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# Complex Tourism Dynamics and Fiscal Sustainability

Akash Sedai, Francesca Medda*

*University College London, Gower Street, London, UK, WC1e 6BT*

**Abstract**

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Tourist arrivals in large numbers inflict costs attributable to congestion and pollution onto host cities. Internalising these externalities is the main economic argument for a tourism levy. Therefore, an appropriate and sustainable levy, that is at least equivalent to the marginal cost, is required to compensate the host cities Under the umbrella of Complex Systems analysis, we simulate an Agent Based two-city tourism market model (ABM) to demonstrate how negative externalities can be cut without compromising aggregate income from the tourism industry. The capped arrival permit model of tourism levy outperforms the tax model by leveraging tax elasticities of tourism demand in cities. We show that the aggregate income of cities that adopt the system can be improved at a given total cost, or the total cost can be reduced while maintaining a given level of income. The objective of the paper is to help reduce negative externalities in major cities where over-tourism is a pressing issue while simultaneously improving the distribution of revenue to less frequented towns by channeling tourists through subsidies.


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*Keywords:*

## 1. Introduction

Here Complex systems, present in many fields, involve structures where interactions between constituents produce emergent behaviours that cannot be easily deduced from individual elements. In economics, non-linear, adaptive interactions lead to emergent phenomena like growth and inflation, which arise from the dynamic interactions among agents (Kirman 2006; Hayek 1964). The economy, as a complex system, is inherently non-equilibrium and constantly evolving (Arthur 2010). Tourism shares these features as a dynamic system where interdependent actors, such as visitors and institutions, interact in non-linear ways, contributing to GDP (Baggio 2008). Traditional linear models fall short in capturing these complexities, creating a need for more nuanced models that incorporate non-traditional variables (Mckercher 1999).

* Corresponding author. Tel.: +0-000-000-0000 ; fax: +0-000-000-0000 .
*E-mail address: akash.sharma@ucl.ac.uk*


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In tourism, a key challenge is developing frameworks to address both spatial and temporal dynamics. Many economic models fail to fully capture the spatial complexity of tourism. For example, dynamic extensions of New Economic Geography explore regional growth through agglomeration and innovation but are limited to two locations and risk over-concentration (Baldwin & Martin 2003). Models like Zipf's Law explain city sizes but lack geographic distribution considerations (Gabaix 1999; Duranton 2007). While some models incorporate capital mobility, they often treat regions as independent, failing to account for the interconnected nature of tourism destinations (Desmet & Rossi-Hansberg 2009; Brito 2004).

Tourism, a major global industry, has faced significant challenges, particularly during the Covid-19 pandemic, which presents an opportunity for more sustainable growth. The sector contributes to environmental degradation, including 8% of global emissions (Lenzen et al. 2018). Sustainable policies, such as tourism levies and tradable permits, can help internalise negative externalities like congestion and pollution, while also improving income distribution to less-visited areas (Ihalanayake 2007; Schwartz 2017). Simulations suggest such policies can mitigate the negative impacts of tourism while fostering more equitable economic growth (Hughes 1981; Sheng et al. 2017).

## 2. Agent-Based Modeling

Agent-Based Models (ABMs) simulate real-world systems through the interactions of unique, autonomous agents, making them ideal for studying complex phenomena such as market dynamics and resource use (Railsback & Grimm 2012; Mo et al. 2013). ABMs have gained popularity in economics for their ability to model heterogeneous agents making independent decisions, unlike general equilibrium models (Zhu et al. 2016). Early ABM applications include greenhouse gas emissions trading (Mizuta & Yamagata 2001), EU carbon trading (Chappin & Dijkema 2007), and biodiversity permits (Drechsler & Hartig 2011). In tourism, ABMs have been used to model visitor arrivals, decision-making, and destination choices, helping researchers understand tourism's adaptive and chaotic nature (Johnson & Sieber 2010; Alvarez & Brida 2019).

In this study, we extend ABM to simulate permits in tourism, where the price is determined by visitor behaviour rather than the cities themselves. Overcrowded destinations, with limited growth potential, aim to maintain their income by controlling arrivals. Income is calculated as revenue minus cost, and in over-touristed cities, rising costs often outpace revenue. By adjusting arrivals, costs decrease, allowing cities to sustain income while also internalising externalities and preventing overconsumption. The model reflects how cities can balance growth and sustainability through dynamic visitor management.

A sustainable levy definitely helps to limit demand, but this problem could be further mitigated if tourist destinations were more dispersed rather than concentrated in a few select cities at a given time. To do this, we suggest a pricing mechanism where cities charge a tourism levy that changes with the number of arrivals and depends on two parameters. The process is explained below

Procedure

- All cities are subject to a cap on tourist arrivals. Among them, some cities will be popular destinations and some may not reach this cap, even if they do not impose a tax on arrivals
- Set the cap at a level that any city is able to purchase, if required
- Set a fixed price on per unit permit or a block of permits
- Divide proceeds among each city proportionally based on the surplus retained
- Use the proceeds to give away tourism subsidies

Outcome

- The policymaker has two parameters they can control to achieve their objectives: level of cap and fixed price per permit block
- Cities receiving the fewest tourists will get the most proceeds. This new funding will allow them to create subsidies to increase tourism demand in the next period
- Because elasticities of tourism demand differ among cities, popular destinations may lose less from a small increase in levy than what non-popular destinations would gain from small increases in subsidies.

Because cities have limited capacities, the externalities and their abatement costs increase at a faster rate as demand increases. Our goal is to find a combination of cap and price that fits the objective of the policymaker: one where limiting tourist arrivals during peak seasons does not affect a city's annual revenues as it decreases its overall externalities. At the same time, the situation is creating a new source of revenue for those towns lacking in investment, but which are also low, or even negative, in externality abatement costs. The simulation framework is explained in the next section.

#### 3.1.1 Revenue function

The tourism sector balance (revenue - expenditure) of city is given by Bi.

$$B_i = R_i(\alpha_i) - C_i(\alpha_i) \tag{1}$$

$R_i(\alpha_i)$ is the revenue function and $C_i(\alpha_i)$ is the minimum total expenditure and associated social costs of allowing an arrival of $\alpha_i$

Revenue function: We have a revenue that is a linear function of arrivals (in 000s). The functions differ under permits and taxes as can be seen in the equations below. The cumulative total revenue of city i at time t is given by

$$\begin{aligned} R_{i_t} &= \int_0^{\alpha_t} \alpha_{i_t} + \gamma_{i_t}\alpha_{i_t} - p(\alpha_{i_t} - q_t^0), \ \text{ if } \alpha_{i_t} > q_t^0 \\ R_{i_t} &= \int_0^{\alpha_t} \alpha_{i_t} + \gamma_{i_t}\alpha_{i_t}, \ \text{ if } \alpha_{i_t} \leq q_t^0 \end{aligned} \tag{2}$$

where, $\alpha_i$ = arrivals in city $I$, $q_i^0$ = arrival cap of city $I$, $p$ = pre-specified permit price and $\gamma_i$ = tax or subsidy of city $i$

#### 3.1.2 Cost function

There are significant positive and negative externalities arising from tourism. Positive externalities exist where third-party businesses and consumers benefit from tourism activity, e.g., increased choice for domestic residents and preservation of heritage, reinforcing the city's attractiveness as a location from which to conduct international business (Deloitte & Oxecon 2008). Whereas negative externalities exist when other businesses and consumers are adversely affected by tourism activity, e.g., congestion, erosion of natural heritage where open access to spaces can lead to both economic and environmental overexploitation of the natural environment.

The cost function we use is assumed to include both private and social costs. We have negative cost for smaller values of $\alpha$ to account for the assumption that tourism in towns where average arrivals is low do show higher total benefits (private and social) than total cost. We use a Cobb-Douglas format for the cost function where total cost is an increasing function of arrivals. The cumulative total cost of city $i$ at time $t$ is given by

$$C_{i_t} = \int_0^{\alpha_t} b\alpha_{i_t} + c\alpha_{i_t}^2 - d\alpha_{i_t}^3 \tag{3}$$

#### 3.1.3 Arrival demand

The arrival demand has a basic demand function, where $\alpha_{\min}$ is the intercept, $m_i$ is the slope, and $\gamma_i$ is the suistanable levy or subsidy charged by city $i$. The slope $m_i$ is higher for unpopular cities and lower for popular ones. It is important in determining the sensitivity of change in arrival demands when a levy is imposed or changed.

$$\alpha_i = \alpha_{\min} - m_i * \gamma_i \tag{4}$$

#### 3.1.4 Growth rates

The arrival growth rate demonstrates how demand changes over time. Because the cost function is non-linear, as arrivals approach critical levels, abatement costs increase faster than the marginal revenue. This has an impact on $\gamma_i$ charged by cities, and consequently on the demand for arrivals. The permit growth rate, on the other hand, is necessary to ensure that cities in deficit will always have the option to buy permits whenever required at a fixed price per unit, or block set by the allocator.

$$(t) = \alpha_0 e^{rt} \quad (5)$$
$$\text{cap}(t) = \text{cap}_0 e^{rt} \quad (6)$$

### 3.2.1 Two-city simulation setup

In our simulation, one second represents 100 days (0.01 second per day) and we run the model for 18.5 seconds, which is comparable to five years in real time. There are two cities, A, which has high arrivals and B, with lower arrivals – only A imposes a levy on visitors. We also assume that both cities have the same cost and function. We set the arrival cap at 2000 for each; any arrival beyond this limit must be purchased from another city at a fixed $P_0$. The equations are chosen such that cities will be able to buy as many permits as they need to allow more visitors, but they will be limited by a fast-increasing cost function. The arrival growth rate is chosen as 5% per year (0.27% per day) while the growth rate of permits in circulation is taken to be 1% for the same period; both increase with continuous compounding. We use the same growth rate for all cities even though popular cities tend to have higher growth rates. The initial values for arrival demand equation are intercept=200 and slope=10 for city A and intercept=1000 and slope=25 for city B.

All cities having arrivals over the cap will pay a pre-specified price per deficit. The proceeds will be shared among the cities with surpluses on their cap proportionally based on their surplus. The deficit and surplus are computed as follows:

$$\text{Excess demand} = \Sigma(\alpha_i - q_i^0) * I_d \quad (7)$$
$$\text{Surplus} = \Sigma(q_i^0 - \alpha_i) * I_s \quad (8)$$

where $I_d$ and $I_s$ are deficit and surplus indicator functions that take a value 1 if $\alpha > q^0$, or 0 otherwise and vice versa, respectively.

### 3.2.2 Tax and subsidy

The cities imposing a sustainable levy will price their tax similar to the way monopolistically competitive firms charge, i.e., at marginal revenue = marginal cost. The $\gamma_i$ is computed as shown below.
(See also appendix A)

$$\gamma_i\,(\text{tax}) = b + 2c\alpha_i - 3d\alpha_i^2 + p - 1,\ \text{if } \alpha_i > q^0 \quad (9)$$

The revenue generated from cities with deficits is distributed to the cities with surpluses, divided by the number of arrivals, and then paid as subsidies.

$$\gamma_i\,(\text{subsidy}) = \frac{\text{excess demand} * p * \text{weight}_i}{\alpha_i},\ \text{if } \alpha_i \leq q^0 \quad (10)$$

## 4 Discussion and conclusion

The simulations show that the capped model outperforms the tax model in terms of total income and total externalities. By leveraging tax elasticities, we can increase the combined income of each region (city/town/municipality) at a given cost, or decrease cost at a given income. The strength of the result will of course depend on the difference in tax elasticity of tourism of the cities that use some form of levy. Based on the demand, revenue and cost functions we used in the simulations, we find that both cities with over-tourism and under-tourism are able to benefit from adopting this model.

The simulations are run four times with different combinations of cap levels and prices under the cap model, and once under the tax model. All demand and cost functions and growth rate used are identical in both tax and cap models. The price charged to the visitors is different for each city and can take negative values (subsidy). This is computed in each time step based on equalising marginal cost and marginal revenue of the levying city and as shown in eq. 10 for the non-levying city.

In many popular cities, the decrease in demand as a result of a levy is often not sufficient to offset the impact of the higher price paid per unit because it does not account for the true social cost. If the sustainable levy is charged where the marginal revenue is equal to marginal cost, this ensures there is no overconsumption. However, pricing the levy equal to marginal revenue has a wider purpose in this case rather than just maximising income. The extra income that comes from the difference between marginal revenue and marginal cost can be used to make these cities buy permits from other cities that are in surplus of these permits. They can then use those revenues to subsidise their own tourism sector. Channelling tourists in this way has the potential to increase the aggregate tourism income among cities. Below are the aggregate results of four simulations compared with the output from the fixed tax model. The individual output (non-aggregate) figures and tables of Cities A and B are given in appendix B and C.

**Figure 1. Simulation 1. cap = 2400; price = 1**

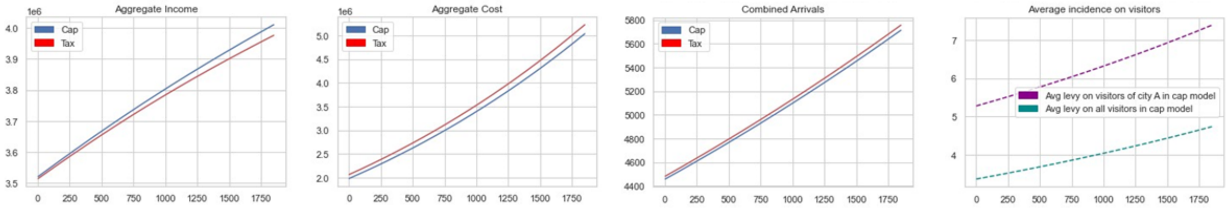



**Figure 2. Simulation 2. Cap = 2400; Price = 6**

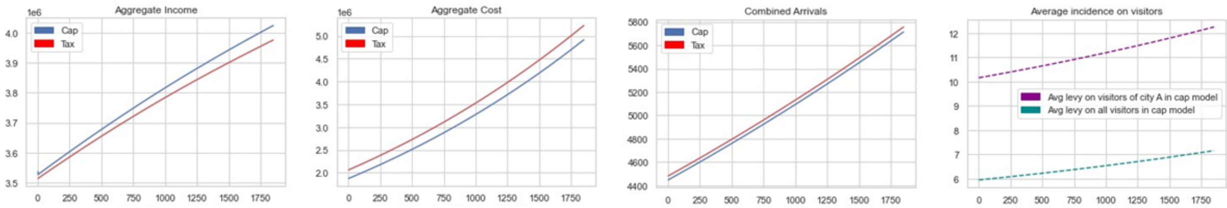



**Figure 3. Simulation 3. Cap = 2800; Price = 10**

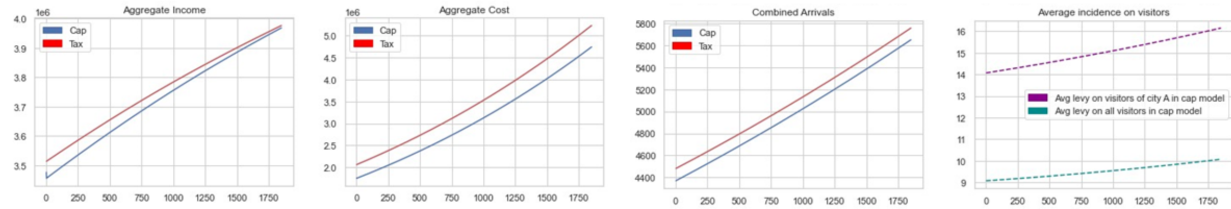
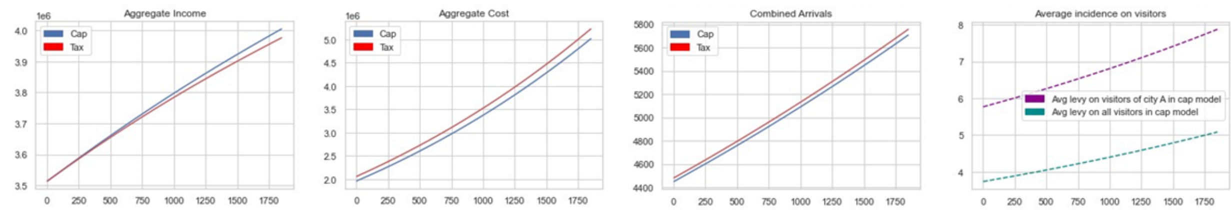



**Figure 4. Simulation 4. Cap = 2700; Price = 1.5**



From figures 1-4 we can observe that in 3 out of 4 combinations of cap and price, the cap model has a higher aggregate output, and 4 out of 4 have a lower aggregate cost. Low cap low price (sim 1): In this scenario the levying city needs to start buying blocks of permits before it reaches critical levels, but at a lower price. The aggregate incomes of both (tax and cap) models are similar in the beginning, but they diverge as number of arrivals increases because cost is increasing faster than price being paid for permits. Low cap medium price (sim 2): Similar to scenario two in terms of aggregate results, but individually, city B is better off while city A is worse off. High cap high price (sim 3): This combination has the least desirable outcome. The price, $p$ is a factor in the marginal revenue function which partly determines the sustainable levy, $\gamma_i$. The $\gamma_i$ is high enough to lower the arrivals to a level that is less than desirable. However, even though the fixed tax model has a superior aggregate income, the income gap between the two models is closing in while holding the gap between the level of total cost. High cap high price (sim 4): In this simulation we observe that the welfare gain is the least strong for city B, since the price per unit permit is low, and the allocation for city A is high. This also indicates that as cap increases and price decreases, the output from the cap model approaches the tax model for city B. In case of city A, the levy is still higher than that of the tax model, and this difference is also larger than the amount the city spends on per unit of permits. Hence, the income curves are diverging.

The dynamics is such that, given a fixed cap at time $t$, varying the price affects the demand in the levying city as it directly affects $\gamma_i$, but whether it increases the revenue for the city with a surplus is ambiguous and depends on the tax elasticity of demand. Whereas given a fixed price at time $t$, reducing the cap increases the revenue from the sale of permits in cities with surpluses which will go towards the subsidies in non-levying cities with a surplus on cap.

We have demonstrated that our pricing model can potentially generate higher aggregate revenues. The best combination of cap and price depends on the objective of the allocator, or the kind of social welfare philosophy they follow. This is possible when cities have different elasticities of tourism demand (or when they differ significantly in trade-offs of industry growth and externalities). Given the public administration of many cities, there is a need to develop policies that address both externality management and aggregate income goals. To maintain long-run competitiveness and true well-being of the locals, cities must internalise their externalities directly and swiftly. Our results presented here may assist in achieving better externality and revenue management and potentially encourage further research in this field to develop other practical strategies for correcting market failures. The model can be extended to incorporate seasonality and varying elasticities of tourism as well as a spatial aspect of proximity of cities. We leave this for future research.

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