# A General Equilibrium Analysis of Over-tourism

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**Abstract**

To explore the desirable policy for over-tourism, this paper constructs a general equilibrium model of small open economy with pollution generated by consumption of tourism service. There are two types of consumers in the home country: domestic residents and foreign tourists, with possibly different rates of emission per unit of tourism consumption. Under constant expenditure of tourists (the case of exogenous tourism), we examine the effect of pollution tax on the tourism terms of trade, pollution, and welfare. The increase in pollution tax deteriorates the tourism terms of trade. Counterintuitively, the amount of pollution can *increase* with pollution tax. The increase (decrease) in pollution tax for only foreign tourists (domestic residents) can improve domestic welfare. The increase in pollution taxes for both types of consumers improves domestic welfare if emission per unit of tourism consumption by foreign tourists is no less than that by domestic residents and the pollution tax rate does not exceed the Pigouvian level. The case of endogenous tourism is also examined.

**Keywords:** Over-tourism, Consumption-generated pollution, Pollution tax, Tourism terms-of-trade effect, Welfare, Endogenous tourism

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## 1 Introduction

Between 2010 and 2019, the amount of international tourism, which is measured by international tourist arrivals or international tourism receipts, increased about 150% (see Figure 1). In 2020, however, the

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amount of international tourism suddenly dropped due to Covid-19 pandemic. From 2021 to 2023, following the abolishment of entry restriction in each country, the amount of international tourism rapidly recovered to the pre-pandemic level. The rapid growth of international tourism caused degradation of the environment due to congestion of road, hotel, and restaurant in the tourist spot, air and water pollution, noise pollution, littering of rubbish, etc. These negative effects of tourism expansion on the environment are sometimes called 'over-tourism'. However, a unique definition of over-tourism seems to not exist. According to UNWTO (2018, p. 4), a definition of over-tourism is "the impact of tourism on a destination, or parts thereof, that extensively influences perceived quality of life of citizens and/or quality of visitors experiences in a negative way". Notice that the degradation of the environment is caused by not only foreign tourists but also domestic residents. For example, domestic residents may contributes to congestion in the tourist spot. In fact, UNWTO (2018, p. 5) points out that "Tourism congestion is not a tourism-only problem", meaning that both domestic residents and foreign tourists use domestic tourism service such as transport, accommodation or restaurants. Recently, over-tourism has been a serious problem in many countries, thus this paper explores desirable policy in terms of welfare of host country.

Typically, tourism services, such as accommodation or food service, are consumed inside the home country. Due to visit of tourists, tourism service becomes exportable, and thus we can call its price the tourism terms-of-trade (TOT). Furthermore, the price of tourism service, which is endogenously determined by domestic demand and supply, surely affects welfare, yielding the tourism TOT effect.

Copeland (1991) constructs a general equilibrium model of a small open economy with tourism and focuses on the tourism TOT effect, by which the increase in tourism affects domestic welfare. Although Copeland (1991) is a pioneering study on general equilibrium analysis of tourism, he did not formally treat the environmental problems. Beladi et al. (2009) introduced environmental pollution which harms consumers into Copeland (1991).[1] They revealed that in the presence of the tourism TOT effect, the optimal pollution tax rate that maximizes domestic welfare does not coincide with the Pigouvian level, that is, the marginal environmental damage to domestic residents. Initiated by Beladi et al. (2009), there have been many theoretical studies on tourism and the environment: Chao et al. (2012) incorporated imperfect competition, Furukawa et al. (2019) and Yabuuchi (2015) negative production externality, Gupta and Dutta (2018) dynamic aspects, Shimizu and Okamoto (2024) tourism infrastructure, Yabuuchi

[1]While Copeland (1991) presented a three-sector model with two traded goods, Beladi et al. (2009) develop a simplified version of two-sector model with one traded good.

(2013) unemployment, Yabuuchi (2018) subsidy to agricultural sector, and Yanase (2017) import tariff and optimal policy mix. All of the above studies are based on production-generated pollution; that is, pollution is generated through the production of tourism service.[2] However, the above examples of over-tourism are consumption-generated pollution, rather than production-generated pollution. Thus we construct a general equilibrium model with pollution generated from consumption of domestic residents as well as foreign tourists.[3] For this purpose, we modify Beladi et al. (2009), a first theoretical analysis of tourism and the environment, by changing production-generated pollution to consumption-generated pollution. Then we analyze the effects of pollution tax on tourism TOT, pollution, and welfare.

There are at least two advantages of analysis based on consumption-generated pollution relative to that based on production-generated pollution. First, we can take into account that emissions per unit of consumption may be different between domestic residents and foreign tourists: foreign tourists may leave more trash or make more noises than domestic residents, whereas private cars of domestic residents tend to contribute to traffic congestion greater than sightseeing bus. Second, we can separately analyze the effect of environmental policy on foreign tourists and domestic residents. As we will show, it is possible that the increase (decrease) in pollution tax for only foreign tourists (domestic residents) improves welfare. The above results provide a rationale for two-tier pricing of tourism service: higher price for foreign tourists than for domestic residents.[4]

This paper is also related to the literature on tourism tax (e.g., Chang et al. (2011)). Tourism taxes are introduced in many countries and account for major source of government revenue for some countries. They include accommodation tax, arrival or departure taxes, entry fee for tourist spot, etc.

The rest of the paper proceeds as follows. Section 2 sets up the model with exogenous tourism and analyzes the effects of environmental policy and tourism expansion. In Section 3, we introduce the tourists' destination choice into the basic model and analyze the effects of environmental policy. Section

[2]In the literature of trade and the environment, main focus is also on production-generated pollution rather than consumption-generated pollution ((Copeland, 1994) and (Copeland and Taylor, 2003)). See Copeland (2011, section 6.2) for an analysis of consumption-generated pollution.

[3]Another modeling of over-tourism is that the amount of pollution increases with the number of tourists as in Kondoh and Shimizu (2024). Note that consumption of tourism service by foreign tourists consists of the number of foreign tourists and their per-capita consumption. Thus this paper implicitly takes into account the effect of the number of foreign tourists on the environment.

[4]For example, at Taj Mahal in India, entry fee is Rs. 50 for Indian while it is Rs. 1,100 for foreigner. See official website of Taj Mahal: `https://www.tajmahal.gov.in/ticketing.aspx`. As another example, Himeji city in Japan decides to raise entry fee to Himeji castle for non-resident.

4 conducts numerical simulations. Some concluding remarks are made in Section 5.

[Figure 1 around here]

## 2 The Model with Exogenous Tourism

We consider a small open economy, called the home, that produces tradable good $X$ and tourism service $Y$, which is non-tradable in the absence of tourists, under perfect competition. Thus, the home country faces a fixed price of tradable good. By choosing good X as the *numéraire*, the relative price of good $Y$ is denoted by $p$. There are two types of consumers: domestic residents and foreign tourists. Foreign tourists come to the home country and consume both traded good and tourism service. It follows that tourism service is exported through international tourists, and tradable good is imported. Domestic residents also consume both trade good and tourism service. We assume that pollution is emitted by consumption of tourism service. Suppose that one unit of consumption of tourism service by domestic residents (foreign tourists) emits $\theta$ ($\theta^*$) units of pollution. As in Beladi et al. (2009), pollution negatively affects utility of both domestic residents and foreign tourists. To control the amount of pollution, the national government levies pollution tax on consumption of tourism service. Let $s$ ($s^*$) be the pollution tax rate per unit of emissions from the consumption of domestic tourism service by domestic residents (foreign tourists). Then, the after-tax or tax-inclusive price of domestic tourism service is $p + \theta s$ ($p + \theta^* s^*$) for domestic residents (foreign tourists). The government transfers all the tax revenue to domestic residents in lump-sum fashion. That is, the government does not rebate the tax revenue to foreign tourists since they suffer from pollution only temporarily during the stay in the home country. In the case of commodity taxes on tourism services, Copeland (1991) and Chang et al. (2011) assume that the government rebates tax revenue from foreign tourists to domestic residents.[5] Thus, the pollution tax imposed on foreign tourists causes income transfer from foreign tourists to domestic residents.

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

$$R(p) \equiv \max\,[X + pY : (X, Y) \in \Gamma(\Psi)],$$

where $\Gamma(\Psi)$ is the production possibility as the function of the given input vector $\Psi$. By the envelope

[5] Copeland (1991, p. 521) states that a rebate of commodity taxes at the border "is often not feasible (or is very costly) in the case of exports of tourist services, since tourists typically consume most of their purchases of goods and services while inside the foreign country."

theorem, we have $R_p \equiv \partial R/\partial p = Y$. The upward sloping supply function requires $R_{pp} \equiv \partial^2 R/\partial p^2 = \partial Y/\partial p > 0$.

The demand side of the economy is described by the behavior of domestic residents and foreign tourists. The expenditure function of domestic residents is defined as

$$E(p+\theta s, Z, u) \equiv \min\{C_X + (p+\theta s)C_Y : U(C_X, C_Y, Z) = u\},$$

where $C_X$ ($C_Y$) is the consumption of the tradable good (the domestic tourism service) by domestic residents. $u$ is the level of utility and $Z$ denotes the amount of pollution. Note that $\partial U/\partial Z < 0$ since pollution harms domestic residents. Following Beladi et al. (2009), we specify the utility function of domestic residents as the isoelastic form:

$$U(C_X, C_Y, Z) = \frac{(C_X^a C_Y^{1-a} Z^{-\rho})^{1-\lambda} - 1}{1-\lambda}, \tag{1}$$

where $a$, $\rho$, and $\lambda$ are the parameters satisfying $0 < a < 1$, $\rho \geq 0$, $\lambda > 0$, and $\lambda \neq 1$. $a$ is the share of traded good in residents' expenditure, $\rho$ the degree of the disutility of pollution, and $\lambda$ the elasticity of marginal utility of consumption. The expenditure function is derived as follows:

$$E(p+\theta s, Z, u) = \frac{(p+\theta s)^{1-a} Z^{\rho}}{k}[(1-\lambda)u + 1]^{\frac{1}{1-\lambda}}, \tag{2}$$

where $k \equiv a^a(1-a)^{1-a}$. Applying the envelope theorem, we obtain the compensated demand for the tourism service: $E_p \equiv \partial E/\partial(p+\theta s) = C_Y$. The downward sloping demand function implies $E_{pp} \equiv \partial^2 E/\partial(p+\theta s)^2 = \partial C_Y/\partial(p+\theta s) < 0$. $E_Z \equiv \partial E/\partial Z (>) 0$ denotes the marginal damage to domestic residents caused by pollution. $E_u \equiv \partial E/\partial u (> 0)$ represents the inverse of the marginal utility of income. $E_{pu} \equiv \partial^2 E/\partial u \partial(p+\theta s) > 0$ means that the tourism service is normal in consumption. $E_{pZ} \equiv \partial^2 E/\partial Z \partial(p+\theta s) > 0$ holds since the compensated demand for tourism service increases with the amount of pollution to offset the disutility of pollution.[6]

Similarly, foreign tourists' utility function is given by

$$U^*(D_X, D_Y, Z) = \frac{(D_X^{\alpha} D_Y^{1-\alpha} Z^{-\gamma})^{1-\eta} - 1}{1-\eta}, \tag{3}$$

[6]If the utility function is a multiplicative form $U(C_X, C_Y, Z) = C_X^a C_Y^{1-a}/h(Z)$ or an additively separable form $U(C_X, C_Y, Z) = C_X^a C_Y^{1-a} - h(Z)$, where $h'(Z) > 0$, the expenditure function becomes $E(p+\theta s, Z, u) = (p+\theta s)^{1-a} h(Z) u/k$ for the former case or $E(p+\theta s, Z, u) = (p+\theta s)^{1-a}[h(Z)+u]/k$ for the latter. In either case, $E_{pp} < 0$, $E_Z > 0$, $E_u > 0$, $E_{pu} > 0$, and $E_{pZ} > 0$ hold and analytical results will not change. See Yanase (2017, note 15).

where $\alpha$, $\gamma$, and $\eta$ are similar parameters to $a$, $\rho$, and $\lambda$, respectively. That is, $0 < \alpha < 1$, $\gamma \geq 0$, $\eta > 0$, and $\eta \neq 1$. $D_X$ ($D_Y$) is consumption of the traded good (the domestic tourism service) by foreign tourists. The budget constraint of foreign tourists is given by $T = D_X + (p + \theta^* s^*)D_Y$, where $T$ is expenditure of foreign tourists. In this section, we consider the case of exogenous tourism where tourists' expenditure is exogenously given.[7] The foreign tourists' ordinary demand function for traded good and tourism service is $D_X = \alpha T$ and

$$D_Y(p + \theta^* s^*, T) = \frac{(1-\alpha)T}{p + \theta^* s^*}, \tag{4}$$

respectively.[8] Note that the price elasticity of tourists' demand for tourism service is unity (i.e., $D_Y/(p + s^*\theta^*) = -\partial D_Y/\partial p$).[9] We obtain the indirect utility of foreign tourists given by

$$V^*(p + s^*\theta^*, T, Z) = \frac{[\kappa T(p + s^*\theta^*)^{-(1-\alpha)} Z^{-\gamma}]^{1-\eta} - 1}{1 - \eta}, \tag{5}$$

where $\kappa \equiv \alpha^\alpha (1-\alpha)^{1-\alpha}$.

Based on the above setup, we derive the equilibrium conditions of the economy. Since the government transfers all the revenue from pollution tax to domestic residents, the budget constraint of the economy is

$$E(p + s\theta, Z, u) = R(p) + s\theta E_p(p + s\theta, Z, u) + s^*\theta^* D_Y(p + s^*\theta^*, T). \tag{6}$$

(6) implies that the total expenditure equals to total revenue plus lump-sum transfer from the government, which consists of tax revenue from the consumption of tourism service by domestic residents and that by foreign tourists.

The market clearing condition for domestic tourism service requires

$$R_p(p) = E_p(p + s\theta, Z, u) + D_Y(p + s^*\theta^*, T), \tag{7}$$

where the LHS (Left Hand Side) denotes the supply the domestic tourism service, while the RHS (Right Hand Side) is demand for it, which consists of consumption demand by domestic residents and that by foreign tourists.

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[7] For the analysis of endogenous tourism where tourists' expenditure is endogenously determined by tourists' destination choice, see Section 3.

[8] The ordinary demand does not depend on the amount of pollution since the marginal rate of substitution in consumption is not affected by pollution.

[9] For notational simplicity, we use $\partial D_Y/\partial p$ instead of $\partial D_Y/\partial(p + s^*\theta^*)$. Of course, these two expressions are the same.

The amount of pollution, which is generated from consumption of domestic tourism service, is given by

$$Z = \theta E_p(p + s\theta, Z, u) + \theta^* D_Y(p + s^*\theta^*, T). \tag{8}$$

The first term on the RHS is pollution emissions from consumption of domestic tourism service by domestic residents and the second term is those by foreign tourists. Note that tourism consumption of each consumers consists of the number of foreign tourists (or domestic residents) and their per-capita tourism consumption. That is, not only the number of visitors to tourist spot but also their individual tourism consumption contributes to degradation of the environment.

(6), (7), and (8) simultaneously determine the tourism terms of trade $p$, the amount of pollution $Z$, and domestic welfare $u$. We utilize this system of equations to analyze the effects of a stricter environmental policy and an increase in tourists' expenditure.

Differentiating (6) and substituting (7), we obtain

$$\begin{aligned} &\left(p\frac{\partial D_Y}{\partial p} - \theta s E_{pp}\right) dp + (E_Z - \theta s E_{pZ})\, dZ + (E_u - \theta s E_{pu})\, du \\ &\quad = s\theta^2 E_{pp} ds - \theta^* p \frac{\partial D_Y}{\partial p} ds^* + s^*\theta^* \frac{\partial D_Y}{\partial T} dT, \end{aligned} \tag{9}$$

where we have used $D_Y/(p + s^*\theta^*) = -\partial D_Y/\partial p$ from (4).

Differentiating (7) leads to

$$\left(R_{pp} - E_{pp} - \frac{\partial D_Y}{\partial p}\right) dp - E_{pZ} dZ - E_{pu} du = E_{pp}\theta ds + \frac{\partial D_Y}{\partial p}\theta^* ds^* + \frac{\partial D_Y}{\partial T} dT. \tag{10}$$

Differentiating (8) yields

$$\left(-\theta E_{pp} - \theta^* \frac{\partial D_Y}{\partial p}\right) dp + (1 - \theta E_{pZ}) dZ - \theta E_{pu} du = \theta^2 E_{pp} ds + (\theta^*)^2 \frac{\partial D_Y}{\partial p} ds^* + \theta^* \frac{\partial D_Y}{\partial T} dT. \tag{11}$$

(9), (10), and (11) are written as the matrix form:

$$\begin{pmatrix} p\frac{\partial D_Y}{\partial p} - \theta s E_{pp} & E_Z - \theta s E_{pZ} & E_u - \theta s E_{pu} \\ R_{pp} - E_{pp} - \frac{\partial D_Y}{\partial p} & -E_{pZ} & -E_{pu} \\ -\theta E_{pp} - \theta^* \frac{\partial D_Y}{\partial p} & 1 - \theta E_{pZ} & -\theta E_{pu} \end{pmatrix} \begin{pmatrix} dp \\ dZ \\ du \end{pmatrix} = \begin{pmatrix} s\theta^2 E_{pp} ds - \theta^* p \frac{\partial D_Y}{\partial p} ds^* + s^*\theta^* \frac{\partial D_Y}{\partial T} dT \\ E_{pp}\theta ds + \frac{\partial D_Y}{\partial p}\theta^* ds^* + \frac{\partial D_Y}{\partial T} dT \\ \theta^2 E_{pp} ds + (\theta^*)^2 \frac{\partial D_Y}{\partial p} ds^* + \theta^* \frac{\partial D_Y}{\partial T} dT \end{pmatrix}. \tag{12}$$

Let $J$ be the determinant of the $3 \times 3$ matrix on the LHS of (12). Notice that $E_Z E_{pu} = E_u E_{pZ}$ holds and $(p + \theta s)E_{pu}/E_u \in (0, 1)$ is the marginal propensity to tourism service by domestic residents, which equals $1-a$ from the expenditure function (2).[10] Then it is straightforward to show that $J$ is positive (see Appendix A):

$$J = R_{pp}(E_u - \theta s E_{pu}) - E_{pp}E_u - \frac{\partial D_Y}{\partial p} a E_u > 0 \tag{13}$$

since

$$E_u - \theta s E_{pu} > E_u - (p+\theta s)E_{pu} = E_u[1-(p+\theta s)E_{pu}/E_u] = aE_u > 0. \tag{14}$$

## 2.1 Environmental Policy

We analyze the effects of the pollution tax on the tourism terms of trade (the price of tourism service), the amount of emissions, and domestic welfare. We consider two scenarios: (i) the government can control the pollution tax rate for domestic residents $s$ and that for foreign residents $s^*$ separately, and (ii) the government cannot discriminate between domestic residents and foreign tourists in implementing environmental regulation, that is, the government is under the constraint $ds = ds^*$.

We first examine the effect on tourism terms of trade. Solving (12) for $dp$, we obtain (note that $dT = 0$)

$$dp = E_u \frac{a\frac{\partial D_Y}{\partial p}\theta^* ds^* + E_{pp}\theta ds}{J}. \tag{15}$$

Then, we have

$$\left.\frac{\partial p}{\partial s}\right|_{ds^*=0} = \frac{E_u E_{pp}\theta}{J} < 0, \tag{16}$$

$$\left.\frac{\partial p}{\partial s^*}\right|_{ds=0} = \frac{aE_u\frac{\partial D_Y}{\partial p}\theta^*}{J} < 0, \tag{17}$$

$$\left.\frac{dp}{ds}\right|_{ds=ds^*} = E_u\frac{a\frac{\partial D_Y}{\partial p}\theta^* + E_{pp}\theta}{J} < 0. \tag{18}$$

(16) and (17) correspond to case (i) and (18) to case (ii). In both cases, the increase in pollution tax decreases the price of tourism service. The intuition is straightforward. The increase in the pollution tax leads to the rise in the after-tax price of tourism service, which decreases demand for tourism service. To restore the equilibrium of tourism service market (7), the price of tourism service declines to reduce the output of tourism service (recall that $R_{pp} > 0$). The negative effect of pollution tax on the tourism TOT stands in sharp contrast to that of Beladi et al. (2009), where pollution is generated from production of tourism service.

[10] Even if we assume a multiplicative or an additively separable utility function, these relationships hold. See footnote 6.

We investigate the effect on the after-tax price of tourism service. Using (13) and (15), the changes in the after-tax price for domestic residents and foreign tourists are derived as

$$d(p+\theta s) = \frac{aE_u \frac{\partial D_Y}{\partial p}\theta^* ds^* + \left[R_{pp}(E_u - s\theta E_{pu}) - \frac{\partial D_Y}{\partial p} aE_u\right]\theta ds}{J}, \tag{19}$$

$$d(p+\theta^* s^*) = \frac{E_u E_{pp}\theta ds + [R_{pp}(E_u - s\theta E_{pu}) - E_{pp}E_u]\theta^* ds^*}{J}. \tag{20}$$

Then, (19) and (20) imply

$$\left.\frac{\partial(p+s\theta)}{\partial s}\right|_{ds^*=0} = \underbrace{\left.\frac{\partial p}{\partial s}\right|_{ds^*=0}}_{\text{indirect effect } (-)} + \underbrace{\theta}_{\text{direct effect } (+)} = \theta\frac{R_{pp}(E_u - s\theta E_{pu}) - \frac{\partial D_Y}{\partial p} aE_u}{J} > 0, \tag{21}$$

$$\left.\frac{\partial(p+s^*\theta^*)}{\partial s^*}\right|_{ds=0} = \underbrace{\left.\frac{\partial p}{\partial s^*}\right|_{ds=0}}_{\text{indirect effect } (-)} + \underbrace{\theta^*}_{\text{direct effect } (+)} = \theta^*\frac{R_{pp}(E_u - s\theta E_{pu}) - E_{pp}E_u}{J} > 0, \tag{22}$$

for scenario (i), and

$$\left.\frac{d(p+s\theta)}{ds}\right|_{ds=ds^*} = \underbrace{\left.\frac{dp}{ds}\right|_{ds=ds^*}}_{\text{indirect effect } (-)} + \underbrace{\theta}_{\text{direct effect } (+)} = \frac{\theta R_{pp}(E_u - s\theta E_{pu}) - (\theta-\theta^*)aE_u\frac{\partial D_Y}{\partial p}}{J} > 0 \text{ if } \theta \geq \theta^*, \tag{23}$$

$$\left.\frac{d(p+s^*\theta^*)}{ds}\right|_{ds=ds^*} = \underbrace{\left.\frac{dp}{ds}\right|_{ds=ds^*}}_{\text{indirect effect } (-)} + \underbrace{\theta^*}_{\text{direct effect } (+)} = \frac{\theta^* R_{pp}(E_u - s\theta E_{pu}) - (\theta^*-\theta)E_{pp}E_u}{J} > 0 \text{ if } \theta^* \geq \theta, \tag{24}$$

for scenario (ii), respectively. Note that $E_u - s\theta E_{pu} > 0$ from (14). Thus, in case (i), the after-tax price of tourism service increases with the pollution tax. This is because the direct effect of the increase in pollution tax outweighs the indirect effect through the decrease in the price of tourism service. Then, we have the following proposition.

**Proposition 1** *An increase in pollution tax deteriorates the tourism TOT, regardless of the target. If the government raises pollution tax for only domestic residents or only foreign tourists, the after-tax price of tourism service for that consumers increases.*

In scenario (ii), the negative indirect effect becomes larger since both the increases in $s$ and $s^*$ decrease the price of tourism service. Thus, the after-tax price of tourism service increases if the direct effect is sufficiently large. Then we have the following corollary to Proposition 1.

**Corollary 1** *If the governments raises pollution tax for both domestic residents and foreign tourists, the after-tax price of tourism service for consumers whose emission per unit of tourism consumption is greater than or equal to that for other type of consumers increases.*

We next investigate the effect on the amount of pollution. Solving (12) for $dZ$, we have

$$dZ = -\frac{(\theta^* - \theta)\frac{\partial D_Y}{\partial p}E_u E_{pp}(\theta^* ds^* - \theta ds) - R_{pp}\frac{\partial D_Y}{\partial p}[\theta^* E_u - \theta E_{pu}(p + s\theta^*)]\theta^* ds^* - \theta^2 R_{pp} E_u E_{pp} ds}{J}, \quad (25)$$

from which we obtain

$$\left.\frac{\partial Z}{\partial s}\right|_{ds^*=0} = -E_{pp}E_u\theta\frac{(\theta - \theta^*)\frac{\partial D_Y}{\partial p} - \theta R_{pp}}{J}, \quad (26)$$

$$\left.\frac{\partial Z}{\partial s^*}\right|_{ds=0} = -\frac{\partial D_Y}{\partial p}\theta^*\frac{E_{pp}(\theta^* - \theta)E_u - R_{pp}[\theta^* E_u - \theta E_{pu}(p + s\theta^*)]}{J}, \quad (27)$$

$$\left.\frac{dZ}{ds}\right|_{ds=ds^*} = -\frac{E_{pp}(\theta^* - \theta)^2\frac{\partial D_Y}{\partial p}E_u - R_{pp}\theta^*\frac{\partial D_Y}{\partial p}[\theta^* E_u - \theta E_{pu}(p + s\theta^*)] - \theta^2 R_{pp}E_u E_{pp}}{J}. \quad (28)$$

From (26), we immediately obtain a sufficient condition for a stricter environmental policy aimed at only domestic residents to reduce the amount of pollution: $\partial Z/\partial s|_{ds^*=0} < 0$ if $\theta \geq \theta^*$. Investigating (27), we can conclude that $\partial Z/\partial s^*|_{ds=0} < 0$ if $\theta^* \geq \theta$.[11] That is, the amount of pollution decreases with pollution tax aimed at consumers with emission per unit of consumption higher than or equal to other type of consumers. The intuition is as follows. An increase in pollution tax for that type of consumers pushes up the after-tax price of tourism service, which decreases tourism consumption and hence pollution. At the same time, the price of tourism service decreases, leading to the increase in tourism consumption by other type of consumers. If emission per unit of consumption by that type of consumers is greater than or equal to than that by other type of consumers, the former effect dominates the latter. The effect of pollution tax on the amount of pollution is summarized as follows.

**Proposition 2** *If the government raises the pollution tax to consumers with emission per unit of tourism consumption greater than or equal to other type of consumers, the amount of pollution decreases.*

[11] Using $(p + s\theta)E_{pu}/E_u = 1 - a$, the following relationship holds:

$$\theta^* E_u - \theta E_{pu}(p + s\theta^*) = E_u(p + s\theta^*)\left[\frac{(\theta^* - \theta)p}{(p + s\theta^*)(p + s\theta)} + \frac{a\theta}{p + s\theta}\right] > 0 \quad \text{if } \theta^* \geq \theta.$$

By contrast, if the government raises the pollution tax to consumers with emission per unit of tourism consumption smaller than other type of consumers, the amount of pollution can *increase* (see numerical simulations of section 4).

We examine the effect of the increase in pollution tax for both types of consumers. (28) implies $dZ/ds|_{ds=ds^*} < 0$ if $\theta^* \geq \theta$. See footnote 11. In this case, the increase in pollution from consumption of foreign tourists is dominant, although the qualitative effect on pollution from consumption of domestic residents is ambiguous (note that the price elasticity of demand for tourism service by foreign tourists is unity).

**Corollary 2** *If the government raises the pollution tax to both domestic residents and foreign tourists and emission per unit of consumption by foreign tourists is greater than or equal to that by domestic residents, the amount of pollution decreases.*

The above comparative static results are summarized in Table 1.

Table 1: Comparative static results (exogenous tourism)

| | $p$ | $p+s\theta$ | $p+s^*\theta^*$ | $Z$ |
|---|---|---|---|---|
| $ds>0,\ ds^*=0$ | $\downarrow$ | $\uparrow$ | $\downarrow$ | $\downarrow^1$ |
| $ds^*>0,\ ds=0$ | $\downarrow$ | $\downarrow$ | $\uparrow$ | $\downarrow^2$ |
| $ds=ds^*>0$ | $\downarrow$ | $\uparrow^1$ | $\uparrow^2$ | $\downarrow^2$ |

1: $\theta \geq \theta^*$, 2: $\theta^* \geq \theta$

Lastly we explore the welfare impact. Combining (9), (10), and (11), we obtain an expression for the welfare change (see Appendix B):

$$E_u du = -(E_Z - s)dZ - (p + s\theta^*)\frac{\partial D_Y}{\partial p}dp - \theta^*(p + s\theta^*)\frac{\partial D_Y}{\partial p}ds^* + \theta^*(s^* - s)\frac{\partial D_Y}{\partial T}dT. \tag{29}$$

According to (29), welfare effects are divided into four terms on the RHS of this equation. Note that since $E_Z$ is the Pigouvian pollution tax level, the pollution distortion $E_Z - s > 0$ ($< 0$) means that the amount of pollution is socially excessive (insufficient). Then the first term implies that if $E_Z - s > 0$ ($< 0$), the decreased (increased) pollution improves domestic welfare. This effect was pointed out by Copeland (1994) in a small open economy model without tourism. Following Copeland (1994), we call this effect pollution distortion effect. The second term reflects the tourism TOT effect, which is negative from Proposition 1. Since the price of tourism service is endogenouly determined by domestic market, the tourism TOT can affect welfare even in a small open economy. This effect was highlighted by Copeland (1991). The third term represents a positive welfare effect of pollution tax on tourism consumption by foreign tourists (recall that this taxation causes income transfer from foreign tourists to domestic residents). This effect is called wealth effect by Chang et al. (2011). The last term represent the effect of expenditure by foreign tourists on domestic welfare. In (7) and (8), the increase in $T$ leads to a rise in tourists' demand for services, which must be offset by a decrease in demand for tourism service by domestic residents due to a deterioration of domestic welfare $u$ (recall that $E_{pu} > 0$). By contrast, the increase in $T$ raises domestic welfare through (6).[12] The former negative effect on $u$ exactly offsets the latter positive effect at $s = s^*$.

Adding the second term and the third term on the RHS of (29) leads to

$$E_u du = -(E_Z - s)dZ - (p + s\theta^*)\frac{\partial D_Y}{\partial p}(dp + \theta^* ds^*) + \theta^*(s^* - s)\frac{\partial D_Y}{\partial T}dT. \tag{30}$$

Thus, the positive welfare effect due to income transfer from foreign tourists outweighs the negative TOT effect when the government increases a pollution tax for only foreign tourists (see (22)). Notice that the last term on the RHS vanishes since we consider only the changes in pollution taxes and we are in the case of exogenous tourism.

(30) is further rewritten as

$$E_u J du = -E_Z J dZ - p\frac{\partial D_Y}{\partial p}J(dp + \theta^* ds^*) + J\left[dZ - \theta^*\frac{\partial D_Y}{\partial p}(dp + \theta^* ds^*)\right]s, \tag{31}$$

where the first term on the RHS of (31) represents the welfare gain (loss) from pollution reduction (increase). Substituting (20) and (25), the last term on the RHS of (31) becomes

$$J\left[dZ - \theta^*\frac{\partial D_Y}{\partial p}(dp + \theta^* ds^*)\right]s = \theta\left[E_u E_{pp}\left(R_{pp} - \frac{\partial D_Y}{\partial p}\right)\theta ds + \frac{\partial D_Y}{\partial p}(E_{pp}E_u - pR_{pp}E_{pu})\theta^* ds^*\right]s, \tag{32}$$

which is negatively (positively) related to $ds$ ($ds^*$). Substituting (32) into (31), we obtain

$$E_u J du = -E_Z J dZ - p\frac{\partial D_Y}{\partial p}J(dp + \theta^* ds^*) + \theta\left[E_u E_{pp}\left(R_{pp} - \frac{\partial D_Y}{\partial p}\right)\theta ds + \frac{\partial D_Y}{\partial p}(E_{pp}E_u - pR_{pp}E_{pu})\theta^* ds^*\right]s. \tag{33}$$

[12] The increase in $T$ raises the RHS of (6). To restore the equality in (6), $u$ must change, given $p$ and $Z$. The increase in $u$ raises $E$ on the LHS. At the same time, it also pushes up $s\theta E_p$ on the RHS. We can show that the first effect is larger than the second effect (see (14)).

Taking (16) and (22) into account, (33) implies that $\partial u/\partial s|_{ds^*=0} < 0$ ($\partial u/\partial s^*|_{ds=0} > 0$) if $\partial Z/\partial s|_{ds^*=0} \geq 0$ ($\partial Z/\partial s^*|_{ds=0} \leq 0$). Furthermore, from (27), a sufficient condition for $\partial Z/\partial s^*|_{ds=0} < 0$ is $\theta^* \geq \theta$, which is also a sufficient condition for $\partial u/\partial s^*|_{ds=0} > 0$. Consider the case of $E_Z - s \leq 0$ (the amount of pollution is socially insufficient). From (30), $\partial u/\partial s|_{ds^*=0} < 0$ ($\partial u/\partial s^*|_{ds=0} > 0$) if $\partial Z/\partial s|_{ds^*=0} \leq 0$ ($\partial Z/\partial s^*|_{ds=0} \geq 0$). Therefore, if $E_Z - s \leq 0$, $\partial u/\partial s|_{ds^*=0} < 0$ and $\partial u/\partial s^*|_{ds=0} > 0$ always hold.

Thus, we have the following proposition.

**Proposition 3** *The increase (decrease) in pollution tax for foreign tourists (domestic residents) improves domestic welfare if (a) the amount of pollution is socially insufficient or (b) $\theta$ is so small relative to $\theta^*$ that $\partial Z/\partial s_{ds^*=0} \geq 0$ holds.*

Proposition 3 suggests that it is possible that charging higher price of tourism service for foreign tourists than domestic residents improves welfare. Thus, it provides a rationale for two-tier pricing of tourism service. If $\theta$ is sufficiently small relative to $\theta^*$, it is possible that $\partial Z/\partial s|_{ds^*=0} > 0$. Numerical simulation in Section 4 reveals that this is the case for a certain set of parameter values. Numerical simulation also shows that even if $\partial Z/\partial s < 0$, there exists a certain set of parameter values yielding $\partial u/\partial s|_{ds^*=0} < 0$ and $\partial u/\partial s^*|_{ds=0} > 0$.

We examine the effect on domestic welfare for scenario (ii). Dividing both sides of (30) by $ds = ds^* \neq 0$, we obtain (note that $dT = 0$)

$$E_u \left. \frac{du}{ds} \right|_{ds=ds^*} = -(E_Z - s) \left. \frac{dZ}{ds} \right|_{ds=ds^*} - (p + s\theta^*) \frac{\partial D_Y}{\partial p} \left( \left. \frac{dp}{ds} \right|_{ds=ds^*} + \theta^* \right).$$

From (24), the second term on the RHS of the above equation is positive if $\theta^* \geq \theta$. In this case (28) implies $dZ/ds|_{ds=ds^*} < 0$. Thus, if $\theta^* \geq \theta$ and $E_Z \geq s$, the stricter environmental policy for both domestic residents and foreign tourists improves domestic welfare. The former condition implies that positive welfare effect of pollution tax on consumption of tourism service by foreign tourists outweighs the negative TOT effect (see (24)) and pollution tax decreases the amount of pollution (see (28)). The latter condition means the amount of pollution is socially excessive and thus decreased pollution improves domestic welfare.

We have the following corollary to Proposition 3.

**Corollary 3** *When the government increases pollution tax for both domestic residents and foreign tourists, domestic welfare improves under the sufficient condition that emission per unit of consump-*

*tion of tourism by foreign tourists is no less than that by domestic residents and pollution tax rate for domestic residents does not exceed the Pigouvian level.*

If the above condition of Corollary 3 is not satisfied, domestic welfare may deteriorate. See numerical simulations of section 4.

### 2.2 Tourism Expansion

We consider the effect of an increase in tourist expenditure $T$. An interpretation of this change is a 'tourism boom', which increases demand for tourism service by foreign tourists (see (4)).

First, we examine the effect on the tourism terms of trade. Solving (12) for $dp$, we have

$$\frac{dp}{dT} = \frac{\partial D_Y}{\partial T} \frac{E_u - s\theta E_{pu} + s^* \theta^* E_{pu}}{J} > 0. \tag{34}$$

Using (14), the RHS of (34) is positive. An increase in tourist expenditure pushes up the demand for tourism service by foreign tourists (see (4)). To restore the equilibrium of tourism service market (7), the price of tourism service goes up to increase output of tourism service. This result is similar to that of Beladi et al. (2009).

Next, we investigate the effect on the amount of pollution. Solving (12) for $dZ$, we obtain

$$\frac{dZ}{dT} = \frac{\partial D_Y}{\partial T} \frac{E_{pp}(\theta - \theta^*)E_u + R_{pp}\theta^*(E_u - s\theta E_{pu} + s^*\theta E_{pu}) - D_Y(\theta^* - \theta)E_{pu}}{J}. \tag{35}$$

The effect on the amount of pollution is in general ambiguous. An increase in tourist expenditure leads to an increase in demand for tourism service by foreign tourists, which increases pollution. At the same time, the increase in tourism leads to the increase in the price of tourism service (see (34)), which reduces the amount of pollution, by decreasing the demand for tourism service. In the special case of $\theta = \theta^*$, the increase in tourism expands the amount of pollution. In this case, the amount of pollution is proportional to the output of tourism service (see (7) and (8)). The increase in tourism raises the price of tourism service, which, in turn, expands the output of tourism service as in Beladi et al. (2009).

Finally, we explore the welfare implications. From (29), the welfare effect of tourism expansion is given by

$$E_u \frac{du}{dT} = -(p + s\theta^*) \frac{\partial D_Y}{\partial p} \frac{dp}{dT} - (E_Z - s) \frac{dZ}{dT} + \theta^*(s^* - s) \frac{\partial D_Y}{\partial T}.$$

Although the tourism TOT effect is positive, the qualitative effect on the amount of pollution is unclear except for the special case of $\theta = \theta^*$. Thus, the welfare effect of tourism expansion is in general ambiguous even if $s = s^*$.

## 3 Endogenous Tourism

Section 2 treated tourists' expenditure $T$ as exogenously given. That is, the previous analysis assumed that the increase in pollution tax does not affect the behavior of foreign tourists. Following Beladi et al. (2009), we now consider the case of endogenous tourism, where $T$ is endogenously determined by the destination choice of foreign tourists. In equilibrium, they are indifferent to where they will visit. The total expenditure of foreign tourists $T$ is determined by the following condition:

$$\partial V^*/\partial T = \omega, \tag{36}$$

where $\omega$ is the marginal utility of tourists' spending in various destinations and is assumed to be constant. Taking (5) into account, (36) becomes

$$T^{-\eta}[k(p + s^*\theta^*)^{-\beta} Z^{-\gamma}]^{1-\eta} = \omega. \tag{37}$$

In the case of endogenous tourism, (6), (7), (8), and (37) determine $p$, $Z$, $u$, and $T$. We utilize this system of equations to analyze the effects of the increase in pollution taxes.

Differentiating (37), we have

$$dT = -\frac{1-\eta}{\eta} D_Y (dp + \theta^* ds^*) - \frac{1-\eta}{\eta}\frac{\gamma T}{Z} dZ. \tag{38}$$

Following Chao et al. (2010b) and Chao et al. (2010a), we assume $\eta < 1$. Then (38) implies that an increase in the after-tax price of tourism service or the amount of pollution reduces tourists' expenditure.

(9), (10), (11), and (38) are written as the matrix form:

$$\begin{pmatrix} p\frac{\partial D_Y}{\partial p} - s\theta E_{pp} & E_Z - s\theta E_{pZ} & E_u - s\theta E_{pu} & -s^*\theta^*\frac{\partial D_Y}{\partial T} \\ R_{pp} - E_{pp} - \frac{\partial D_Y}{\partial p} & -E_{pZ} & -E_{pu} & -\frac{\partial D_Y}{\partial T} \\ -\theta E_{pp} - \theta^*\frac{\partial D_Y}{\partial p} & 1 - \theta E_{pZ} & -\theta E_{pu} & -\theta^*\frac{\partial D_Y}{\partial T} \\ \frac{1-\eta}{\eta} D_Y & \frac{1-\eta}{\eta}\frac{\gamma T}{Z} & 0 & 1 \end{pmatrix} \begin{pmatrix} dp \\ dZ \\ du \\ dT \end{pmatrix} = \begin{pmatrix} s\theta^2 E_{pp} ds - \theta^* p \frac{\partial D_Y}{\partial p} ds^* \\ E_{pp}\theta ds + \frac{\partial D_Y}{\partial p}\theta^* ds^* \\ \theta^2 E_{pp} ds + (\theta^*)^2 \frac{\partial D_Y}{\partial p} ds^* \\ -\frac{1-\eta}{\eta} D_Y \theta^* ds^* \end{pmatrix}. \tag{39}$$

Let $\widetilde{J}$ be the determinant of the $4 \times 4$ matrix on the LHS of (39). The sign of $\widetilde{J}$ is ambiguous:

$$\begin{aligned} \widetilde{J} = J &+ \frac{1-\eta}{\eta} D_Y \frac{\partial D_Y}{\partial T}(E_u - s\theta E_{pu} + s^*\theta^* E_{pu}) \\ &+ \frac{1-\eta}{\eta}\frac{\gamma T}{Z}\frac{\partial D_Y}{\partial T}\left\{R_{pp}\theta^*[E_u + \theta E_{pu}(s^* - s)] - E_{pp}(\theta^* - \theta)E_u - D_Y(\theta^* - \theta)E_{pu}\right\}. \end{aligned} \tag{40}$$

To fix the sign of $\widetilde{J}$, we consider the price adjustment process in the domestic tourism service market. From (6), (7), (8), and (37), we obtain

$$\frac{dp}{dG} = -\frac{\frac{1-\eta}{\eta}\frac{\gamma T}{Z}\theta^*\frac{\partial D_Y}{\partial T}(E_u - s\theta E_{pu} + s^*\theta E_{pu}) + (E_u - s\theta E_{pu})}{\widetilde{J}}, \tag{41}$$

where $G \equiv E_p + D_Y - R_p$ is the excess demand for domestic tourism service. Note that the numerator on the RHS of (41) is positive if $1-\eta > 0$. The stability of domestic tourism service market requires that the excess demand for domestic tourism service should decrease with its price. Then, $\widetilde{J}$ must be positive.

First, we examine the effect on the price of tourism service. Solving (39) for $dp$, we have

$$\begin{aligned}\widetilde{J}dp &= \Phi_{ps}ds + \Phi_{ps^*}ds^* \\ &+ \frac{1-\eta}{\eta}\frac{\partial D_Y}{\partial T}\left[\frac{\gamma T}{Z}(\theta^* - \theta)(E_{pu}D_Y\theta^* ds^* + E_u E_{pp}\theta ds) - D_Y(E_u - s\theta E_{pu} + s^*\theta^* E_{pu})\theta^* ds^*\right],\end{aligned} \tag{42}$$

where $\Phi_{ps}$ ($\Phi_{ps^*}$) denotes $J\partial p/\partial s|_{ds^*=0}$ ($J\partial p/\partial s^*|_{ds=0}$) in the case of exogenous tourism. That is, $\Phi_{ps} \equiv E_u E_{pp}\theta < 0$ and $\Phi_{ps^*} \equiv aE_u(\partial D_Y/\partial p)\theta^* < 0$ from (16) and (17), respectively.

(42) implies that

$$\widetilde{J}\left.\frac{\partial p}{\partial s}\right|_{ds^*=0} = \Phi_{ps} + \frac{1-\eta}{\eta}\frac{\partial D_Y}{\partial T}\frac{\gamma T}{Z}(\theta^* - \theta)E_u E_{pp}\theta, \tag{43}$$

$$\widetilde{J}\left.\frac{\partial p}{\partial s^*}\right|_{ds=0} = \Phi_{ps^*} + \frac{1-\eta}{\eta}D_Y\frac{\partial D_Y}{\partial T}\left[\frac{\gamma T}{Z}(\theta^* - \theta)E_{pu} - (E_u - s\theta E_{pu} + s^*\theta^* E_{pu})\right]\theta^*, \tag{44}$$

$$\begin{aligned}\widetilde{J}\frac{dp}{ds} &= \Phi_{ps} + \Phi_{ps^*} + \frac{1-\eta}{\eta}\frac{\partial D_Y}{\partial T}\left[\frac{\gamma T}{Z}(\theta^* - \theta)\left(E_{pu}\theta^* D_Y + E_u E_{pp}\theta\right) - \theta^* D_Y(E_u - s\theta E_{pu} + s^*\theta^* E_{pu})\right] < 0 \\ &\text{if } \theta = \theta^*.\end{aligned} \tag{45}$$

Thus we have $\partial p/\partial s|_{ds^*=0} < 0$ ($\partial p/\partial s^*|_{ds=0} < 0$) if $\theta^* \geq \theta$ ($\theta \geq \theta^*$). These results are somewhat different from the case of exogenous tourism. Suppose that the government increases pollution tax for only one side of consumers. As is clear from the analysis of exogenous tourism, the increase in pollution tax decreases the price of tourism service (see (16) or (17)). In the present situation of endogenous tourism, the pollution tax affects the amount of pollution, which in turn affects the price of tourism service through the change in $T$. The increase in pollution tax decreases the amount of pollution if emission per unit of tourism consumption by consumers, for which tax is levied, is greater than or equal to that by other type of consumers at constant $T$ (see Proposition 2).[13] Then, decreased pollution pushes up the tourists' expenditure (see (38)), which in turn raises the price of tourism service (see (34)). When the above condition is satisfied, the latter effect through $T$ goes against the former effect (at constant $T$) and the total effect on $p$ is in general ambiguous. When the above condition is not satisfied, the latter effect is weakened and the former effect can be dominant. If the government increases pollution tax for both types of consumers, the effect on the price of tourism service is in general ambiguous except for the special case of $\theta = \theta^*$. In this case, both the increases in $s$ and $s^*$ decrease the price of tourism service, and thus the tourism TOT deteriorates.

Using (40) and (42), the changes in the after-tax price of domestic tourism service for domestic residents and foreign tourists are

$$\begin{aligned}\widetilde{J}d(p+s\theta) &= \Phi_{ps}ds + \Phi_{ps^*}ds^* + J\theta ds + \frac{1-\eta}{\eta}\frac{\gamma T}{Z}\frac{\partial D_Y}{\partial T}R_{pp}\theta^*[E_u + \theta E_{pu}(s^*-s)]\theta ds \\ &+ \frac{1-\eta}{\eta}\frac{\partial D_Y}{\partial T}D_Y\left[(E_u - s\theta E_{pu} + s^*\theta^* E_{pu}) + (\theta-\theta^*)\frac{\gamma T}{Z}E_{pu}\right](\theta ds - \theta^* ds^*),\end{aligned} \tag{46}$$

$$\widetilde{J}(dp+\theta^* ds^*) = \Phi_{ps}ds + \Phi_{ps^*}ds^* + J\theta^* ds^* + \frac{1-\eta}{\eta}\frac{\partial D_Y}{\partial T}\frac{\gamma T}{Z}H, \tag{47}$$

where

$$H \equiv (\theta^*)^2 R_{pp}[E_u + (s^*-s)E_{pu}\theta]ds^* - (\theta^*-\theta)E_u E_{pp}(\theta^* ds^* - \theta ds). \tag{48}$$

From (46), the after-tax price for domestic residents increases due to stricter environmental policy aimed at them if $\theta \geq \theta^*$:

$$\begin{aligned}\widetilde{J}\left.\frac{\partial(p+s\theta)}{\partial s}\right|_{ds^*=0} &= \Phi_{ps} + J\theta + \frac{1-\eta}{\eta}\frac{\gamma T}{Z}\frac{\partial D_Y}{\partial T}R_{pp}\theta^*[E_u + \theta E_{pu}(s^*-s)]\theta \\ &+ \frac{1-\eta}{\eta}\frac{\partial D_Y}{\partial T}D_Y\left[(E_u - s\theta E_{pu} + s^*\theta^* E_{pu}) + (\theta-\theta^*)\frac{\gamma T}{Z}E_{pu}\right]\theta > 0 \text{ if } \theta \geq \theta^*,\end{aligned} \tag{49}$$

$$\begin{aligned}\widetilde{J}\left.\frac{d(p+s\theta)}{ds}\right|_{ds=ds^*} &= \Phi_{ps} + \Phi_{ps^*} + J\theta + \frac{1-\eta}{\eta}\frac{\gamma T}{Z}\frac{\partial D_Y}{\partial T}R_{pp}\theta^*[E_u + \theta E_{pu}(s^*-s)]\theta \\ &+ \frac{1-\eta}{\eta}\frac{\partial D_Y}{\partial T}D_Y\left[(E_u - s\theta E_{pu} + s^*\theta^* E_{pu}) + (\theta-\theta^*)\frac{\gamma T}{Z}E_{pu}\right](\theta-\theta^*) > 0 \text{ if } \theta \geq \theta^*.\end{aligned} \tag{50}$$

Notice that $\Phi_{ps} + J\theta$ is always positive from (21). Notice also that (23) implies that $\Phi_{ps} + \Phi_{ps^*} + J\theta$ is positive if $\theta \geq \theta^*$.

[13] We will show that the same result holds even if $T$ is endogenous (see (54) or (55)).

From (47), the after-tax price for foreign tourists increases due to stricter environmental policy aimed at them if $\theta^* \geq \theta$:

$$\widetilde{J}\left.\frac{\partial(p+s^*\theta^*)}{\partial s^*}\right|_{ds=0} = \Phi_{ps^*} + J\theta^* + \frac{1-\eta}{\eta}\frac{\gamma T}{Z}\frac{\partial D_Y}{\partial T}\left\{\theta^* R_{pp}[E_u + (s^*-s)\theta E_{pu}] - (\theta^*-\theta)E_u E_{pp}\right\}\theta^* > 0 \quad \text{if } \theta^* \geq \theta, \tag{51}$$

$$\widetilde{J}\left.\frac{d(p+s^*\theta^*)}{ds}\right|_{ds=ds^*} = \Phi_{ps}ds + \Phi_{ps^*} + J\theta^* + \frac{1-\eta}{\eta}\frac{\gamma T}{Z}\frac{\partial D_Y}{\partial T}\{(\theta^*)^2 R_{pp}[E_u + (s^*-s)\theta E_{pu}] - (\theta^*-\theta)^2 E_u E_{pp}\} > 0 \text{ if } \theta^* \geq \theta. \tag{52}$$

Note that $\Phi_{ps^*} + J\theta^*$ is always positive by (22). Note also that $E_u + (s^*-s)\theta E_{pu} > 0$ from (14). Note that from (24) $\Phi_{ps}ds + \Phi_{ps^*} + J\theta^*$ is positive if $\theta^* \geq \theta$.

When the government increases pollution tax for consumers with emission per unit of tourism consumption higher than or equal to other consumers, the after tax price for the consumers increases. The reason is straightforward. Although the indirect effect through the tourism TOT is in general ambiguous, the after-tax price of tourism service increases with the pollution tax if the direct effect is sufficiently large.

Next, we investigate the effect on the amount of pollution. Solving (39) for $dZ$, we obtain

$$\widetilde{J}dZ = \Phi_{Zs}ds + \Phi_{Zs^*}ds^* - \frac{1-\eta}{\eta}D_Y\frac{\partial D_Y}{\partial T}H, \tag{53}$$

where $\Phi_{Zs}$ ($\Phi_{Zs^*}$) denotes $J\partial Z/\partial s|_{ds^*=0}$ ($J\partial Z/\partial s^*|_{ds=0}$) in the case of exogenous tourism. That is, from (26) and (27),

$$\Phi_{Zs} \equiv -E_{pp}E_u\theta\left[(\theta-\theta^*)\frac{\partial D_Y}{\partial p} - \theta R_{pp}\right] < 0 \text{ if } \theta \geq \theta^*,$$

$$\Phi_{Zs^*} \equiv -\frac{\partial D_Y}{\partial p}\theta^*\{E_{pp}(\theta^*-\theta)E_u - R_{pp}[\theta^* E_u - \theta E_{pu}(p+s\theta^*)]\} < 0 \text{ if } \theta^* \geq \theta,$$

respectively (see footnote 11).

From (53), we obtain the effects on the amount of pollution due to stricter environmental policy:

$$\widetilde{J}\left.\frac{\partial Z}{\partial s}\right|_{ds^*=0} = \Phi_{Zs} + \frac{1-\eta}{\eta}D_Y\frac{\partial D_Y}{\partial T}(\theta-\theta^*)E_u E_{pp}\theta < 0 \text{ if } \theta \geq \theta^*, \tag{54}$$

$$\widetilde{J}\left.\frac{\partial Z}{\partial s^*}\right|_{ds=0} = \Phi_{Zs^*} - \frac{1-\eta}{\eta}D_Y\frac{\partial D_Y}{\partial T}\left\{\theta^* R_{pp}[E_u + (s^*-s)E_{pu}\theta] - (\theta^*-\theta)E_u E_{pp}\right\}\theta^* < 0 \text{ if } \theta^* \geq \theta. \tag{55}$$

$$\widetilde{J}\left.\frac{dZ}{ds}\right|_{ds=ds^*} = \Phi_{Zs}+\Phi_{Zs^*}-\frac{1-\eta}{\eta}D_Y\frac{\partial D_Y}{\partial T}\{(\theta^*)^2R_{pp}[E_u+(s^*-s)E_{pu}\theta]-(\theta^*-\theta)^2E_uE_{pp}\}<0 \text{ if } \theta^*\geq\theta. \tag{56}$$

From (28) $\Phi_{Zs}+\Phi_{Zs^*}<0$ if $\theta^*\geq\theta$. See footnote 11. Therefore, we obtain qualitatively similar results to those of exogenous tourism. The intuition is basically the same as the case of exogenous tourism, although the effect on pollution generated by other consumers is ambiguous.

The effects on the tourism TOT, the after-tax price of tourism service, the amount of pollution are summarized in Table 2.

Table 2: Main results (endogenous tourism)

| | $p$ | $p+s\theta$ | $p+s^*\theta^*$ | $Z$ |
|---|---|---|---|---|
| $ds>0,\ ds^*=0$ | $\downarrow^2$ | $\uparrow^1$ | $\downarrow^2$ | $\downarrow^1$ |
| $ds^*>0,\ ds=0$ | $\downarrow^1$ | $\downarrow^1$ | $\uparrow^2$ | $\downarrow^2$ |
| $ds=ds^*>0$ | $\downarrow^3$ | $\uparrow^1$ | $\uparrow^2$ | $\downarrow^2$ |

1: $\theta\geq\theta^*$, 2: $\theta^*\geq\theta$, 3: $\theta=\theta^*$

Lastly, we derive the effect on the tourist expenditure. Substituting (47) and (53) into (38), we obtain the change in tourist expenditure:

$$\widetilde{J}dT=-\frac{1-\eta}{\eta}D_Y(\Phi_{ps}ds+\Phi_{ps^*}ds^*+\theta^*Jds^*)-\frac{1-\eta}{\eta}\frac{\gamma T}{Z}(\Phi_{Zs}ds+\Phi_{Zs^*}ds^*). \tag{57}$$

We are ready to examine the welfare effect of environmental policy. From (30), the welfare change in the case of endogenous tourism is given by

$$E_u\widetilde{J}du=-(p+\theta^*s)\frac{\partial D_Y}{\partial p}\widetilde{J}(dp+\theta^*ds^*)-(E_Z-s)\widetilde{J}dZ+\theta^*(s^*-s)\frac{\partial D_Y}{\partial T}\widetilde{J}dT, \tag{58}$$

where $\widetilde{J}(dp+\theta^*ds^*)$ is given by (47), $\widetilde{J}dZ$ by (53), and $\widetilde{J}dT$ by (57).

Using (32), (47), (53), and (57), (58) is rewritten as

$$\begin{aligned} E_u\widetilde{J}du=&-E_Z\widetilde{J}dZ-p\frac{\partial D_Y}{\partial p}\widetilde{J}(dp+\theta^*ds^*) \\ &+\theta\left[E_uE_{pp}\left(R_{pp}-\frac{\partial D_Y}{\partial p}\right)\theta ds+\frac{\partial D_Y}{\partial p}(E_{pp}E_u-pR_{pp}E_{pu})\theta^*ds^*\right]s \\ &+\frac{1-\eta}{\eta}\frac{\partial D_Y}{\partial T}\left(\theta^*\frac{\gamma T}{Z}M+D_YN\right), \end{aligned} \tag{59}$$

where

$$M\equiv -sH\frac{\partial D_Y}{\partial p}-(s^*-s)(\Phi_{Zs}ds+\Phi_{Zs^*}ds^*),$$

$$N \equiv -sH - \theta^*(s^* - s)(\Phi_{ps}ds + \Phi_{ps^*}ds^* + \theta^* J ds^*).$$

The last term on the RHS of (59) is specific to the case of endogenous tourism (when $\eta \to 1$, the term vanishes). The remaining terms (first through third terms) increase with the pollution tax for tourists if $\theta^* \geq \theta$

Using (25) and (48), $M$ becomes

$$M = R_{pp}\frac{\partial D_Y}{\partial p}[-s^*\theta^* E_u + (s^* - s)\theta p E_{pu}]\theta^* ds^* + s^* E_u(\theta^* - \theta)\frac{\partial D_Y}{\partial p}E_{pp}(\theta^* ds^* - \theta ds)$$
$$- (s^* - s)E_u(\theta)^2 R_{pp}E_{pp}ds,$$

where the coefficient of the first term on the RHS is

$$-s^*\theta^* E_u + (s^* - s)\theta p E_{pu} = -s\theta p E_{pu} + s^*(\theta p E_{pu} - \theta^* E_u) < 0 \text{ if } \theta^* \geq \theta$$

since

$$\theta p E_{pu} - \theta^* E_u < \theta(p + s\theta^*)E_{pu} - \theta^* E_u < 0 \text{ if } \theta^* \geq \theta.$$

See footnote 11. Thus, $M$ is positively related to $ds^*$ if $\theta^* \geq \theta$. However, the effect of $ds$ on $M$ is ambiguous.

Using (20) and (48), $N$ is expressed as follows:

$$N = E_u[-s^*(\theta^*)^2 R_{pp}ds^* + (\theta^* s^* - \theta s)E_{pp}(\theta^* ds^* - \theta ds)].$$

The effect of $ds$ or $ds^*$ on $N$ is ambiguous except for the special case of $\theta = \theta^*$ and $ds = ds^*$.

Although welfare effect of environmental policy aimed at only one side of consumers is in general unclear, numerical simulations in Section 4 will show that there exists a set of parameter values under which stricter environmental regulation aimed at only domestic residents (foreign tourists) deteriorates (improves) domestic welfare.

Lastly, we examine the welfare effect of the stricter environmental policy for both domestic residents and foreign tourists. The welfare expression is given by (58). It is natural to assume $s = s^*$ since we consider the case of $ds = ds^* > 0$. Then the last term on the RHS of (58) vanishes. From (52) and (56), the welfare change is positive if $\theta^* \geq \theta$ and $E_Z - s \geq 0$. This is qualitatively similar result as the case of exogenous tourism.

## 4 Numerical Simulations

We verify unclear analytical results by numerical methods. Numerical simulations in this section utilize MATLAB R2022b. To conduct numerical simulations, we have to specify the production side. Suppose that factors of production are capital and labor. The market-clearing condition for labor is $L = L_X + L_Y$ while that for capital is $K = K_X + K_Y$, where $L$ $(K)$ is the labor (capital) endowment and $L_i$ $(K_i)$ is the amount of labor (capital) devoted to sector $i = X, Y$.

We assume that the production function of each sector is Cobb-Douglas:

$$X = AL_X^{\varepsilon} K_X^{1-\varepsilon}, \tag{60}$$

$$Y = BL_Y^{\delta} K_Y^{1-\delta} = B(L - L_X)^{\delta}(K - K_X)^{1-\delta}, \tag{61}$$

where we have substituted the factor market-clearing conditions into (61). $A$ and $B$ are productivity parameters and $\varepsilon$ $(\delta) \in (0, 1)$ is the labor cost share in sector $X$ $(Y)$.

The free mobility of labor between sectors ensures

$$\varepsilon AL_X^{\varepsilon-1} K_X^{1-\varepsilon} = p\delta B(L - L_X)^{\delta-1}(K - K_X)^{1-\delta}, \tag{62}$$

where we have substituted the factor market clearing conditions.

The free mobility of capital between sectors results in

$$(1 - \varepsilon)AL_X^{\varepsilon} K_X^{-\varepsilon} = p(1 - \delta)B(L - L_X)^{\delta}(K - K_X)^{-\delta}, \tag{63}$$

where we have substituted the factor market clearing conditions as in (62).

The consumption side is already specified. The utility function of domestic residents is given by (1). Then the utility maximization by domestic residents leads to

$$\frac{C_X}{a} = (p + \theta s)\frac{C_Y}{1 - a}. \tag{64}$$

The utility function of foreign tourists is given by (3). Thus, the demand of tourism service by foreign tourists is still given by (4).

In the present setting, the market-clearing condition for tourism service (7) becomes

$$Y = C_Y + D_Y. \tag{65}$$

The amount of pollution (8) is slightly modified as

$$Z = \theta C_Y + \theta^* D_Y. \tag{66}$$

Substituting (65), the budget constraint of the economy (6) is rewritten as

$$pD_Y - (C_X - X) + s^*\theta^* D_Y = 0. \tag{67}$$

The break-even condition for destination choice is still given by (37).

(4), (37), (60), (61), (62), (63), (64), (65), (66), and (67) determine $C_X$, $C_Y$, $D_Y$, $X$, $Y$, $p$, $L_X$, $K_X$, $T$, and $Z$. Then domestic welfare $u$ is calculated by (1). As in Beladi et al. (2009), we obtain the model in the case of exogenous tourism by setting $\eta = 1$, otherwise the model is in the case of endogenous tourism. For the numerical simulation, we set the parameter values as follows: $A = 1$, $B = 1$, $\delta = 0.7$, $\varepsilon = 0.3$, $a = \alpha = 1/3$, $\lambda = 0.8$, $\gamma = \rho = 0.1$, $L = 10$, $K = 10$, $\omega = 1/3$, $s = 0.1$, and $s^* = 0.1$.[14]

## 4.1 Scenario (i)

We explore the possibility of two-tier pricing of tourism service in scenario (i). First, we consider the case of exogenous tourism by setting $\eta = 1$. Proposition 3 states that two-tier pricing arises if condition (a) is satisfied. We consider the case where condition (a) is not satisfied, that is, the amount of pollution is socially insufficient. We will show that two-tier pricing can arise even when neither condition (a) nor condition (b) is satisfied.

### Case (A): $\theta \ll \theta^*$ ($\theta = 1/20$ and $\theta^* = 1$) and $E_Z - s > 0$

In this case, condition (a) of Proposition 3 is not satisfied while condition (b) is satisfied. Table 3 (4) corresponds to the case of exogenous (endogenous) tourism. Benchmark tax rates are $(s, s^*) = (0.1, 0.1)$. We increase $s$ and/or $s^*$ from 0.1 to 0.11. In all the parameter values, $E_Z - s > 0$ holds, meaning that condition (a) is not satisfied.[15] Since $\theta$ is much smaller than $\theta^*$, $\partial Z/\partial s|_{ds^*=0} > 0$ holds. Then, from (33), $\partial u/\partial s|_{ds^*=0} < 0$ holds. See Table 3. In the case of endogenous tourism, we obtain a similar result (see Table 4).

### Case (B): $\theta^* < \theta$ ($\theta = 1/2$ and $\theta^* = 1$) and $E_Z - s > 0$

In this case, neither condition (a) nor condition (b) holds. Although $E_Z - s$ is positive, the absolute value is not so large. For $ds > 0$ amd $ds^* > 0$, the pollution distortion effect is against the two-tier pricing.

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[14]When $\delta = \varepsilon$, we have $p = A/B$ from (62) and (63). In this case, the price of tourism service is fixed by the productivity parameters. In order to take into account the tourism TOT effect, we suppose $\delta \neq \varepsilon$.

[15]From (2), we calculate the Pigouvian tax level as $E_Z = \rho E/Z = \rho[C_X + (p + s\theta)C_Y]/Z$.

Table 3: Exdogenous tourism ($\eta = 1$): $\theta \ll \theta^*$ ($\theta = 1/20$ and $\theta^* = 1$)

| $(s, s^*)$ | (0.1, 0.1) | (0.11, 0.1) | (0.1, 0.11) | (0.11, 0.11) |
|---|---|---|---|---|
| $p$ | 1.23465 | 1.23458 | 1.23436 | 1.23429 |
| $p + \theta^* s^*$ | 1.33465 | 1.33458 | 1.34436 | 1.34429 |
| $Z$ | 1.83920 | 1.83923 | 1.82876 | 1.82879 |
| $u$ | 2.02268 | 2.02267 | 2.02497 | 2.02495 |
| $E_Z$ | 0.68886 | 0.68900 | 0.69342 | 0.69356 |

Table 4: Endogenous tourism ($\eta = 0.8 \neq 1$): $\theta \ll \theta^*$ ($\theta = 1/20$ and $\theta^* = 1$)

| $(s, s^*)$ | (0.1, 0.1) | (0.11, 0.1) | (0.1, 0.11) | (0.11, 0.11) |
|---|---|---|---|---|
| $p$ | 1.24095 | 1.24089 | 1.24052 | 1.24045 |
| $p + \theta^* s^*$ | 1.34095 | 1.34089 | 1.35052 | 1.35045 |
| $Z$ | 1.90921 | 1.90926 | 1.89691 | 1.89696 |
| $u$ | 2.01928 | 2.01926 | 2.02169 | 2.02168 |
| $E_Z$ | 0.66672 | 0.66685 | 0.67161 | 0.67174 |

Regarding (30), the pollution distortion effect is small, and thus the sum of tourism TOT effect and wealth effect is dominant. Thus, two-tier pricing arises. See Table 5 for the case of exogenous tourism. Results in the case of endogenous tourism are presented in Table 6.

### Case (B'): $\theta^* < \theta$ ($\theta = 1$ and $\theta^* = 1/2$) and $E_Z - s \gg 0$

We consider the case where tax rate is small and the pollution distortion effect is strong. When the government increases the pollution tax rate for only domestic residents (foreign tourists), the pollution distortion effect is against (in favor of) the two-tier pricing. For $ds > 0$, the pollution distortion effect dominates negative tourism TOT effect. In this case, two-tier pricing fails to arise: for the government, optimal policy is to increase pollution taxes for both domestic residents and foreign tourists. See Tables 7 and 8.

Table 5: Exogenous tourism ($\eta = 1$): $\theta^* < \theta$ ($\theta = 1$ and $\theta^* = 1/2$)

| $(s, s^*)$ | (0.1, 0.1) | (0.11, 0.1) | (0.1, 0.11) | (0.11, 0.11) |
|---|---|---|---|---|
| $p$ | 1.22309 | 1.22175 | 1.22292 | 1.22158 |
| $p + \theta^* s^*$ | 1.27309 | 1.27175 | 1.27792 | 1.27658 |
| $Z$ | 7.40154 | 7.38612 | 7.40271 | 7.38729 |
| $u$ | 1.81931 | 1.81921 | 1.82009 | 1.81999 |
| $E_Z$ | 0.17740 | 0.17850 | 0.17746 | 0.17856 |

Table 6: Endogenous tourism ($\eta = 0.8 \neq 1$): $\theta^* < \theta$ ($\theta = 1$ and $\theta^* = 1/2$)

| $(s, s^*)$ | (0.1, 0.1) | (0.11, 0.1) | (0.1, 0.11) | (0.11, 0.11) |
|---|---|---|---|---|
| $p$ | 1.22619 | 1.22487 | 1.22594 | 1.22462 |
| $p + \theta^* s^*$ | 1.27619 | 1.27487 | 1.28094 | 1.27962 |
| $Z$ | 7.41741 | 7.40218 | 7.41821 | 7.40296 |
| $u$ | 1.81969 | 1.81959 | 1.82048 | 1.82037 |
| $E_Z$ | 0.17739 | 0.17848 | 0.17745 | 0.17854 |

### 4.2 Scenario (ii)

We consider scenario (ii). From Corollary 3, the simultaneous increase in pollution taxes for both domestic residents and foreign tourists improves domestic welfare if $\theta^* \geq \theta$ and $E_Z - s \geq 0$. Without these conditions, domestic welfare may deteriorate.

#### Case (C): $\theta^* \ll \theta$ ($\theta = 1$ and $\theta^* = 1/20$) and $E_Z - s < 0$

Suppose that the government raises pollution taxes for both types of consumers. When $\theta^*$ is sufficiently small relative to $\theta$, wealth effect is small. Then negative tourism TOT effect outweighs positive wealth effect. The pollution distortion effect is negative since the amount of pollution is insufficient and the increase in pollution taxes further decreases the amount of pollution. Both effects *deteriorate* welfare (see (30) or (58) and note that we consider the case of $s = s^*$ and the effect of $T$ is negligible even in the case of endogenous tourism). See Tables 9 and 10.

Table 7: Exogenous tourism ($\eta = 1$): $\theta^* < \theta$ ($\theta = 1$ and $\theta^* = 1/2$)

| $(s, s^*)$ | (0.015, 0.015) | (0.025, 0.015) | (0.015, 0.025) | (0.025, 0.025) |
|---|---|---|---|---|
| $p$ | 1.23613 | 1.23474 | 1.23596 | 1.23457 |
| $p + \theta^* s^*$ | 1.24363 | 1.24224 | 1.24846 | 1.24707 |
| $Z$ | 7.52379 | 7.50799 | 7.52512 | 7.50930 |
| $u$ | 1.81286 | 1.81287 | 1.81367 | 1.81368 |
| $E_Z$ | 0.16761 | 0.16870 | 0.16767 | 0.16876 |

Table 8: Endogenous tourism ($\eta = 0.8 \neq 1$): $\theta^* < \theta$ ($\theta = 1$ and $\theta^* = 1/2$)

| $(s, s^*)$ | (0.015, 0.015) | (0.025, 0.015) | (0.015, 0.025) | (0.025, 0.025) |
|---|---|---|---|---|
| $p$ | 1.23969 | 1.23833 | 1.23943 | 1.23808 |
| $p + \theta^* s^*$ | 1.24719 | 1.24583 | 1.25193 | 1.25058 |
| $Z$ | 7.54130 | 7.52568 | 7.54225 | 7.52662 |
| $u$ | 1.81319 | 1.81320 | 1.81402 | 1.81403 |
| $E_Z$ | 0.16762 | 0.16870 | 0.16768 | 0.16877 |

## 5 Conclusions

In order to seek a desirable policy to over-tourism, this paper constructs a small open economy model where pollution is generated from consumption of tourism service by domestic residents and foreign tourists. First, we consider the case of exogenous tourism. An increase in pollution tax on consumption of tourism service decreases the price of tourism service, regardless of the target. If the government increases pollution tax for consumers with less emission per unit of tourism consumption than other type of consumers, the amount of pollution can *increase*. The increase (decrease) in pollution tax for foreign tourists (domestic residents) can improve welfare, providing a rationale for two-tier pricing of tourism service implemented in many countries. When the government increases pollution tax for both domestic residents and foreign tourists, domestic welfare can improve. Section 4 reveled that numerical results are similar to the case of endogenous tourism.

There remain some topics not addressed in the paper. First, this paper assumed that pollution reduces only utility of consumers. If traded good is agricultural good, pollution is likely to reduce productivity

Table 9: Exogenous tourism ($\eta = 1$): $\theta^* \ll \theta$ ($\theta = 1$ and $\theta^* = 1/20$)

| $(s, s^*)$ | (0.5, 0.5) | (0.51, 0.5) | (0.5, 0.51) | (0.51, 0.51) |
|---|---|---|---|---|
| $p$ | 1.17524 | 1.17414 | 1.17522 | 1.17412 |
| $p + \theta^* s^*$ | 1.20024 | 1.19914 | 1.20072 | 1.19962 |
| $Z$ | 6.07123 | 6.05720 | 6.07161 | 6.05759 |
| $u$ | 1.81757 | 1.81708 | 1.81765 | 1.81716 |
| $E_Z$ | 0.24784 | 0.24914 | 0.24784 | 0.24914 |

Table 10: Endogenous tourism ($\eta = 0.8 \neq 1$): $\theta^* \ll \theta$ ($\theta = 1$ and $\theta^* = 1/20$)

| $(s, s^*)$ | (0.5, 0.5) | (0.51, 0.5) | (0.5, 0.51) | (0.51, 0.51) |
|---|---|---|---|---|
| $p$ | 1.18026 | 1.17919 | 1.18023 | 1.17916 |
| $p + \theta^* s^*$ | 1.20526 | 1.20419 | 1.20573 | 1.20466 |
| $Z$ | 6.07172 | 6.05772 | 6.07212 | 6.05812 |
| $u$ | 1.81835 | 1.81786 | 1.81843 | 1.81794 |
| $E_Z$ | 0.24846 | 0.24976 | 0.24845 | 0.24976 |

of agricultural sector as in Furukawa et al. (2019), Kondoh and Shimizu (2024), Yabuuchi (2015), and Yabuuchi (2018). Second, this paper assumes tourism industry is under perfect competition. However, tourism industry such as accommodation or restaurants may be under monopolistic competition. Third, the tax revenue can be used to cleansing activity or improving productivity of tourism industry. These topics are left for future research.

## Appendix A Derivation of (13)

$$J = \begin{vmatrix} p\frac{\partial D_Y}{\partial p} - s\theta E_{pp} & E_Z - s\theta E_{pZ} & E_u - s\theta E_{pu} \\ R_{pp} - E_{pp} - \frac{\partial D_Y}{\partial p} & -E_{pZ} & -E_{pu} \\ -\theta E_{pp} - \theta^* \frac{\partial D_Y}{\partial p} & 1 - \theta E_{pZ} & -\theta E_{pu} \end{vmatrix}.$$

Multiply the second row by $s\theta$ and then subtract from the first row to obtain

$$= \begin{vmatrix} (p+s\theta)\frac{\partial D_Y}{\partial p} - s\theta R_{pp} & E_Z & E_u \\ R_{pp} - E_{pp} - \frac{\partial D_Y}{\partial p} & -E_{pZ} & -E_{pu} \\ -\theta E_{pp} - \theta^* \frac{\partial D_Y}{\partial p} & 1 - \theta E_{pZ} & -\theta E_{pu} \end{vmatrix}.$$

Multiply the second row by $\theta$ and then subtract from the third row to obtain

$$= \begin{vmatrix} (p+s\theta)\frac{\partial D_Y}{\partial p} - s\theta R_{pp} & E_Z & E_u \\ R_{pp} - E_{pp} - \frac{\partial D_Y}{\partial p} & -E_{pZ} & -E_{pu} \\ -(\theta^* - \theta)\frac{\partial D_Y}{\partial p} - \theta R_{pp} & 1 & 0 \end{vmatrix}.$$

Expand by the third row to obtain (notice that $E_Z E_{pu} = E_u E_{pZ}$ from the expenditure function (2))

$$\begin{aligned}
&= -\begin{vmatrix} (p+s\theta)\frac{\partial D_Y}{\partial p} - s\theta R_{pp} & E_u \\ R_{pp} - E_{pp} - \frac{\partial D_Y}{\partial p} & -E_{pu} \end{vmatrix} \\
&= \begin{vmatrix} (p+s\theta)\frac{\partial D_Y}{\partial p} - s\theta R_{pp} & -E_u \\ R_{pp} - E_{pp} - \frac{\partial D_Y}{\partial p} & E_{pu} \end{vmatrix} \\
&= (p+s\theta)\frac{\partial D_Y}{\partial p} E_{pu} - s\theta R_{pp} E_{pu} + \left( R_{pp} - E_{pp} - \frac{\partial D_Y}{\partial p} \right) E_u \\
&= -\frac{\partial D_Y}{\partial p} [E_u - (p+s\theta)E_{pu}] + R_{pp}(E_u - s\theta E_{pu}) - E_{pp}E_u \\
&= -\frac{\partial D_Y}{\partial p} E_u [1 - (p+s\theta)E_{pu}/E_u] + R_{pp}(E_u - s\theta E_{pu}) - E_{pp}E_u \\
&= -\frac{\partial D_Y}{\partial p} E_u [1 - (1-a)] + R_{pp}(E_u - s\theta E_{pu}) - E_{pp}E_u \\
&= R_{pp}(E_u - s\theta E_{pu}) - \frac{\partial D_Y}{\partial p} a E_u - E_{pp}E_u,
\end{aligned}$$

where we have used $(p+s\theta)E_{pu}/E_u = 1 - a$ from the expenditure function (2).

## Appendix B Derivation of (29)

Firstly, multiply (10) by $s\theta$ and then subtract from (9) to obtain

$$\left[(p+s\theta)\frac{\partial D_Y}{\partial p} - s\theta R_{pp}\right] dp + E_Z dZ + E_u du = -\theta^*(p+s\theta)\frac{\partial D_Y}{\partial p} ds^* + (s^*\theta^* - s\theta)\frac{\partial D_Y}{\partial T} dT. \tag{B.1}$$

Secondly, multiply (10) by $\theta$ and then subtract from (11) to obtain

$$\left[-(\theta^* - \theta)\frac{\partial D_Y}{\partial p} - \theta R_{pp}\right] dp + dZ = \theta^*(\theta^* - \theta)\frac{\partial D_Y}{\partial p} ds^* + (\theta^* - \theta)\frac{\partial D_Y}{\partial T} dT. \tag{B.2}$$

Lastly, multiply (B.2) by $s$ and then subtract from (B.1) to obtain (29).

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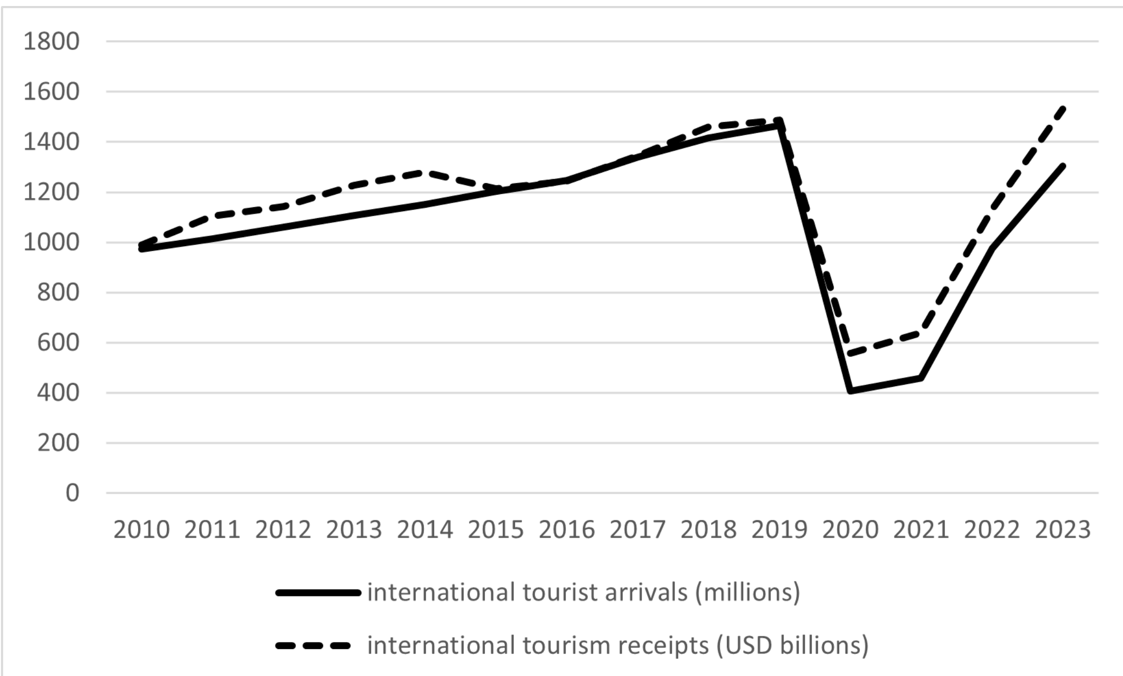


Figure 1: International Tourist arrivals and International tourism receipts: 2010-2023. *Source:* Tourism (2024), International Tourism Highlights, 2024 Edition (data as of September 2024)