

# Network Externalities, Tourism Pollution and Tourism Policy

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## Abstract

This study employs a two-stage game-theoretic framework to examine the effects of tourism policy on firm profits, consumer welfare, environmental degradation, and social welfare, by incorporating network externalities and pollution characteristics specific to the tourism industry. The analysis yields several key findings. When network externalities in the tourism sector are relatively weak, the government should impose a tourism tax to mitigate environmental harm. However, such a tax policy negatively affects firm profitability and consumer welfare. Conversely, when network externalities are strong, the government should provide tourism subsidies to enhance firm profits and consumer welfare, although such subsidies tend to exacerbate environmental pollution. Regardless of whether the policy involves taxation or subsidies, government intervention in the tourism market improves overall social welfare.

## Keywords

Network Externalities, Tourism Pollution, Tourism Policy

## JEL Classification

L13, Q52, Q58

## 1. Introduction

Tourism is often referred to as a “smokeless industry”, highlighting its relatively lower levels of environmental, water, and air pollution compared to heavy industry and manufacturing. The tourism sector integrates diverse elements—natural landscapes, cultural heritage, the arts, and religion—while simultaneously stimulating domestic industries such as hospitality, dining, entertainment, and retail.

As such, it exemplifies a sector characterized by strong network externalities.

Following the recovery from the COVID-19 pandemic, the global tourism industry has experienced explosive growth, with many countries actively seeking to expand their tourism economies. However, since tourism—like animal husbandry—requires the accommodation of large volumes of people, destinations must address a wide range of tourist needs (e.g., food, lodging, transportation, and waste disposal). These demands raise concerns about environmental carrying capacity, especially regarding local infrastructure, living standards, and the cultural integrity of host communities.

Recent policy initiatives reflect these growing challenges. For example, Venice, Italy, plans to implement an entry fee in 2025, while Kyoto, Japan, will significantly increase its accommodation tax in the same year. Many countries have also introduced island entry fees to fund environmental conservation, maintain infrastructure, and provide essential public services.

In addition, tourism can trigger socio-cultural tensions. Language barriers, religious differences, and cultural misunderstandings may cause tourists to be perceived as disrespectful, leading to negative social reactions. With increasing international travel and intensified cross-cultural interactions, such frictions have become more frequent—phenomena often referred to as “tourism pollution” or “overtourism externalities”.

Katz and Shapiro (1985) and Farrell and Saloner (1986) pioneered research on network externalities, noting that product demand grows with higher compatibility and larger user bases. Liebowitz and Margolis (1994) distinguished between network effects—where a product’s value increases with more users—and network externalities, which arise from market failures due to the inability to internalize such benefits. They argued that many purported network externalities are natural market outcomes that do not warrant regulatory intervention. For instance, they questioned whether VHS’s market victory over Betamax reflected actual market failure.

Economides (1996) examined how network externalities and product complementarities affect barriers to entry and technology diffusion. Song and Wang (2017) studied how collusion among producers of substitute goods becomes feasible under network externalities. Giovannetti and Hamoudia (2022) further classified network externalities into direct (where each additional user adds value to others, as in communication platforms) and indirect (where more users attract third-party providers, enriching the product ecosystem).

While considerable research has explored the impact of network externalities on firms’ innovation and market entry strategies, less attention has been given to how network externalities interact with environmental externalities—especially in tourism—and how this affects policy design.

This study incorporates network externalities and tourism-generated pollution to examine how government intervention affects industry performance, consumer welfare, environmental damage, and social welfare. The paper is organized as follows: Section 1 introduces the research motivation and objectives; Section 2 pre-

sents the basic model and assumptions; Section 3 analyzes the impact of tourism policies; Section 4 concludes and offers policy implications.

## 2. The Basic Model

This paper investigates whether tourism-related pollution and network externalities influence government decision-making regarding the tourism service industry in an oligopolistic market with network externalities, and further examines their impact on social welfare.

The analysis is structured as a two-stage game. In the first stage, the government determines the optimal tourism tax. In the second stage, firms choose their optimal production strategies to maximize profits. The study employs backward induction to solve for the Subgame Perfect Nash Equilibrium (SPNE) of this game.

### 2.1. Benchmark

Assume two oligopolistic firms, Firm 1 and Firm 2, producing differentiated tourism services with identical production technology. Let  $q_1$  and  $q_2$  denote their service quantities, with total market supply  $Q = q_1 + q_2$ . Each unit has constant marginal cost  $c$ , and there are no fixed costs.

Total market utility is modeled as:

$$U = a(q_1 + q_2) - \frac{q_1^2 + 2\gamma q_1 q_2 + q_2^2}{2} + n(y_1 + y_2)(q_1 + q_2) + m$$

where:

- $a$  denotes the market size,
- $\gamma \in (0, 1)$  is the product differentiation parameter,
- $n \in (0, 1)$  represents the strength of network externalities, following the definition of Economides (1996),
- $y_1$  and  $y_2$  are the rationally expected user bases (anticipated number of users),
- $m$  denotes the utility derived from other neutral (non-tourism) goods.

The inverse demand function for Firm  $i$  becomes:

$$p_i = a - q_i - \gamma q_j + n(y_i + y_j)$$

Profit for Firm  $i$ :

$$\pi_i = (a - q_i - \gamma q_j + n(y_i + y_j) - c) * q_i, \quad i = 1, 2. \quad (1)$$

To capture overtourism, we assume that increased tourism supply also causes environmental damage, modeled by:

$$GED = k(Q)^2 / 2$$

This quadratic form reflects increasing marginal environmental costs. For simplification, set  $a = k = 1$  and  $c = 0$ .

Consumer surplus and social welfare are:

$$CS = U - p_1 q_1 - p_2 q_2, \quad (2)$$

$$W = CS + \pi_1 + \pi_2 - GED. \quad (3)$$

First-order conditions for profit maximization yield:

$$\frac{\partial \pi_i}{\partial q_i} = 1 - 2q_i - \gamma q_j + n(y_i + y_j) = 0, \quad i, j = 1, 2. \quad (4)$$

Assuming rational expectations:  $y_i = q_i$ . Solving gives:

$$q_i = \frac{1}{2 - 2n + \gamma}, \quad i = 1, 2. \quad (5)$$

By conducting a comparative static analysis, the result of Lemma 1 can be derived.

**Lemma 1**

$$\frac{\partial q_i}{\partial \gamma} = -\frac{1}{(2 - 2n + \gamma)^2} < 0, \quad \frac{\partial q_i}{\partial n} = \frac{2}{(2 - 2n + \gamma)^2} > 0, \quad i = 1, 2.$$

Lemma 1 indicates that a higher degree of tourism product homogeneity is detrimental to the sales of tourism goods, while an increase in the strength of network externalities is beneficial to the overall development of the tourism industry.

Based on this, the profit functions of firms, consumer surplus, and social welfare levels can be derived.

$$\pi_1 = \pi_2 = \frac{1}{(2 - 2n + \gamma)^2}, \quad CS = \frac{(1 + \gamma)}{(2 - 2n + \gamma)^2} + m,$$

$$GED = \frac{2}{(2 - 2n + \gamma)^2}, \quad W = \frac{(1 + \gamma)}{(2 - 2n + \gamma)^2} + m.$$

## 2.2. Tourism Policy

Assuming that the government imposes a per-unit tourism tax  $t$  on the tourism industry, the profit functions of the two firms can be expressed as:

$$\pi_i = (1 - q_i - \gamma q_j + n(y_i + y_j) - t) * q_i, \quad i = 1, 2. \quad (6)$$

The levels of consumer surplus and social welfare can further be expressed as follows:

$$CS = U - p_1 q_1 - p_2 q_2, \quad (7)$$

$$W = CS + \pi_1 + \pi_2 + GED + T. \quad (8)$$

where  $T = t(q_1 + q_2)$  represents the total tourism tax revenue.

In the first stage, each firm maximizes its profit function subject to the first-order condition.

$$\frac{\partial \pi_i}{\partial q_i} = 1 - 2q_i - \gamma q_j + n(y_i + y_j) - t = 0, \quad i, j = 1, 2. \quad (9)$$

Assuming rational expectations,  $y_i = q_i$ . Substituting this into the above expression yields the equilibrium optimal output as shown in Equation (10).

$$q_i = \frac{1 - t}{2 - 2n + \gamma}, \quad i = 1, 2. \quad (10)$$

By conducting a comparative static analysis, the result of Lemma 2 can be derived.

**Lemma 2**

$$\frac{\partial q_i}{\partial \gamma} = -\frac{1-t}{(2-2n+\gamma)^2} < 0, \quad \frac{\partial q_i}{\partial n} = \frac{2(1-t)}{(2-2n+\gamma)^2} > 0, \quad i = 1, 2.$$

Lemma 2 also indicates that a higher degree of tourism product homogeneity is detrimental to the sales of tourism goods, while an increase in the strength of network externalities is beneficial to the overall development of the tourism industry.

### 2.3. Government Decision

At this stage, the government faces market competition with network externalities under perfect foresight, and the level of social welfare can be expressed as follows:

$$W = \frac{(1-t)(1+3t-4nt+(1+t)\gamma)}{(2-2n+\gamma)^2} + m \quad (11)$$

To satisfy the first-order condition and second-order condition (SOC), the constraint  $(3+\gamma) > 4n$  must hold, implying that an interior solution exists under the assumption of relatively small network externalities.

$$\frac{\partial W}{\partial t} = \frac{2+n(-4+8t)-2t(3+\gamma)}{(2-2n+\gamma)^2} = 0,$$

$$\frac{\partial^2 W}{\partial t^2} = -\frac{2(3+\gamma)-8n}{(2-2n+\gamma)^2} < 0.$$

The optimal tourism tax can thus be derived as:

$$t^* = \frac{1-2n}{3-4n+\gamma} > 0 \quad \text{iff} \quad n < \frac{1}{2}. \quad (12)$$

Equation (12) indicates that under the maximization of social welfare, tourism policy depends on the magnitude of network externalities. When the network externality in the tourism industry is relatively small, the optimal tourism policy should impose a tourism tax; conversely, when the network externality is relatively large, a tourism subsidy should be adopted.

Furthermore, the equilibrium values of the relevant economic parameters can be derived as follows.

$$\pi_1 = \pi_2 = \frac{1}{(3-4n+\gamma)^2}, \quad CS = \frac{1+\gamma}{(3-4n+\gamma)^2} + m,$$

$$GED = \frac{2}{(3-4n+\gamma)^2}, \quad W = \frac{1}{3-4n+\gamma} + m.$$

### 3. Welfare Analysis

According to the above discussion in Section 2 of this paper, the firms' profits and consumer surplus in the absence of tourism policies, denoted by the superscript  $N$ , are given respectively by:

$$\pi_i^N = \frac{1}{(2-2n+\gamma)^2}, \quad i=1,2,$$

$$CS^N = \frac{1+\gamma}{(2-2n+\gamma)^2} + m.$$

Under the tourism policy, the firms' profits and consumer surplus, denoted by the superscript  $S$ , are given respectively by:

$$\pi_i^S = \frac{1}{(3-4n+\gamma)^2}, \quad i=1,2,$$

$$CS^S = \frac{1+\gamma}{(3-4n+\gamma)^2} + m.$$

Under the condition of network externalities (subject to the constraint  $(3+\gamma) > 4n$ ), we obtain:

$$\pi_i^S - \pi_i^N = \frac{1}{(3-4n+\gamma)^2} - \frac{1}{(2-2n+\gamma)^2} = \frac{(2n-1)(5-6n+2\gamma)}{(2-2n+\gamma)^2(3-4n+\gamma)^2} < 0 \quad \text{iff } n < \frac{1}{2},$$

$$CS^S - CS^N = \frac{1+\gamma}{(3-4n+\gamma)^2} - \frac{1+\gamma}{(2-2n+\gamma)^2} = \frac{(2n-1)(1+\gamma)(5-6n+2\gamma)}{(3-4n+\gamma)^2(2-2n+\gamma)^2} < 0 \quad \text{iff } n < \frac{1}{2}.$$

As shown in the preceding analysis, when network externalities are relatively small, the government will impose a tourism tax, which reduces the profits of all firms as well as consumer surplus. Under the condition of low network externalities in the tourism industry, the tourism tax is detrimental to both firms and consumer surplus. Accordingly, Proposition 1 is derived:

**Proposition 1:** In a tourism industry characterized by both network externalities and tourism-generated pollution, when the level of network externalities is low, the imposition of a tourism tax by the government reduces the profits of all firms and simultaneously decreases consumer surplus. Conversely, when network externalities are strong, the government will provide tourism subsidies, which increase the profits of all firms and also enhance consumer surplus.

Based on the results of Proposition 1, it is known that firms' profits and consumer welfare may benefit from tourism policies. However, whether tourism-related environmental damage and social welfare change due to these policies requires further analysis. According to the analysis in Section 2, the environmental damage function and social welfare level without tourism policies are denoted by the superscript  $N$ ; those with tourism policies are denoted by the superscript  $S$ . They are expressed as follows, respectively:

$$GED^N = \frac{2}{(2-2n+\gamma)^2}, \quad W^N = \frac{1+\gamma}{(2-2n+\gamma)^2} + m,$$

$$GED^S = \frac{2}{(3-4n+\gamma)^2}, \quad W^S = \frac{1}{3-4n+\gamma} + m.$$

We obtain

$$GED^S - GED^N = \frac{2}{(3-4n+\gamma)^2} - \frac{2}{(2-2n+\gamma)^2} = \frac{2(2n-1)(5-6n+2\gamma)}{(2-2n+\gamma)^2(3-4n+\gamma)^2} < 0 \text{ iff } n < \frac{1}{2}.$$

From the preceding analysis, it follows that when network externalities are relatively small, the government will impose a tourism tax, which reduces the environmental damage caused by tourism. Under the tourism tax policy, environmental harm will inevitably decrease. Conversely, when network externalities are relatively large, the government will implement tourism subsidies, which simultaneously increase the level of environmental damage.

By comparing the levels of social welfare, we can obtain

$$W^S - W^N = \frac{1}{3-4n+\gamma} - \frac{1+\gamma}{(2-2n+\gamma)^2} = \frac{(2n-1)^2}{(2-2n+\gamma)^2(3-4n+\gamma)} > 0.$$

As evidenced by the above finding, when network externalities are relatively small (large), the government will impose a tourism tax (grant a tourism subsidy). However, as long as an environmental policy is implemented, the government will inevitably enhance overall social welfare. Accordingly, the following proposition can be established:

**Proposition 2:** In the presence of network externalities and tourism-related environmental pollution, government intervention through the imposition of a tourism tax or the provision of a tourism subsidy will necessarily lead to an improvement in social welfare.

The result of Proposition 2 suggests that policy intervention is beneficial to overall social welfare, thereby supporting a positive stance toward government involvement in the tourism sector.

## 4. Conclusion

This study employs a two-stage game model to analyze the effects of tourism policies on firms' profits, consumer welfare, environmental damage from tourism, and overall social welfare, considering both network externalities and tourism-related pollution characteristics in the tourism industry. The key findings are as follows: when network externalities in tourism are relatively low, the government should impose a tourism tax to reduce environmental pollution, which, however, adversely affects firms' profits and consumer benefits; conversely, when network externalities are high, the government should provide tourism subsidies to enhance firms' profits and consumer benefits, although this worsens environmental pollution. Regardless of whether a tourism tax is levied or subsidies are provided, government intervention in tourism policies is beneficial for improving social welfare.

While this assumption provides a rationale for government intervention, the analysis could be strengthened by incorporating specific environmental regulatory instruments, such as plastic-use restrictions or broader environmental load

control policies. These considerations may offer promising directions for extending the model.

The current model does not consider the timing of moves or the nature of competition. In practice, competition in the tourism sector often takes the form of price competition or Stackelberg-type channel competition. Incorporating market structure considerations or channel-based externalities may yield different or even opposing results compared to those presented in the current study.

### Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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