decreases permits price r since the demand for emission permits is largely substituted by unskilled labor. Thus the revenue from emission permits and the output of tourism infrastructure decrease. It follows that the output of tourism service falls due to decrease in both emission permits and positive externality from tourism infrastructure. Additionally, the wage of unskilled labor decreases despite the initial increase in demand. Meanwhile, the capital flows from tourism infrastructure sector to manufacturing sector, leading to an increase in output of manufacturing sector. The increased output of manufacturing good pushes up the wage of skilled labor due to increase in demand.

Thus, we have the following proposition.

Proposition 1: *Suppose that the tourism terms of trade* p_T *is constant. When the elasticity of substitution in tourism sector is sufficiently small, stricter environmental regulation expands tourism sector and tourism infrastructure sector while it contracts manufacturing sector. It narrows the wage inequality between skilled and unskilled labor. The rental rate of capital and the price of emission permits rise. As the elasticity of substitution in tourism sector becomes larger, all the above results are reversed.*

The effects on the output of tourism service and the unskilled wage rate depend also on the positive externality from tourism infrastructure ξ. When $\sigma_T < \theta_{LT}$, stricter environmental regulation raises the output of tourism infrastructure M. If ξ is sufficiently large, the output of tourism service increases greatly and the wage of unskilled labor rises. That is, the larger ξ, the higher the possibility of the increase in the output of tourism service and the unskilled wage rate. When $\sigma_T > \theta_{LT}$, both the output of tourism service and the unskilled wage rate unambiguously decrease since $B < A < \theta_{LT} < \sigma_T$. In this case, the output of tourism service falls due to decrease in both pollution permits and positive externality from tourism infrastructure.

Similarly, the effect on the price of emission permits depends on ξ. When $\sigma_T > \theta_{LT}$, the output of tourism infrastructure is decreased by the stricter environmental regulation. If ξ is sufficiently large, the drop in the output of tourism service becomes large. Then the price of emission permits decreases since a decline in demand for emission permits outweighs the decrease in supply. When $\sigma_T < \theta_{LT}$, the output of tourism infrastructure increases, and the price of emission permits unambiguously rises since $\sigma_T < \theta_{LT} < C$. That is, the decrease in supply of emission permits pushes up the price of emission permits even when the output of tourism service falls.

In particular, the case of $\hat{T}/\hat{Z} < 0$ (stricter environmental regulation increases the output of tourism service) is paradoxical in the usual sense because pollution emission is a specific input to tourism industry and we try to explain this result graphically. For this purpose, we introduce the production possibility curve, or the transformation curve. The properties of the production possibility curve in our model are proved in the Appendix B and summarized in the following proposition.

Proposition 2: *The production possibility curve in our model is flatter (steeper) than the price line if and only if the marginal value product of tourism infrastructure is larger (smaller) than its price. The curve is strictly concave to the origin.*

Since we do not assume Lindahl pricing rule (i.e., the price of infrastructure equals its marginal value product), tangency property with respect to the production possibility curve does not hold. From equation (8), we obtain $p_T \frac{\partial T}{\partial M} - p_M = p_M \left(\frac{\xi}{\theta_{ZT}} - 1 \right)$. It follows that Lindahl pricing requires $\xi = \theta_{ZT}$ and otherwise the marginal value product of tourism infrastructure is larger (smaller) than its price if and only if $\xi > (<) \theta_{ZT}$. In what follows, we focus on the case of $\xi > \theta_{ZT}$ since otherwise the national government has no incentive to construct tourism infrastructure. The initial production possibility curve is depicted by the curve ABC. When Z is decreased, the curve shifts inward to AB'C'. At the same time, the price line shifts upward if the elasticity of substitution in the tourism sector is sufficiently small: otherwise it shifts downward.[13] Accordingly, the production point moves from point B to B', leading to a decrease in X and increase in T. Figure 1 (2) corresponds to the case where stricter environmental regulation decreases (increases) total revenue.

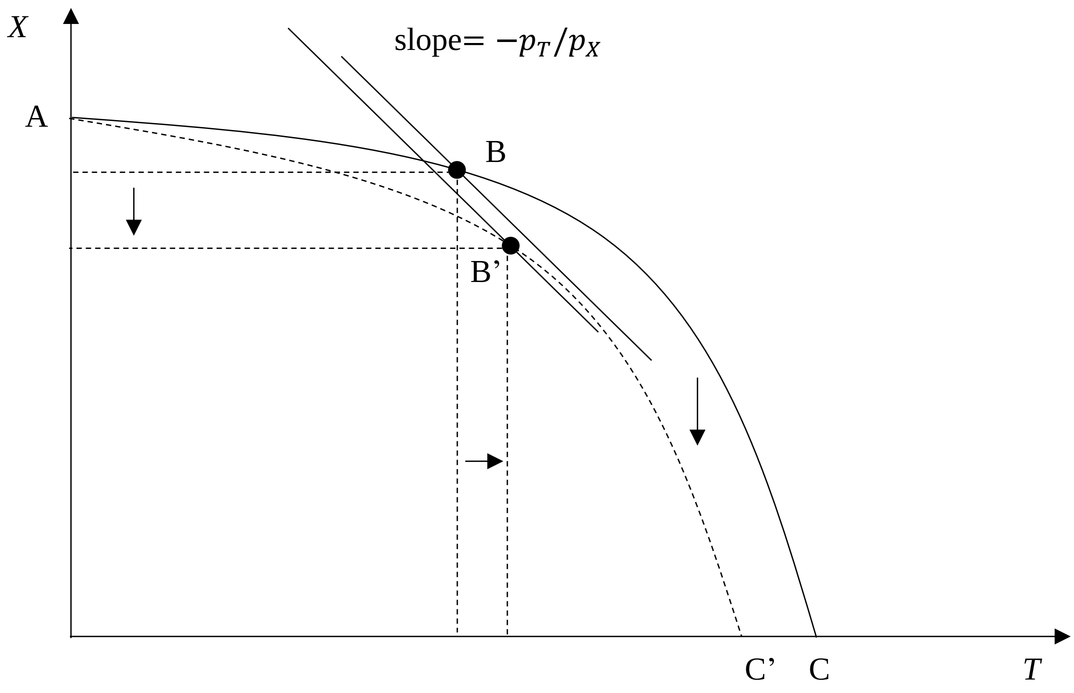

Figure 1. The case where stricter environmental regulation decreases total revenue

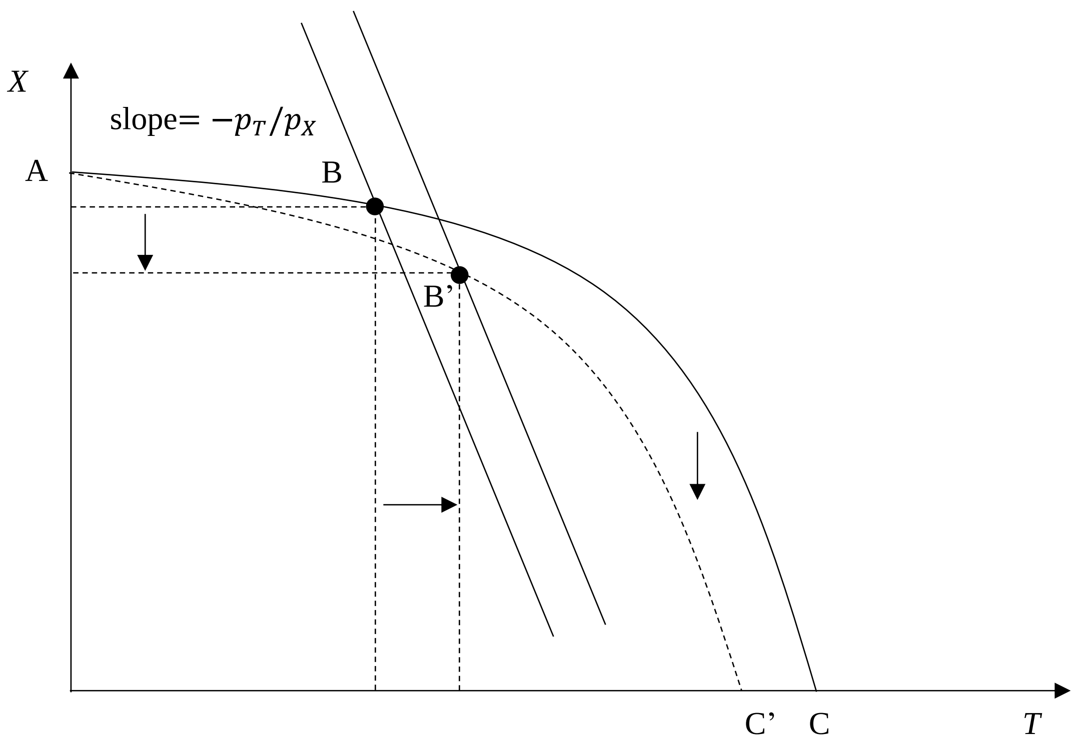

Figure 2. The case where stricter environmental regulation increases total revenue

Improvement in the tourism terms of trade

In this section, we investigate the effects of an improvement in the tourism terms of trade p_T. Note that equations (26), (27), and (28) still hold. Substituting equations (26) and (28) into equation (24), we have

$$\frac{\hat{r}}{\hat{p}_T} = \frac{\hat{q}}{\hat{p}_T} + \frac{\widehat{M}}{\hat{p}_T} = -\frac{\lambda_{KM}\theta_{SX} + \lambda_{KX}\sigma_X}{\lambda_{KM}\theta_{KX}}\frac{\widehat{w}_S}{\hat{p}_T}.$$

Meanwhile, equation (29) implies $\widehat{w}_L/\hat{p}_T = \hat{r}/\hat{p}_T$.

Substituting equation (28) into equation (22) and considering $\widehat{w}_L/\hat{p}_T - \hat{r}/\hat{p}_T = 0$ from equation (29), we have

$$\frac{\widehat{T}}{\hat{p}_T} = \xi\frac{\widehat{M}}{\hat{p}_T} = -\xi\frac{\lambda_{KX}\sigma_X}{\lambda_{KM}\theta_{KX}}\frac{\widehat{w}_S}{\hat{p}_T}. \tag{34}$$

Solving equation (25), we obtain (see Appendix A)

$$\frac{\widehat{w}_S}{\hat{p}_T} = -\frac{\theta_{KX}\lambda_{KM}\sigma_T}{\Delta} < 0. \tag{35}$$

The effects of tourism terms of trade on the price of emission permits and the wage of unskilled labor have magnification effects ($\hat{r}/\hat{p}_T = \widehat{w}_L/\hat{p}_T > 1$). This result is different from that of Nakai et al. (2018) where pollution is a general input to both manufacturing and tourism industries while the unskilled labor is a specific input to tourism sector. In Nakai et al. (2018), tourism terms of trade has magnification effect on the wage of unskilled labor, but does not have on the price of emission permits.

Since we do not assume Lindahl pricing, traditional reciprocity relationship (i.e., $\partial T/\partial Z = \partial r/\partial p_T$) does not necessarily hold. Therefore, we have obtained an interesting result that stricter environmental regulation may expand tourism sector.

The effects of an increase in p_T are summarized in Table 2 and proposition 3.

	$\hat{X}$	$\hat{T}$	$\widehat{M}$	$\widehat{w}_S$	$\widehat{w}_L$	$\hat{q}$	$\hat{r}$
$p_T \uparrow$	$-$	$+$	$+$	$-$	$+$	$+$	$+$

Table 2. The effects of an increase in p_T

Proposition 3: *An improvement in the tourism terms of trade expands tourism sector and tourism infrastructure sector while it contracts manufacturing sector. It narrows the wage inequality between skilled and unskilled labor. The rental rate of capital and the price of emission permits rise.*

An intuition is straightforward. The improvement in tourism terms of trade expands the tourism sector and thus the wage of unskilled labor and the price of emission permits rise. The revenue from selling pollution permits rZ and the output of tourism infrastructure increase at the sacrifice of manufacturing sector, leading to a decrease in the wage of skilled labor. Since the price of manufacturing good is unchanged, the rental rate of capital rises (see equation (17)).

4. Total effect of environmental regulation

Effects on welfare and tourism terms of trade

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, that is, supply of and demand for it. In this section, we consider the effects of stricter environmental regulation, taking into account that p_T is not constant.

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, domestic tourism service, and foreign 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[14]

$$E(p_T, Z, u) \equiv \min \left[p_X C_X + p_T C_T + p_T^* C_T^* | u = \ln C_X + Z^a \ln C_T + (Z^*)^b \ln C_T^* \right],$$

where C_X is the consumption of manufacturing good, C_T the consumption of domestic tourism service, C_T^* the consumption of foreign tourism service by domestic residents, p_T^* the (constant) price of foreign tourism service,[15] u the level of utility, and Z^* the amount of pollution in the foreign country. $a < 0$ and $b < 0$ are parameters. The utility function has the property that the marginal utility from tourism service decreases with the amount of pollution in the destination. For the marginal utility from pollution to be negative ($\frac{\partial u}{\partial Z} < 0$ and $\frac{\partial u}{\partial Z^*} < 0$), we assume $C_T > 1$ and $C_T^* > 1$. The expenditure function is derived as

$$E = [1 + Z^a + (Z^*)^b](e^u p_X)^{\frac{1}{1+Z^a+(Z^*)^b}} \left(\frac{p_T}{Z^a}\right)^{\frac{Z^a}{1+Z^a+(Z^*)^b}} \left[\frac{p_T^*}{(Z^*)^b}\right]^{\frac{(Z^*)^b}{1+Z^a+(Z^*)^b}}.$$

Applying the envelope theorem, we obtain the compensated demand for tourism service: $E_T \equiv \frac{\partial E}{\partial p_T} = C_T = \left\{(e^u p_X)\left(\frac{Z^a}{p_T}\right)^{1+(Z^*)^b} \left[\frac{p_T^*}{(Z^*)^b}\right]^{(Z^*)^b}\right\}^{\frac{1}{1+Z^a+(Z^*)^b}}$. The downward sloping demand function implies $E_{TT} \equiv \partial^2 E / \partial p_T^2 < 0$. $E_Z \equiv \frac{\partial E}{\partial Z} = -\frac{aZ^{a-1}E}{[1+Z^a+(Z^*)^b]^2} \ln\left\{(e^u p_X)\left(\frac{Z^a}{p_T}\right)^{1+(Z^*)^b} \left[\frac{p_T^*}{(Z^*)^b}\right]^{(Z^*)^b}\right\} > 0$ denotes the marginal damage for consumers caused by pollution. The effect of stricter environmental regulation on the compensated demand for tourism service is given by

$$\frac{\partial C_T}{\partial Z} = E_{TZ} \equiv \frac{\partial^2 E}{\partial Z \partial p_T}$$

$$= -\frac{aZ^{a-1}C_T}{[1 + Z^a + (Z^*)^b]^2} \ln\left\{(e^u p_X)\left(\frac{Z^a}{p_T}\right)^{1+(Z^*)^b} \left[\frac{p_T^*}{(Z^*)^b}\right]^{(Z^*)^b}\right\}$$

$$+ \frac{aZ^{a-1}C_T[1 + (Z^*)^b]}{[1 + Z^a + (Z^*)^b]Z^a}.$$

The first term indicates the effect that a decrease in pollution reduces the amount of compensated demand required to offset the disutility from pollution while the second term indicates the effect that the decrease in pollution raises the attractiveness of tourism service. If the second effect outweighs the first, stricter environmental regulation increases the compensated demand for tourism service.[16]

Foreign tourists also consume manufacturing good, domestic tourism service, and foreign tourism service. Their utility function is given by $u^* = \ln D_X + Z^\alpha \ln D_T + (Z^*)^\beta \ln D_T^*$, where D_X is the consumption of manufacturing good, D_T the consumption of domestic tourism service, and D_T^* the consumption of foreign tourism service by foreign tourists. $\alpha < 0$ and $\beta < 0$ are parameters. For the marginal utility from pollution to be negative, we assume $D_T > 1$ and $D_T^* > 1$. Foreign tourists' demand for the domestic tourism service is derived as $D_T = \frac{Z^{\alpha}}{1+Z^{\alpha}+(Z^*)^{\beta}} \frac{Y^*}{p_T}$, where Y^* is the budget of foreign tourists and is exogenously given. Note that $\frac{\partial D_T}{\partial Z} < 0$ because a decrease in pollution raises the attractiveness of tourism service.[17]

The supply side of the economy is characterized by the revenue function

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

Since Lindahl pricing rule is not assumed, the usual envelope theorem does not hold. The properties of the revenue function with positive externality from tourism infrastructure are given in the Appendix C.

Now we can derive the equilibrium conditions for both demand and supply sides of the economy. Firstly, the budget constraint of the economy is given by

$$E(p_T, Z, u) = R(p_T, Z), \tag{36}$$

which states that the total expenditure equals the total revenue.

Secondly, the market equilibrium condition of the tourism service is

$$E_T(p_T, Z, u) + D_T(p_T, Z) = T(p_T, Z). \tag{37}$$

Here the LHS denotes the demand for domestic tourism service while the RHS denotes its supply.

The above two equations simultaneously determine the tourism terms of trade p_T and the domestic welfare u. We analyze the effects of stricter environmental regulation on p_T and u. Totally differentiating equations (36) and (37), we obtain

$$\begin{pmatrix} -D_T - \Gamma \dfrac{\partial M}{\partial P_T} & E_u \\ -S_T & E_{Tu} \end{pmatrix} \begin{pmatrix} dp_T \\ du \end{pmatrix} = \begin{pmatrix} r + \Gamma \dfrac{\partial M}{\partial Z} - E_Z \\ \dfrac{\partial T}{\partial Z} - E_{TZ} - \dfrac{\partial D_T}{\partial Z} \end{pmatrix} dZ, \tag{38}$$

where $\Gamma \equiv p_T \frac{\partial T}{\partial M} - p_M$ is the difference between the marginal value product of tourism infrastructure and its shadow price, $S_T \equiv \partial T/\partial p_T - E_{TT} - \partial D_T/\partial p_T > 0$ represents the slope of the excess supply function of the tourism service, and subscripts with respect to the expenditure function denote partial derivatives: e.g., $E_{Tu} \equiv \partial^2 E/\partial u \partial p_T$. Note that $\partial T/\partial p_T > 0$ and $\partial M/\partial p_T > 0$ from the analysis of section 3. Let Δ^* be the determinant of the matrix on the LHS of equation (38). Then stability condition requires $\Delta^* > 0$.[18] Solving equation (38), we obtain

$$\begin{aligned}\frac{dp_T}{dZ} &= -\frac{E_{Tu}(E_Z - r - \Gamma \frac{\partial M}{\partial Z}) + E_u(\frac{\partial T}{\partial Z} - E_{TZ} - \frac{\partial D_T}{\partial Z})}{\Delta^*} \\ &= -\frac{E_{Tu}(E_Z - r) - E_{Tu}\Gamma \frac{\partial M}{\partial Z} + E_u(\frac{\partial T}{\partial Z} - E_{TZ} - \frac{\partial D_T}{\partial Z})}{\Delta^*},\end{aligned} \tag{39}$$

$$\begin{aligned}\frac{du}{dZ} &= -\frac{(D_T + \Gamma \frac{\partial M}{\partial P_T})(\frac{\partial T}{\partial Z} - E_{TZ} - \frac{\partial D_T}{\partial Z}) + S_T(E_Z - r - \Gamma \frac{\partial M}{\partial Z})}{\Delta^*} \\ &= -\frac{D_T(\frac{\partial T}{\partial Z} - E_{TZ} - \frac{\partial D_T}{\partial Z}) + \Gamma \frac{\partial M}{\partial P_T}(\frac{\partial T}{\partial Z} - E_{TZ} - \frac{\partial D_T}{\partial Z}) + S_T(E_Z - r) - S_T\Gamma \frac{\partial M}{\partial Z}}{\Delta^*}.\end{aligned} \tag{40}$$

An emission reduction affects the tourism terms of trade and domestic welfare through two conventional channels, as stated in Beladi et al. (2009) and Yanase (2017). On the one hand, if a pollution reduction decreases domestic excess supply of tourism service ($\frac{\partial}{\partial Z}(T - D_T - E_T) = \frac{\partial T}{\partial Z} - \frac{\partial D_T}{\partial Z} - E_{TZ} > 0$), then 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 larger 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 term of trade. In this paper, there exists an additional term ($-E_{Tu}\Gamma \frac{\partial M}{\partial Z}$). In the following explanation, we assume (i) $\Gamma > 0$ (the marginal value product of tourism infrastructure is larger than its price), (ii) $M_Z \equiv \partial M/\partial Z < 0$ (the output of tourism infrastructure is increased by stricter environmental regulation), and (iii) $\frac{\partial T}{\partial Z} - E_{TZ} - \frac{\partial D_T}{\partial Z} > 0$ (the excess supply of tourism service decreases with stricter environmental regulation). The effect of the additional term is explained as follows. A decrease in pollution raises tourism infrastructure, which in turn increases the total revenue and thus demand for tourism service.[19]

Next, we consider the effect on welfare. In addition to the aforementioned two conventional effects, there are two extra effects. First, a decrease in excess supply of tourism service raises tourism terms of trade, which in turn increases tourism infrastructure ($\partial M/\partial p_T > 0$). Thus the total revenue and welfare of domestic residents go up. This effect is captured by the term $\Gamma \frac{\partial M}{\partial P_T}(\frac{\partial T}{\partial Z} - E_{TZ} - \frac{\partial D_T}{\partial Z})$. Second, the increase in tourism infrastructure directly raises total revenue and welfare. This is captured by the term $(-S_T \Gamma \frac{\partial M}{\partial Z})$. If the conditions from (i) to (iii) are satisfied, both effects become positive and the possibility of welfare-improving environmental regulation is higher than that in the absence of tourism infrastructure.

Thus we can establish the following proposition.

Proposition 4: *If the conditions (i) the marginal value product of tourism infrastructure is larger than its price, (ii) the output of tourism infrastructure is increased by stricter environmental regulation, and (iii) the excess supply of tourism service decreases with stricter environmental regulation, are satisfied, the tourism infrastructure enhances the possibility of welfare-improving environmental regulation.*

The first condition is likely to hold when the marginal value product of tourism infrastructure is sufficiently large. The second condition holds if and only if the elasticity of substitution in tourism industry is sufficiently small to increase the revenue from selling pollution permits. The third condition tends to hold when the output of tourism service is decreased by stricter environmental regulation, which occurs if the elasticity of substitution in that sector is not so small. Therefore, the elasticity of substitution must be a moderately small value.

Effects on outputs and factor prices

The total effect (including the change in tourism terms of trade) of the environmental regulation on the wage of skilled labor is

$$\frac{dw_S}{dZ} = \frac{\partial w_S}{\partial Z} + \frac{\partial w_S}{\partial p_T}\frac{dp_T}{dZ}$$

or

$$\frac{Z}{w_S}\frac{dw_S}{dZ} = \frac{Z}{w_S}\frac{\partial w_S}{\partial Z} + \frac{p_T}{w_S}\frac{\partial w_S}{\partial p_T}\frac{Z}{p_T}\frac{dp_T}{dZ}. \tag{41}$$

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. Since the sign of the direct effect is ambiguous, we consider the necessary and sufficient conditions for the indirect effect to be dominant. The indirect effect is proportional to the change in tourism terms of trade, and thus the indirect effect dominates the direct effect if the tourism terms of trade effect $\left|\frac{Z}{p_T}\frac{dp_T}{dZ}\right|$ is sufficiently large.[20]

Using equation (41), the stricter environmental regulation decreases the wage of skilled labor if and only if

$$\frac{Z}{p_T}\frac{dp_T}{dZ} < \frac{\theta_{LT} - \sigma_T}{\sigma_T} \equiv D.$$

From equations (26), (27), and (28), the total effects on q, X, and M are proportional to those of w_S.

Similarly, a decrease in pollution reduces production of tourism service T if and only if

$$\frac{Z}{p_T}\frac{dp_T}{dZ} > -\frac{\theta_{ZT}(1-\xi) + m}{\xi} + D \equiv F.$$

The necessary and sufficient condition for a decrease in pollution to reduce the wage of unskilled labor w_L is

$$\frac{Z}{p_T}\frac{dp_T}{dZ} > -\frac{\theta_{ZT}\left(1 + \frac{m}{\theta_{ZT}}\right) + \xi(\sigma_T - 1)}{\left(1 + \frac{m}{\theta_{ZT}}\right)\sigma_T} \equiv G.$$

Finally, the amount of pollution and the price of emission permits r move to the same direction if and only if

$$\frac{Z}{p_T}\frac{dp_T}{dZ} > \frac{\theta_{LT}\left(1 + \frac{m}{\theta_{ZT}}\right) - \xi\sigma_T}{\left(1 + \frac{m}{\theta_{ZT}}\right)\sigma_T} \equiv H.$$

By the straightforward calculation, we have $H - D = \frac{1-\xi+m/\theta_{ZT}}{1+m/\theta_{ZT}} > 0$ and $H - G = \frac{1-\xi+m/\theta_{ZT}}{\sigma_T(1+m/\theta_{ZT})} > 0$. Then it is straightforward to show that $F < D < H$. It follows that there are three cases to be considered: (i) when $\sigma_T < \frac{\xi}{\theta_{ZT}+m+\xi}$, $G < F < D < H$, (ii) when $\frac{\xi}{\theta_{ZT}+m+\xi} < \sigma_T < 1$, $F < G < D < H$, and (iii) when $\sigma_T > 1$, $F < D < G < H$. These results are summarized in Tables 3 - 5.[21]

$\frac{Z}{p_T}\frac{dp_T}{dZ}$	---	G	---	F	---	D	---	H	---
dT/dZ	$-$	$-$	$-$	0	+	+	+	+	+
dw_S/dZ	+	+	+	+	+	0	$-$	$-$	$-$
dw_L/dZ	$-$	0	+	+	+	+	+	+	+
dr/dZ	$-$	$-$	$-$	$-$	$-$	$-$	$-$	0	+

Table 3. $\boldsymbol{\sigma_T < \frac{\xi}{\theta_{ZT}+m+\xi}}$

$\frac{Z}{p_T}\frac{dp_T}{dZ}$	---	F	---	G	---	D	---	H	---
dT/dZ	$-$	0	+	+	+	+	+	+	+
dw_S/dZ	+	+	+	+	+	0	$-$	$-$	$-$
dw_L/dZ	$-$	$-$	$-$	0	+	+	+	+	+
dr/dZ	$-$	$-$	$-$	$-$	$-$	$-$	$-$	0	+

Table 4. $\boldsymbol{\frac{\xi}{\theta_{ZT}+m+\xi} < \sigma_T < 1}$

$\frac{Z}{p_T}\frac{dp_T}{dZ}$	---	F	---	D	---	G	---	H	---
dT/dZ	$-$	0	$+$	$+$	$+$	$+$	$+$	$+$	$+$
dw_S/dZ	$+$	$+$	$+$	0	$-$	$-$	$-$	$-$	$-$
dw_L/dZ	$-$	$-$	$-$	$-$	$-$	0	$+$	$+$	$+$
dr/dZ	$-$	$-$	$-$	$-$	$-$	$-$	$-$	0	$+$

Table 5. $\boldsymbol{\sigma_T > 1}$

The above results are summarized by the following proposition.

Proposition 5: *When* $\frac{Z}{p_T}\frac{dp_T}{dZ} < \min(F, G)$, *stricter environmental regulation expands tourism sector and tourism infrastructure sector while it contracts manufacturing sector. It narrows wage inequality between skilled labor and unskilled labor. The rental rate of capital and the price of emission permits rise. If* $\frac{Z}{p_T}\frac{dp_T}{dZ} > H$, *all the above results are reversed.*

As a related issue, we have the following corollary.

Corollary 5: *When* $\frac{Z}{p_T}\frac{dp_T}{dZ} < min\,(F, G)$, *stricter environmental regulation yields a double dividend in reducing pollution and narrowing domestic wage inequality. While if* $\frac{Z}{p_T}\frac{dp_T}{dZ} > H$, *there is a trade-off between reducing pollution and widening wage inequality.*

If the tourism terms of trade improvement is sufficiently large, stricter environmental regulation can provide a further benefit in improving domestic welfare.[22] This result is consistent with Chao et al. (2012) and Nakai et al. (2018).

When the production function of tourism sector is Cobb-Douglas (i.e., $\sigma_T = 1$), the above analysis becomes quite simple (see Appendix D). In this case, at constant tourism terms of trade, the effect of stricter environmental regulation on the price of pollution permits is ambiguous. However, the revenue from pollution permits rZ unambiguously declines, leading to a decrease in the output of tourism infrastructure. Thus the output of tourism service and the wage of unskilled labor go down. At the same time, the capital flows from tourism infrastructure sector to traded good sector. It follows that the output of traded good and the wage of skilled labor rise.

5. Conclusions

This paper sets up a small open developing tourism economy with tourism infrastructure and examines welfare, production, and income distribution effects of stricter environmental policy. The tourism sector is pollution-generating industry in the sense that it requires pollution as an input. Since Lindahl pricing rule is not assumed, the usual envelope theorem does not necessarily hold. Thus we can obtain interesting comparative statics results. If the elasticity of substitution in tourism sector is sufficiently small, stricter environmental regulation paradoxically expands tourism sector even under the constant tourism terms of trade. At the same time the wage inequality between skilled labor and unskilled labor narrows.

With regard to welfare implications, this paper contains some new insights. In addition to the conventional effects pointed out by Beladi et al. (2009) and Yanase (2017), this paper contains additional effects working through the difference between marginal value product of tourism infrastructure and its price. Furthermore, the tourism infrastructure increases the possibility of welfare-improving environmental regulation if (i) the marginal value product of tourism infrastructure is larger than its price, (ii) the output of tourism infrastructure is increased by stricter environmental regulation, and (iii) the excess supply of tourism service decreases with stricter environmental regulation.

Before closing this paper, we state some topics for future research. In this paper we have considered that tourism infrastructure enhances only the productivity of tourism industry and includes no congestion effect. However, some tourism infrastructures such as airport and highway contribute many industries and include congestion effect where an increase in users lowers efficiency. Thus it is important to consider such a type of infrastructure. If the infrastructure contributes almost all the industry in the economy, the national government can finance the cost of infrastructure by taxing the income of residents in the economy.

We have assumed that tourism industry is under perfect competition. It will be interesting to consider another market structure, for example, duopoly or monopolistic competition cases.[23] [24]

We have considered only environmental regulation as the national government's policy instrument. It may be possible to consider an optimal policy mix of environmental regulation and import tariff as in Chao et al. (2008) and Yanase (2017).

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[1] We treat low-and middle-income countries as developing countries.

[2] In fact, since the pollution tax provides a double dividend in improving the tourism terms of trade and reducing the amount of pollution, the optimal pollution tax rate exceeds the Pigouvian level in the case of exogenous tourism where the spending of foreign tourists is treated as a constant.

[3] The urban unemployment rate also affects urban-rural wage gap by the following mechanism. An increase in the urban unemployment rate decreases the urban expected wage rate which must be equal to the rural wage rate in equilibrium. It follows that the increase in the urban unemployment rate widens urban-rural wage gap.

[4] For an approach treating emission as an input of production, see Copeland and Taylor (2003) and Ishikawa and Kiyono (2006).

[5] Okamoto (1985) assumes Lindahl pricing in a general equilibrium model with public intermediate good. In his model, the tangency property holds.

[6] Even If tourism infrastructure industry requires both capital and skilled labor, main results do not change as long as manufacturing industry is skilled labor intensive relative to tourism infrastructure sector.

[7] Yanase (2015) makes the same assumption.

[8] Since cost minimization is required in tourism infrastructure sector, cost equals revenue.

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

[10] Notice that $w_L da_{LN} + r da_{ZN} = 0$ holds by the cost minimization in the tourism sector since each firm in that sector does not take into account the positive externality of tourism infrastructure, where $a_{LN} \equiv g \cdot a_{LT}$ and $a_{ZN} \equiv g \cdot a_{ZT}$ are input coefficients of tourism industry in the absence of tourism infrastructure.
[11] From assumptions $g'' < 0$ and $g(0) = 1$, we have $\xi < 1$.
[12] From (33), we have $\hat{r} + \hat{Z} = \frac{(\sigma_T - \theta_{LT})(\lambda_{KM}\theta_{SX} + \lambda_{KX}\sigma_X)}{\Delta}\hat{Z}$. Therefore, if σ_T is less than θ_{LT}, a reduction in emission raises the revenue from selling emission permits rZ.
[13] The total revenue R is given by $R = p_X X + p_T T$, which is depicted by the price line in the (T, X) plane. The slope of the price line is equal to $-p_T/p_X$. An increase (A decrease) in R shifts upward (downward) the price line. The change in total revenue due to stricter environmental regulation is $\frac{\partial R}{\partial Z} \equiv R_Z = r + p_M\left(\frac{\xi}{\theta_{ZT}} - 1\right)\frac{\partial M}{\partial Z}$ (See (C.3) of Appendix C). The fist term is positive while the second term is negative (recall that $p_M\left(\frac{\xi}{\theta_{ZT}} - 1\right) > 0$ and $\frac{\partial M}{\partial Z} < 0$). Note that the smaller the elasticity of substitution in the tourism sector σ_T, the larger the absolute value of $\frac{\partial M}{\partial Z}$.
[14] This specification of the utility function is suggested by Noritsugu Nakanishi.
[15] The home country is sufficiently small relative to the rest of the world and thus the price of foreign tourism service is exogenously given. Since the rest of the world consists of a great number of foreign countries, the foreign tourist takes the price of foreign tourism service as constant.
[16] Beladi et al. (2009) and Chao et al. (2008) assume a multiplicative utility function $U(C_X, C_T, C_T^*, Z) = v(C_X, C_T, C_T^*)/h(Z)$ while Chao et al. (2012) and Chao and Sgro (2013) adopt an additively separable utility function $U(C_X, C_T, C_T^*, Z) = v(C_X, C_T, C_T^*) - h(Z)$. If $v(C_X, C_T, C_T^*)$ is a Cobb-Douglas function, the compensated demand for the tourism service unambiguously increases with the amount of pollution, i.e., $E_{TZ} > 0$. See Yanase (2017, note 15).
[17] If the foreign tourists' utility function is a multiplicative form $U^*(D_X, D_T, D_T^*, Z) = v^*(D_X, D_T, D_T^*)/h^*(Z)$ or an additively separable form $U^*(D_X, D_T, D_T^*, Z) = v^*(D_X, D_T, D_T^*) - h^*(Z)$, the ordinary demand function does not depend on the amount of pollution. It follows from the fact that first order conditions for the utility maximization are $\frac{\partial v^*/\partial D_X}{\partial v^*/\partial D_T} = \frac{p_X}{p_T}$, $\frac{\partial v^*/\partial D_X}{\partial v^*/\partial D_T^*} = \frac{p_X}{p_T^*}$, and $Y^* = p_X D_X + p_T D_T + p_T^* D_T^*$.
[18] Let $\Omega \equiv E_T + D_T - T$ be the domestic excess demand for tourism service. From equations (36) and (37), we have $dp_T/d\Omega = -E_u/\Delta^*$. Hence, stability of tourism service market requires $\Delta^* > 0$.
[19] Note that the change in total revenue is given by $dR = X dp_X + T dp_T + w_S dS + w_L dL + r dZ + q dK + \Gamma dM$. See Appendix C.
[20] The tourism terms of trade depends on σ_T, which affects $\partial M/\partial Z$ and $\partial T/\partial Z$, as well as ξ, which affects Γ. See equation (39).
[21] Straight calculation shows that $G - F > 0 \leftrightarrow \sigma_T > \frac{\xi}{\theta_{ZT} + m + \xi}(> A)$ and $D - G > 0 \leftrightarrow \sigma_T < 1$.
[22] Differentiating equation (36) and substituting equation (37), we obtain $E_u du = \left(D_T + \Gamma\frac{\partial M}{\partial P_T}\right)dp_T - (E_Z - r - \Gamma\frac{\partial M}{\partial Z})dZ$. It follows that, *ceteris paribus*, an improvement in tourism terms of trade raises domestic welfare.

[23] Chao et al. (2012) assume that tourism industry is under oligopoly.
[24] Some tourism industries (for example, hotel and travel agency business) consist of many agents (see Japan Fair Trade Commission (2016)). So it is reasonable to consider tourism industry is under perfect competition or monopolistic competition.

Appendix A.

$$\Delta = \begin{vmatrix} 0 & 0 & 0 & \theta_{SX} & 0 & \theta_{KX} & 0 \\ 0 & 0 & -\xi & 0 & \theta_{LT} & 0 & \theta_{ZT} \\ \lambda_{KX} & 0 & \lambda_{KM} & \lambda_{KX}\theta_{SX}\sigma_X & 0 & -\lambda_{KX}\theta_{SX}\sigma_X & 0 \\ 1 & 0 & 0 & -\theta_{KX}\sigma_X & 0 & \theta_{KX}\sigma_X & 0 \\ 0 & 1 & -\xi & 0 & -\theta_{ZT}\sigma_T & 0 & \theta_{ZT}\sigma_T \\ 0 & 1 & -\xi & 0 & \theta_{LT}\sigma_T & 0 & -\theta_{LT}\sigma_T \\ 0 & 0 & 1 & 0 & 0 & 1 & -1 \end{vmatrix}$$

Add the fourth column to the sixth column and then add the fifth column to the seventh column to obtain

$$= \begin{vmatrix} 0 & 0 & 0 & \theta_{SX} & 0 & 1 & 0 \\ 0 & 0 & -\xi & 0 & \theta_{LT} & 0 & 1 \\ \lambda_{KX} & 0 & \lambda_{KM} & \lambda_{KX}\theta_{SX}\sigma_X & 0 & 0 & 0 \\ 1 & 0 & 0 & -\theta_{KX}\sigma_X & 0 & 0 & 0 \\ 0 & 1 & -\xi & 0 & -\theta_{ZT}\sigma_T & 0 & 0 \\ 0 & 1 & -\xi & 0 & \theta_{LT}\sigma_T & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 1 & -1 \end{vmatrix}$$

Subtract the fifth row from the sixth row to obtain

$$= \begin{vmatrix} 0 & 0 & 0 & \theta_{SX} & 0 & 1 & 0 \\ 0 & 0 & -\xi & 0 & \theta_{LT} & 0 & 1 \\ \lambda_{KX} & 0 & \lambda_{KM} & \lambda_{KX}\theta_{SX}\sigma_X & 0 & 0 & 0 \\ 1 & 0 & 0 & -\theta_{KX}\sigma_X & 0 & 0 & 0 \\ 0 & 1 & -\xi & 0 & -\theta_{ZT}\sigma_T & 0 & 0 \\ 0 & 0 & 0 & 0 & \sigma_T & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 1 & -1 \end{vmatrix}$$

Expand by the second column to obtain

$$= -\begin{vmatrix} 0 & 0 & \theta_{SX} & 0 & 1 & 0 \\ 0 & -\xi & 0 & \theta_{LT} & 0 & 1 \\ \lambda_{KX} & \lambda_{KM} & \lambda_{KX}\theta_{SX}\sigma_X & 0 & 0 & 0 \\ 1 & 0 & -\theta_{KX}\sigma_X & 0 & 0 & 0 \\ 0 & 0 & 0 & \sigma_T & 0 & 0 \\ 0 & 1 & 0 & 0 & 1 & -1 \end{vmatrix}$$

Expand by the fifth row to obtain

$$= \sigma_T \begin{vmatrix} 0 & 0 & \theta_{SX} & 1 & 0 \\ 0 & -\xi & 0 & 0 & 1 \\ \lambda_{KX} & \lambda_{KM} & \lambda_{KX}\theta_{SX}\sigma_X & 0 & 0 \\ 1 & 0 & -\theta_{KX}\sigma_X & 0 & 0 \\ 0 & 1 & 0 & 1 & -1 \end{vmatrix}$$

Add the second row to the fifth row to obtain

$$= \sigma_T \begin{vmatrix} 0 & 0 & \theta_{SX} & 1 & 0 \\ 0 & -\xi & 0 & 0 & 1 \\ \lambda_{KX} & \lambda_{KM} & \lambda_{KX}\theta_{SX}\sigma_X & 0 & 0 \\ 1 & 0 & -\theta_{KX}\sigma_X & 0 & 0 \\ 0 & 1-\xi & 0 & 1 & 0 \end{vmatrix}$$

Expand by the fifth column to obtain

$$= -\sigma_T \begin{vmatrix} 0 & 0 & \theta_{SX} & 1 \\ \lambda_{KX} & \lambda_{KM} & \lambda_{KX}\theta_{SX}\sigma_X & 0 \\ 1 & 0 & -\theta_{KX}\sigma_X & 0 \\ 0 & 1-\xi & 0 & 1 \end{vmatrix}$$

Multiply the third row by λ_{KX} and then subtract from second row to obtain

$$= -\sigma_T \begin{vmatrix} 0 & 0 & \theta_{SX} & 1 \\ 0 & \lambda_{KM} & \lambda_{KX}\sigma_X & 0 \\ 1 & 0 & -\theta_{KX}\sigma_X & 0 \\ 0 & 1-\xi & 0 & 1 \end{vmatrix}$$

Expand by the first column to obtain

$$= -\sigma_T \begin{vmatrix} 0 & \theta_{SX} & 1 \\ \lambda_{KM} & \lambda_{KX}\sigma_X & 0 \\ 1-\xi & 0 & 1 \end{vmatrix}$$

$$= \sigma_T[(1-\xi)\lambda_{KX}\sigma_X + \lambda_{KM}\theta_{SX}] > 0.$$

The numerator of $\hat{T}/\hat{Z}$

$$\begin{vmatrix} 0 & 0 & 0 & \theta_{SX} & 0 & \theta_{KX} & 0 \\ 0 & 0 & -\xi & 0 & \theta_{LT} & 0 & \theta_{ZT} \\ \lambda_{KX} & 0 & \lambda_{KT} & \lambda_{KX}\theta_{SX}\sigma_X & 0 & -\lambda_{KX}\theta_{SX}\sigma_X & 0 \\ 1 & 0 & 0 & -\theta_{KX}\sigma_X & 0 & \theta_{KX}\sigma_X & 0 \\ 0 & 0 & -\xi & 0 & -\theta_{ZT}\sigma_T & 0 & \theta_{ZT}\sigma_T \\ 0 & 1 & -\xi & 0 & \theta_{LT}\sigma_T & 0 & -\theta_{LT}\sigma_T \\ 0 & 1 & 1 & 0 & 0 & 1 & -1 \end{vmatrix}$$

$$= (1-\xi)\theta_{ZT}\sigma_T\lambda_{KX}\sigma_X + \theta_{SX}\theta_{ZT}\sigma_T\lambda_{KM} + \xi(\sigma_T - \theta_{LT})\lambda_{KX}\sigma_X.$$

The numerator of $\hat{w}_S/\hat{p}_T$

$$\begin{vmatrix} 0 & 0 & 0 & 0 & 0 & \theta_{KX} & 0 \\ 0 & 0 & -\xi & 1 & \theta_{LT} & 0 & \theta_{ZT} \\ \lambda_{KX} & 0 & \lambda_{KM} & 0 & 0 & -\lambda_{KX}\theta_{SX}\sigma_X & 0 \\ 1 & 0 & 0 & 0 & 0 & \theta_{KX}\sigma_X & 0 \\ 0 & 1 & -\xi & 0 & -\theta_{ZT}\sigma_T & 0 & \theta_{ZT}\sigma_T \\ 0 & 1 & -\xi & 0 & \theta_{LT}\sigma_T & 0 & -\theta_{LT}\sigma_T \\ 0 & 0 & 1 & 0 & 0 & 1 & -1 \end{vmatrix}$$

$$= -\theta_{KX}\lambda_{KM}\sigma_T < 0.$$

The numerator of $\widehat{w}_S/\hat{Z}$

$$\begin{vmatrix} 0 & 0 & 0 & 0 & 0 & \theta_{KX} & 0 \\ 0 & 0 & -\xi & 0 & \theta_{LT} & 0 & \theta_{ZT} \\ \lambda_{KX} & 0 & \lambda_{KM} & 0 & 0 & -\lambda_{KX}\theta_{SX}\sigma_X & 0 \\ 1 & 0 & 0 & 0 & 0 & \theta_{KX}\sigma_X & 0 \\ 0 & 1 & -\xi & 0 & -\theta_{ZT}\sigma_T & 0 & \theta_{ZT}\sigma_T \\ 0 & 1 & -\xi & 1 & \theta_{LT}\sigma_T & 0 & -\theta_{LT}\sigma_T \\ 0 & 0 & 1 & 1 & 0 & 1 & -1 \end{vmatrix}$$

$$= \theta_{KX}\lambda_{KM}(\theta_{LT} - \sigma_T).$$

The numerator of $\widehat{w}_L/\hat{Z}$

$$\begin{vmatrix} 0 & 0 & 0 & \theta_{SX} & 0 & \theta_{KX} & 0 \\ 0 & 0 & -\xi & 0 & 0 & 0 & \theta_{ZT} \\ \lambda_{KX} & 0 & \lambda_{KM} & \lambda_{KX}\theta_{SX}\sigma_X & 0 & -\lambda_{KX}\theta_{SX}\sigma_X & 0 \\ 1 & 0 & 0 & -\theta_{KX}\sigma_X & 0 & \theta_{KX}\sigma_X & 0 \\ 0 & 1 & -\xi & 0 & 0 & 0 & \theta_{ZT}\sigma_T \\ 0 & 1 & -\xi & 0 & 1 & 0 & -\theta_{LT}\sigma_T \\ 0 & 0 & 1 & 0 & 1 & 1 & -1 \end{vmatrix}$$

$$= \lambda_{KX}\sigma_X[\theta_{ZT} + \xi(\sigma_T - 1)] + \lambda_{KM}\theta_{SX}\theta_{ZT}.$$

The numerator of $\hat{r}/\hat{Z}$

$$\begin{vmatrix} 0 & 0 & 0 & \theta_{SX} & 0 & \theta_{KX} & 0 \\ 0 & 0 & -\xi & 0 & \theta_{LT} & 0 & 0 \\ \lambda_{KX} & 0 & \lambda_{KM} & \lambda_{KX}\theta_{SX}\sigma_X & 0 & -\lambda_{KX}\theta_{SX}\sigma_X & 0 \\ 1 & 0 & 0 & -\theta_{KX}\sigma_X & 0 & \theta_{KX}\sigma_X & 0 \\ 0 & 1 & -\xi & 0 & -\theta_{ZT}\sigma_T & 0 & 0 \\ 0 & 1 & -\xi & 0 & \theta_{LT}\sigma_T & 0 & 1 \\ 0 & 0 & 1 & 0 & 0 & 1 & 1 \end{vmatrix}$$

$$= \xi\sigma_T\lambda_{KX}\sigma_X - \theta_{LT}\lambda_{KM}\theta_{SX} - \lambda_{KX}\sigma_X\theta_{LT}.$$

Appendix B. Shape of the production possibility curve

The first order conditions for profit maximization in manufacturing sector are

$$p_X \frac{\partial X}{\partial S} = w_S, \tag{B.1}$$

$$p_X \frac{\partial X}{\partial K_X} = q. \tag{B.2}$$

Similarly, the first order conditions for profit maximization in tourism sector are

$$p_T \frac{\partial T}{\partial L} = w_L, \tag{B.3}$$

$$p_T \frac{\partial T}{\partial Z} = r. \tag{B.4}$$

Therefore, we have[1]

$$p_X dX + p_T dT = w_S dS + w_L dL + rdZ + qdK + \Gamma dM, \tag{B.5}$$

where $\Gamma \equiv p_T \frac{\partial T}{\partial M} - p_M$ is the difference between the marginal value product of tourism infrastructure and its price. Using the budget constraint of the government (8), we can rewrite $\Gamma = p_M \left(\frac{\xi}{\theta_{ZT}} - 1\right)$. Keeping factor endowments unchanged, the slope of the production possibility curve is given by

$$\frac{dX}{dT} = -\frac{p_T}{p_X} + \frac{\Gamma}{p_X}\frac{dM}{dT} = -\frac{p_T}{p_X}\frac{\theta_{ZT}}{\xi}, \tag{B.6}$$

where we have used equation (8) and $\frac{dM}{dT} = \frac{\hat{M}}{\hat{T}}\frac{M}{T} = \frac{M}{T\xi}$ from equations (22) and (29). Equation (B.6) implies that the production possibility curve is flatter than the relative price line if and only if $\Gamma > 0$ (i.e., $\xi > \theta_{ZT}$).

The absolute value of the slope of production possibility curve is rewritten as

$$\frac{p_T}{p_X}\frac{\theta_{ZT}}{\xi} = \frac{r a_{ZT}}{p_X \xi}.$$

Taking the rates of changes, we obtain[2]

$$\hat{r} + \hat{a}_{ZT} - \hat{p}_X - \hat{\xi} = \left[\frac{\theta_{SX}\lambda_{KM}}{\lambda_{KX}\sigma_X} - \frac{g'' M}{g'}\right]\widehat{M} = \left[\frac{\theta_{SX}\lambda_{KM}}{\lambda_{KX}\sigma_X} - \frac{g'' M}{g'}\right]\frac{\hat{T}}{\xi}.$$

Therefore, we can conclude that $d^2X/dT^2 < 0$. It follows that the production possibility curve is strictly concave to the origin.

Appendix C. Properties of the revenue function

The total revenue is defined as

$$R = p_X X + p_T T.$$

Taking into account equation (B.5), the change in the total revenue is given by

$$dR = X dp_X + T dp_T + w_S dS + w_L dL + r dZ + q dK + \Gamma dM. \qquad \text{(C.1)}$$

The last term in equation (C.1) implies that an increase in tourism infrastructure raises the total revenue R if and only if the marginal value product of tourism infrastructure is larger than its price (i.e., $p_T \frac{\partial T}{\partial M} > p_M$).

From equation (C.1), we obtain

$$\frac{\partial R}{\partial p_T} \equiv R_T = T + \Gamma \frac{\partial M}{\partial p_T}, \qquad \text{(C.2)}$$

$$\frac{\partial R}{\partial Z} \equiv R_Z = r + \Gamma \frac{\partial M}{\partial Z}. \qquad \text{(C.3)}$$

Thus, the envelope theorem does not hold as long as $\Gamma \neq 0$.

Appendix D. Cobb-Douglas production function

When production function of tourism industry is Cobb-Douglas, i.e., $\sigma_T = 1$, the comparative statics results are simplified as

$$\frac{\hat{T}}{\hat{Z}} = \frac{\theta_{ZT}\lambda_{KX}\sigma_X + \theta_{SX}\theta_{ZT}\lambda_{KM}}{\Delta} > 0, \quad \text{(D.1)}$$

$$\frac{\hat{w}_S}{\hat{Z}} = -\frac{\theta_{KX}\lambda_{KM}\theta_{ZT}}{\Delta} < 0, \quad \text{(D.2)}$$

$$\frac{\hat{w}_L}{\hat{Z}} = \frac{\lambda_{KX}\sigma_X\theta_{ZT} + \lambda_{KM}\theta_{SX}\theta_{ZT}}{\Delta} > 0, \quad \text{(D.3)}$$

$$\frac{\hat{r}}{\hat{Z}} = \frac{\lambda_{KX}\sigma_X(\xi - \theta_{LT}) - \theta_{LT}\lambda_{KM}\theta_{SX}}{\Delta}. \quad \text{(D.4)}$$

The total effect

The necessary and sufficient condition for a reduction a in pollution to decrease wage of skilled labor is

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

From equations (26), (27), and (28), the total effects on q, X, and M are proportional to those of w_S.

The environmental regulation contracts tourism industry if and only if

$$\frac{Z}{p_T}\frac{dp_T}{dZ} > -\frac{\theta_{ZT} + m}{\xi} \equiv F'.$$

The necessary and sufficient condition for decreased pollution to push the wage of unskilled labor down is

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

The amount of pollution and the price of emission permit move the same direction if and only if

$$\frac{Z}{p_T}\frac{dp_T}{dZ} > \frac{\theta_{LT}(1+\frac{m}{\theta_{ZT}})-\xi}{1+\frac{m}{\theta_{ZT}}} = \theta_{LT} - \frac{\xi}{1+\frac{m}{\theta_{ZT}}} \equiv H'.$$

It is straightforward to show that $F' < -\theta_{ZT} < H'$.

Therefore, when production function of tourism sector is Cobb-Douglas, Tables 4 - 6 are simplified as follows.

$\frac{Z}{p_T}\frac{dp_T}{dZ}$	---	F'	---	$-\theta_{ZT}$	---	H'	---
dw_S/dZ	$+$	$+$	$+$	0	$-$	$-$	$-$
dT/dZ	$-$	0	$+$	$+$	$+$	$+$	$+$
dw_L/dZ	$-$	$-$	$-$	0	$+$	$+$	$+$
dr/dZ	$-$	$-$	$-$	$-$	$-$	0	$+$

Table D. 1. Total effect: Cobb-Douglas production function

1 We have used equations (3) and (4).

2 We have used equations (16), (17), (20), (21), and (24). Also note that $\widehat{w}_L = \hat{r}$ from equation (29). Substituting $\widehat{w}_L = \hat{r}$ into equation (22) yields $\widehat{M} = \widehat{T}/\xi$.