To regulate congestion with prices: an application of a repeated random utility model to outdoor recreation

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Abstract : *In France open access is the rule for recreational areas. This generally leads to suboptimal equilibrium of visitation due to congestion externality. Furthermore, congestion is a result of a Nash equilibrium. This assumption needs to be taken into account in econometric estimations and in welfare calculations. In our work, we explore some ways of regulating congestion by prices. Repeated random utility models are estimated on data about the visitation of 43 coastal sites from west France, using a procedure which ensures the consistency with the Nash equilibrium. Taxing only one site reduces the collective welfare because of substitution effects, whereas global taxation manages to maximise welfare due to participation reduction.*

Keywords : *congestion, Nash equilibrium, random utility model, regulation, recreation demand.*

JEL classification codes : Q26,Q51

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1 Introduction

Congestion is likely an important attribute of the recreation experience because its quality depends on how many people practice the same activity or visit the same site. In France, open access is the rule for recreational areas, especially for coastal zones. It may lead to overvisitation, a situation close to the tragedy of the commons described for natural resources (Hardin, 1968). People do not take into account the congestion externality they impose on their fellow visitors such that visitation equilibrium is not optimal because of this external effect.

In the 70's, this problem was theoretically analyzed using a continuous demand framework (Fisher and Krutilla, 1972; Anderson and Bonsor, 1974; Anderson, 1980). But in the 90's, these models has been phased out in favor of random utility models (RUM) which allows for substitution effects between alternatives. Visitation equilibrium has also been studied in this framework. Boxall and Adamowicz (2000) assumed that the probability of visiting a site depends on the sum of individual probabilities of visiting this same site, such that congestion is the result of a Nash equilibrium. But, their model is not estimated at this equilibrium. Bayer and Timmins (2007) described a methodology to estimate RUM where congestion effets or spillovers are the result of a Nash equilibrium. In the recreation demand area, only Timmins and Murdock (2007) applied this methodology.

Unfortunately in these papers, optimal visitation is not a concern. In 2009, Leplat and Le Goffe (2009) theoretically derive the equilibrium of visitation and the optimal visitation in a two sites repeated RUM. Optimal visitation is calculated using a recent measure of welfare (Erlander, 2005). The author show a difference between equilibrium and optimum of visitation due to two external effects: a first effect of "participation", people participate too much and a second of " repartition", the high quality site is too much visited. To internalize these two external effects, two taxes are necessary. In fact, introducing only one tax leads to a drop of welfare because of substitution effects between the two sites.

While RUM are interesting to analyze impacts of congestion, they have been little used in this goal. Yet, introducing congestion in RUM is a complicated problem. It is likely an endogenous attribute. If repulsive or attractive unobserved attributes affect site choice, congestion will be correlated with the error term and becomes endogenous rather as independent as it is assumed in RUM. RUM are non linear models so that endogeneity cannot be controlled by an instrumental variables strategy. Berry, Levinsohn and Pakes (1995) proposed a method to control this endogeneity: the BLP approach. This method was adapted to recreational demand model by Bayer and Timmins (2007) and applied by Timmins and Murdock (2007). Berry (1994) pointed out that alternative specific constants can be introduced in the choice model to capture the average effect of alternative observed and unobserved attributes. Next, estimated alternative specific constants have to be regressed against the observed attributes. Briefly, Berry (1994) " *showed that the endogeneity could be taken out the choice model, which is inherently non linear, and put into a linear regression model, where endogeneity can be handled through standard instrumental variables estimation".* (Train, 2008).

O'Hara (2007) proposed an alternative strategy using instrumental variables to control endogeneity of congestion. Even if instrumental variable is not a rigorous way to control endogeneity in RUM, which are non linear models, his iterative procedure ensures the consistency with the Nash equilibrium. This consistency is necessary to conduct simulations of measures of regulation of congestion, which change the equilibrium of visitation.

Our analysis aims to look at the impacts of price regulation of congestion on collective welfare in a repeated RUM. We want to see how a tax at one site or at many sites can improve welfare. This is a more complicated task than in continuous demand models because of substitution effects between sites. Derivation and estimation of equilibrium of visitation in RUM have been studied very recently such that, to our knowledge, regulation has not been addressed yet in a satisfactory way . For instance, Hanley et al. (2002) examined different measures to ration access to rock climbing sites, but congestion remains constant whereas reducing congestion is the goal of the policies. Welfare analysis studied only how ignoring congestion can lead to significant biases in measuring the value of a site or the benefits of a policy (Timmins and Murdock, 2007; O'Hara, 2007).

We use a repeated RUM to explore the impact of congestion on site choice and participation. Because collective welfare is probably more influenced by the level of visitation than the repartition of visitors *i.e.* relative congestion, modelling participation appears particularly relevant to study regulation of crowding. Then, the taxation scheme must influence as much the participation decision as the site choice.

Our data pertains to a part of a coastal zone of Brittany in the west of France. This area is divided in 43 sites. This low number of sites prevents us to use the BLP approach. Furthermore, this technique has not been developed in a repeated RUM. However, we think alternatives are well-described by our typology. Then, we assume that it remains very little heterogeneity in the error term such that congestion is not endogenous.

After a description of our model in section 2, we explain our procedure of estimation in section 3. In section 4, we describe the data set we use in our application. Section 5 reports models estimates. In section 6, regulation policies are simulated and section 7 concludes.

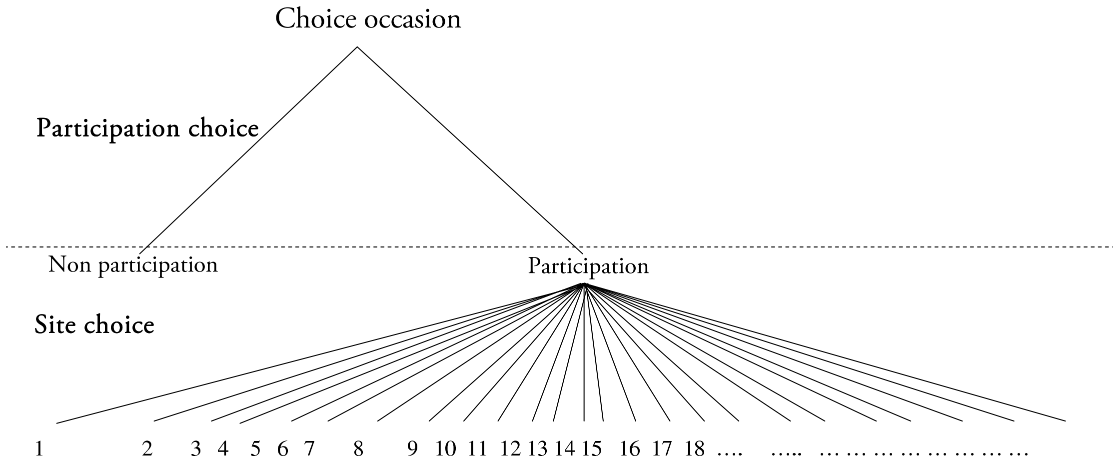
2 The theoretical framework

2.1 The repeated discrete choice model

The multinomial logit and the nested models are the most used models to explain the recreation demand (Berman et al., 1997; Hansen et al., 1999; Yen and Adamowicz, 1994; Salanié, 2006; Schuhman and Schwabe, 2004; Lin et al., 1996). In these models, the participation decision is not modelised. But, to analyze congestion effects, it is important to introduce an alternative of non participation because participation decision and site choice are probably more affected by the level of congestion than relative congestion.

As a result, we choose to use the repeated RUM developed initially by Morey et al. (1993). In this model a no trip alternative is added to the choice set *via* the nesting structure (figure 1).

Figure 1: Structure of the repeated logit model



This is a degenerated nested model because the no trip nest has only one alternative. For a choice occasion t, an individual i can choose to not participate or to visit a recreation site of its choice set. An individual $i = 1, 2, ..., n$ facing $j = 0, 1, 2, ...J$ exhaustive and mutually exclusive alternatives, $j = 0$ corresponding to the no trip alternative, gets the following utility by choosing alternative j:

$$
\begin{aligned}
V_{ijt} &= U_{ijt} + \varepsilon_{ijt} && (1)\\
U_{ijt} &= nogo_j + \beta(X_j) + \varsigma Z_i + \phi(Z_i)X_j + \delta TC_{ij} + \alpha C_{jt} + \theta Q_t && (2)
\end{aligned}
$$

With:

- U_{ijt}, the deterministic utility;
- ε_{ijt}, the random component;
- $nogo_j$, the no participation constant;
- X_j, observable attributes of site j;
- Z_i, observable characteristics of individual i;
- TC_{ij}, travel costs incurred by individual i in visiting site j;
- C_{tj}, congestion at site j for a choice occasion t .
- β, ϕ, δ, θ, α, parameters to estimate.

The individual's probability of visiting site k on a choice occasion t, p_{ikt} can be decomposed into a probability of participating and a probability of visiting site k given participation is chosen. This gives:

$$
\begin{aligned}
p_{ikt} &= p_{k|Gt} \times p_{iGt} && (3)\\
\text{with } p_{ik|Gt} &= \frac{e^{U_{ikt}/\rho}}{\sum_j e^{U_{ijt}/\rho}} && (4)\\
\text{and } p_{iGt} &= \frac{e^{\rho I_{iGt}}}{e^{\rho I_{iGt}} + e^{U_{i0t}}} && (5)
\end{aligned}
$$

Where I_{iGt} is the inclusive value *i.e.* the expected utility of a trip on a choice occasion t:

$$I_{iGt} = \ln\left(\sum_j e^{U_{ijt}/\rho}\right)$$

ρ is the dissimilarity coefficient, which is necessary ranged between 1 and 0. The more the sites are substitutes, the more ρ approaches 0. When $\rho = 1$, the model collapses to a multinomial RUM and $\rho > 1$ means the model is misspecified. U_{i0t} is the individual i's no participation utility on choice occasion t.

In the repeated multinomial logit model, the welfare measure is traditionally derived from Small and Rosen (1981) formula:

$$
\begin{aligned}
W_{it} &= \ln\left(e^{U_{i0t}} + e^{\rho I_{iGt}}\right) && (6)\\
& \quad \text{(Morey, 1999)}
\end{aligned}
$$

.

Given the structure of the repeated logit model, surplus estimates are produced as per choice occasion individual compensating variation.

2.2 Congestion: result of a Nash equilibrium

Recent revealed preference studies (first Boxall and Adamowicz (2000) deepened in Boxall et al. (2005), followed by Timmins and Murdock (2007)) liken the generation of congestion to a Nash bargaining model: individuals make site choices based on their expectations about the choices that will be made by other individuals (it is anticipated congestion). To simplify, we apply the same methodology as Boxall et al. (2005) and Timmins and Murdock (2007) by summing up congestion on all individuals. Then, congestion per site and choice occasion is expressed as:

$$C_{jt} = \sum_{m \neq i} p_{mjt} = \sum_{m \neq i} p_{mjt|Gt} . p_{iGt} \simeq \sum_i p_{ijt|Gt} . p_{iGt} \quad (7)$$

And equilibrium is reached when these expectations are confirmed by other individuals' actual decisions.

Replacing congestion by its definition leads to a new expression of the probabilities:

$$p_{ik|Gt} = \frac{e^{U_{ikt}(nogo_j, X_j, Z_i, TC_{ij}, Q_t, p_{ijt|Gt}, p_{iGt})/\rho}}{\sum_j e^{U_{ijt}(nogo_j, X_j, Z_i, TC_{ij}, Q_t, p_{ijt|Gt}, p_{iGt})/\rho}} \quad (8)$$

$$p_{iGt} = \frac{e^{\rho I_{iGt(nogo_j, X_j, Z_i, TC_{ij}, Q_t, p_{ijt|Gt}, p_{iGt})}}}{e^{\rho I_{iGt}(nogo_j, X_j, Z_i, TC_{ij}, Q_t, p_{ijt|Gt}, p_{iGt})} + e^{U_{i0t}}} \quad (9)$$

This is a system of fixed-points. We assume that utility decreases with congestion $\alpha < 0$ to ensure the uniqueness of the equilibrium (Bayer and Timmins, 2005).

3 Estimation with congestion as a result of a Nash equilibrium

The procedure is inspired by O'Hara (2007). He estimated a site choice model with a observed congestion variable. His approach is applied to a behavioral study of rock climbers. The choice set is composed of seven cliffs, which are supposed to be homogenous. This assumption allows him to not estimate specific alternative constants.

But estimating specific alternative constants leads to an interesting property: predicted shares equal actual shares so that the Nash equilibrium condition is automatically fulfilled.

The use of congestion measure even if it is very close of the "real" congestion does not guarantee that the parameters estimated are consistent with the equilibrium. However, this consistency is necessary to use the estimation results in simulation of regulation policies. In case where alternatives specific constants are not estimated, this consistency with the equilibrium has to be imposed.

O'Hara (2007)'s approach is very useful in this context to ensure this consistency with the Nash equilibrium.

O'Hara (2007) defines the measure of congestion used in the model by the congestion as it is defined by the model itself. This strategy ensures the consistency with the Nash equilibrium. Furthermore, it only uses data available in the sample. Not any additional measure of congestion is needed. O'Hara (2007) describes his procedure for a multinomial logit model. In the following developments, it is adapted to a repeated logit model where congestion depends on site and choice occasion. Recall our utility function:

$$U_{ijt} = nogo_j + \beta(X_j) + \varsigma Z_i + \phi(Z_i)X_j + \delta TC_{ij} + \theta Q_t + \alpha C_{jt}$$

Then, conditional probability of visiting site j by individual i is written:

$$p_{ijt|Gt} = \frac{e^{U_{ijt}(X_j, Z_i, TC_{ij}, Q_t, C_j)/\rho}}{\sum_k e^{U_{ikt}(X_k, Z_i, TC_{ik}, Q_t, C_k)/\rho}} \quad (10)$$

and the probability of participating:

$$p_{iGt} = \frac{e^{\rho I_{iGt(X_j, Z_i, TC_{ij}, Q_t, C_j)}}}{e^{\rho I_{iGt(X_j, Z_i, TC_{ij}, Q_t, C_j)}} + e^{U_{i0t}}} \tag{11}$$

where:

$$C_j = \sum_i p_{ijt} = \sum_i p_{ijt|Gt} \times p_{Gt} \tag{12}$$

As a result, the level of anticipated congestion at site j, is implicitly defined from the model itself.

If congestion has a negative impact on utility, the equilibrium is unique (Bayer and Timmins, 2005). This suggests an iterative procedure to estimate $(\beta, \varsigma, \phi, \delta, \alpha, \theta)$. In the first step, the model is estimated without congestion (Bayer and Timmins, 2007):

$$U_{ijt} = nogo_j + \beta(X_j) + \varsigma Z_i + \phi(Z_i)X_j + \delta TC_{ij} + \theta Q_t \tag{13}$$

We note $\left(\tilde{\beta}, \tilde{\varsigma}, \tilde{\phi}, \tilde{\delta}, \tilde{\theta}, \tilde{\alpha}\right)$, the estimator of $(\beta, \varsigma, \phi, \delta, \theta, \alpha)$. The anticipated level of congestion is approximated using equation (12) with the estimators $\left(\tilde{\beta}, \tilde{\varsigma}, \tilde{\phi}, \tilde{\delta}, \tilde{\theta}\right)$ and we estimate a second model where congestion is an explanatory variable:

$$U_{ijt} = nogo_j + \beta(X_j) + \varsigma Z_i + \phi(Z_i)X_j + \delta TC_{ij} + \theta Q_t + \alpha C_{jt} \tag{14}$$

Then, the iterative process can begin. At every step q, an estimator of $(\beta, \varsigma, \phi, \delta, \theta, \alpha)$ is estimated from the model below by approximating the levels of anticipated congestion with $\left(\tilde{\beta}, \tilde{\varsigma}, \tilde{\phi}, \tilde{\delta}, \tilde{\theta}, \tilde{\alpha}\right)$:

$$\hat{C}_{j,q-1} = \sum_i p_{ijt|Gt}\left(\hat{\beta}_{q-1}, \hat{\varsigma}_{q-1}, \hat{\phi}_{q-1}, \hat{\delta}_{q-1}, \hat{\theta}_{q-1}, \hat{\alpha}_{q-1}\right) \times p_{Gt}\left(\hat{\beta}_{q-1}, \hat{\varsigma}_{q-1}, \hat{\phi}_{q-1}, \hat{\delta}_{q-1}, \hat{\theta}_{q-1}, \hat{\alpha}_{q-1}\right)$$

Convergence is considered as achieved when $\left(\hat{\beta}_q, \hat{\varsigma}_q, \hat{\phi}_q, \hat{\delta}_q, \hat{\theta}_q, \hat{\alpha}_q\right)$ is sufficiently close to:

$$\left(\hat{\beta}_{q-1}, \hat{\varsigma}_{q-1}, \hat{\phi}_{q-1}, \hat{\delta}_{q-1}, \hat{\theta}_{q-1}, \hat{\alpha}_{q-1}\right)$$

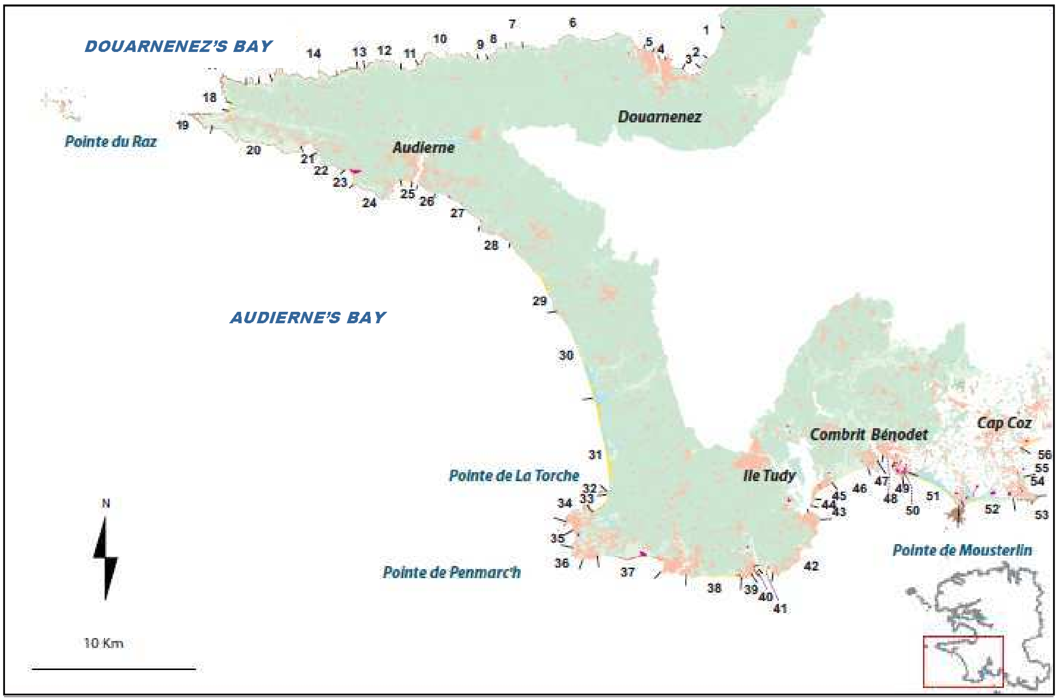
.

Bayer and Timmins (2005) showed this process leads to an unique and stable equilibrium if α is negative. If this parameter is positive, it may exist many equilibria stable or unstable given the initial values. Unfortunately, there is no way to know *a priori* the sign of the parameter of congestion and then, if the equilibrium is unique.

4 Data

In this section, we describe the data on individual characteristics, sites attributes, choice occasion characteristics and travel costs that we use in our application. Our study area is constituted by a part of the coastal zone of west Brittany in France, from Fouesnant to Douarnenez (figure 2).

Figure 2: Study area



This coastal area was divided in 56 homogenous sectors. Because some of then were not well suited for recreational activities (because of accessibility problems mainly), our study was restricted to 43 natural recreation sites. There are beaches, land ends and cliffs. A typology of sites was built (table 1), using the database of the French National Institute of Geography and aerial photos. A lot of visits of the study area helped to fulfilled this typology by some site amenities (number of restaurants, camps, presence of children games...).

Our data on trips and individuals were gathered by organizing a survey outside of the supermarkets of the study area during three weeks. We asked 1079 people, residents and tourists, about their trips on the previous week. Each individual had seven choice occasions corresponding to a day. Then, there are 21 different choice occasion in the study. By analyzing these individual data, we realized residents and tourists behave differently. As a result, we separate our sample in two subsamples. There are 431 residents and 648 tourists. After, we will estimate two separate models, one for each kind of population.

We also needed data on choice occasion. Based on weather data, we built dummy variables about temperature and pluviometry for each choice occasion (table 1).

Gather data on congestion was a difficult task. We organized a flight over the study area, and took pictures of every part of each site. Next, these photos was analized to count the number of people on every sites. Unfortunately, this data is only available for 1 of the 21 choice occasions of the study whereas there is a high variability during on weather the study period and so on congestion.

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Table 1: Typology of site and description of choice occasion

	Description	Mean	Std dev.
Attributes of choice occasions			
Rain	Dummy=1 if it rained during this choice occasion	0,37	
Week-end	Dummy = 1 if choice occasion is a week-end	0,33	
Temp20	Dummy=1 if temperature is higher than 20°C during the afternoon	0,41	
Site attributes			
Distpark	Distance to the park area (meters)	103,25	160,63
Beach	Dummy=1 if site is a beach	0,60	
Camps	numbers of camps around the site	1,32	1,61
Anchorage	Dummy =1 if the site is located near a port	0,09	
Urban environment	Dummy = 1 if the site environment is urban	0,11	
Natural environment	Dummy = 1 if the site environment is natural	0,55	
Access	Dummy=1if the access to the site is difficult	0,16	
Games	Dummy =1 if there is games for child in the site	0,09	
Quality	Dummy =1 if the water quality of the site is bad	0,33	
Restaurant	Dummy = 1 if there is a restaurant near to the site	0,32	

Table 2: Description of individual characteristics

		Tourists		Residents	
		Mean	Std Dev.	Mean	Sdt Dev.
Individual characteristics					
Travel costs	Round-trip tim x opportunity cost of time +0,35 € per km	10,10	11,06	11,42	10,83
Family	Dummy=1 if individual came with his family	0,54		0,36	
Planning	Dummy = 1 if tourists did a planning of visits	0,10			
Length of stay	Dummy = 1 if the length of stay is more than one week	0,73			
Reason sea	Dummy = 1 if tourists came because of the sea	0,37			
Holidays	Dummy = 1 if individual is in holidays	0,93		0,39	
Bac+2	Dummy = 1 if individual has an education superior than 2 years after the "baccalauréat"	0,55		0,39	
Farmer	Dummy = 1 if individual is a farmer	0,01		0,01	
Craftsman	Dummy = 1 if individual is Craftsman	0,04		0,04	
Intermediate	Dummy = 1 if individual has a professional status between employee and executive	0,19		0,13	
Executive	Dummy = 1 if individual is executive	0,36		0,17	
Worker	Dummy = 1 if individual is a workman	0,06		0,07	
Employee	Dummy = 1 if individual is employee	0,23		0,25	
Unemployed	Dummy = 1 if individual is unemployed or student	0,11		0,16	
Household	Number of people in the household	3,22	1,44	2,86	1,45
Bathing	Dummy =1 if bathing is the activity most practiced	0,43		0,43	
Hiking	Dummy =1 if hiking is the activity most practiced	0,31		0,19	
High income	Dummy=1 if income is more than 3000 € monthly	0,13		0,05	

5 Estimations

As we see in the data section, we will estimate "tourists" and "residents" models separately. Because of a flight over the study area, an observed measure of congestion is available. We use this congestion indicator in the first estimation. Unfortunately, this measure is quite unprecise because it is only available for one choice occasion whereas participation and site choice change a lot according to choice occasions in our data. Furthermore, this measure is not consistent with the Nash equilibrium. As a result, the procedure described in section 3 is used for a second estimation, but it needs to be adapted to our two populations case.

5.1 Estimations with observed congestion

Because of the flight over the study area, we know how many people was on every sites the 4^{st} of August 2007 . We use this data to compute the "market share" of site j, $\sigma_{j|G}$:

$$\sigma_{j|G} = \frac{\text{Number of people on the site}}{\text{Number of people on the study area}} \tag{15}$$

The "market share" of site j is the number of visitors of site j divided by the total of visitors on the study. It is the observed relative congestion *i.e.* the conditional probability of visiting a site. But, since site choice is more likely to be determined by the level of congestion than relative congestion, we need to know the probability of participating to approximate the unconditional probability of choosing an alternative. We use the frequency of participation of our sample, f_{Gt}, as a proxy of the probability of participating. As a result, our indicator of observed congestion is :

$$C_{jt} = \sigma_{j|G} \times f_{Gt} \times \frac{1}{l_j} \times 100 \tag{16}$$

with l_j, the length of site j.

Here we make the assumption that relative congestion is the same whatever the choice occasion. Only the participation level changes over time.

The measure of congestion is corrected by the site length to take into account heterogeneity between sites [2]. Results of this estimation are presented in table 3.

[2]The smallest site has a length of 0,462 km and the biggest, 12 km.

Table 3: Results of models estimated with observed congestion

	Tourists			Residents		
	Coef.	**Std Dev.**	**Pr.> |t|**	**Coef.**	**Std Dev.**	**Pr.> |t|**
No participation choice						
No participation constant	1,2117***	0,1805	<,0001	1,9203***	0,1618	<,0001
Reason sea	0,0909	0,0713	0,2024			
Planning	0,0442	0,1162	0,7039			
Length of stay	-0,4054***	0,079	<,0001			
Holidays	-0,2541*	0,1372	0,0641	-0,5846***	0,1019	<,0001
Bac+2	0,1226	0,0775	0,1137	-0,2232**	0,1066	0,0364
Farmer	0,3244	0,4036	0,4215	0,1931	0,4419	0,6622
Craftsman	0,5963***	0,1949	0,0022	0,2085	0,2464	0,3974
Intermediate	-0,0663	0,1018	0,5151	0,0835	0,1577	0,5963
Executive	-0,0136	0,1023	0,894	0,1017	0,1589	0,5224
Worker	0,1657	0,1653	0,3161	-0,0944	0,1858	0,6114
Employee	0,372***	0,107	0,0005	0,5902***	0,1369	<,0001
Unemployed	0,1844	0,1296	0,1549	0,7761***	0,1681	<,0001
Household	0,0716***	0,0255	0,005	0,1188***	0,0419	0,0045
Rain	0,3569***	0,0754	<,0001	0,2616**	0,1018	0,0102
Bathing	-0,791***	0,0852	<,0001	-1,1158***	0,1122	<,0001
Hiking	-0,2553***	0,0938	0,0065	-1,0973***	0,1315	<,0001
Week-end	-0,2535***	0,071	0,0004	-0,3557***	0,0951	0,0002
Temperature	-0,000832	0,0718	0,9908	-0,0771	0,0974	0,4284
High income	-0,1585	0,1312	0,2272	0,0431	0,2288	0,8506
Inclusive value nogo	1	0		1	0	
Inclusive value site choice	0,0577***	0,0144	<,0001	0,1446***	0,031	<,0001
Site choice						
Travel costs	-0,3628***	0,009359	<,0001	-0,3337***	0,0128	<,0001
Quality x family	-1,9322***	0,0728	<,0001	-2,9639***	0,1708	<,0001
Congestion	0,4406***	0,0302	<,0001	0,475***	0,0423	<,0001
Distpark	0,003766***	0,000126	<,0001	0,001404***	0,000267	<,0001
Distpark x beach	-0,0109***	0,000861	<,0001	-0,00738***	0,001191	<,0001
Camps	0,1166***	0,0171	<,0001	0,0848***	0,0241	0,0004
Anchorage	-0,785***	0,1532	<,0001	-0,2244	0,1978	0,2566
Urban environment	-0,2552***	0,0778	0,001	-0,4604***	0,1131	<,0001
Restaurant	0,5588***	0,0569	<,0001	0,7478***	0,078	<,0001
Natural environment	-0,5576***	0,0568	<,0001	-0,1226	0,0834	0,1414
Access	0,0112	0,0908	0,9022	-0,1518	0,1403	0,2794
Games x family	-0,4227***	0,1172	0,0003	-0,0607	0,1806	0,7369
ρ^2	0,2437			0,2838		

***, **, * Parameters significance at the 1%, 5% et 10% respectively.

This observed measure of congestion is a bad measure because it is unprecise and it does not ensure the equilibrium consistency. As a result, estimates may be biased. We are going to verify this bias by estimating models with a better measure of congestion.

5.2 Anticipated congestion

We choose to take Bayer and Timmins (2007)'s instrument of congestion as an indicator of anticipated congestion without estimating alternative specific constants. In fact in our application, alternatives are well described by the sites typology and the weither variables. In our study, 26 sites are beaches. These sites are quite homogenous (fine sand beaches, same temperature of the water…) and their heterogeneity is explained by their observed attributes. For land ends and cliffs, it is quite different. Above all, these sites are points of view and hiking sites. It is more difficult to explain their heterogeneity by observed attributes. By the way, more spectacular are the sites, more sharped there are and more far away are parks area. So, the distance to the park area is introduced as an explanatory variable alone and in interaction with the dummy variable "beach" to explain the heterogeneity of land ends and cliffs. Besides, the most spectacular site, the "pointe du Raz" (19^{th} site) has the biggest distance to the park area: 1 kilometer versus 300 meters in average for the other land ends and cliffs.

Furthermore, estimations conducted in our case study show the introduction of alternatives specific constants has little impact on individual parameters like travel cost even if their introduction improves the quality of the model evaluated by Mc Fadden's pseudo R^2. This result confirms our decision to not introduce alternative specific constants even if this test has no statistical value .

Our measure of anticipated congestion is different from Bayer and Timmins (2007) and Timmins and Murdock (2007) because we estimate two models: one for residents and one for tourists. Yet, congestion is the sum of visitation of these two kinds of people. The indicator of congestion is not specific to tourists in the tourist model and specific to residents in the resident model. This measure must take into account the aggregate behavior of these two populations.

In our notations, the superscripts r represents residents and nr tourists. To calculate our measure of anticipated congestion, we first estimate a model with no congestion (see appendix A). We estimate this model and then we calculate unconditional probabilities of visiting a site, p^{nr}_{ijt} and p^{r}_{ijt}, with parameters estimated without congestion effects. Our sample is composed of 40% of residents and 60% of tourists. We consider this repartition as representative of the real repartition in the study area. So the measure of congestion is expressed by:

$$C_{jt} = \left(\frac{1}{N^{nr}} \sum_i \widehat{p}^{nr}_{ijt} \times 0,6 + \frac{1}{N^r} \sum_i \widehat{p}^{r}_{ijt} \times 0,4 \right) \times \frac{1}{l_j} \times 100 \tag{17}$$

Anticipated congestion is implicitly defined in the repeated discrete choice model: it is defined as it is calculated by the model itself. Without the estimation of alternative specific constants, there is no reason that congestion estimated by the model equals anticipated congestion introduced as an explanatory variable. So, even if the congestion measure used is valid (Jakus and Shaw, 1997), the consistency with the Nash equilibrium is not ensured by the previous estimation.

Imposing this consistency complicates the estimation. But the procedure proposed by O'Hara (2007), and inspired by Bayer and Timmins (2007), is quite intuitive. It defines estimators of the choice model as maximum likelihood estimators constrained by the consistency with the Nash equilibrium *i.e.* the fixed point equilibrium. It is unique since congestion has a negative impact on site choice (Bayer and Timmins, 2005). This condition ensures the numerical convergence of O'Hara (2007)'s procedure.

In our two models case, the definition of equilibrium must take into account the fact that congestion is incurred by tourists and residents. Equilibrium probabilities of visiting resolve the following system:

$$\begin{cases} p_{ijt}^{nr} = \dfrac{e^{nogo_j^{nr}+\beta^{nr}(X_j)+\phi^{nr}(Z_i^{nr})X_j+\delta^{nr}TC_{ij}^{nr}+\alpha\left(\frac{1}{N^{nr}}\sum_i \widehat{p}_{ijt}^{nr}\times 0{,}6+\frac{1}{N^r}\sum_i \widehat{p}_{ijt}^{r}\times 0{,}4\right)\times\frac{1}{l_j}\times 100+\theta Q_t}}{\sum_k e^{nogo_k^{nr}+\beta(X_k)+\phi(Z_i^{nr})X_k+\delta TC_{ik}^{nr}+\alpha\left(\frac{1}{N^{nr}}\sum_i \widehat{p}_{ikt}^{nr}\times 0{,}6+\frac{1}{N^r}\sum_i \widehat{p}_{ikt}^{r}\times 0{,}4\right)+\theta Q_t}} \\ p_{ijt}^{r} = \dfrac{e^{nogo_j^{r}+\beta^{r}(X_j)+\phi^{r}(Z_i^{r})X_j+\delta^{r}TC_{ij}^{r}+\alpha\left(\frac{1}{N^{nr}}\sum_i \widehat{p}_{ijt}^{nr}\times 0{,}6+\frac{1}{N^r}\sum_i \widehat{p}_{ijt}^{r}\times 0{,}4\right)\times\frac{1}{l_j}\times 100+\theta Q_t}}{\sum_k e^{nogo_k^{r}+\beta(X_k)+\phi(Z_i^{r})X_k+\delta TC_{ik}^{r}+\alpha\left(\frac{1}{N^{nr}}\sum_i \widehat{p}_{ikt}^{nr}\times 0{,}6+\frac{1}{N^r}\sum_i \widehat{p}_{ikt}^{r}\times 0{,}4\right)+\theta Q_t}} \end{cases} \tag{18}$$

The equilibrium is reached when probabilities introduced as explanatory variables *via* congestion equals to estimated probabilities:

$$\begin{cases} p_{ijt}^{nr} = \widehat{p}_{ijt}^{nr} \\ p_{ijt}^{r} = \widehat{p}_{ijt}^{r} \end{cases} \tag{19}$$

It is a step by step estimation:

Step 1: The two repeated models are estimated with congestion as an omitted variable. Recovered parameters are biased since congestion influences site choice (Cesario, 1980).

Step 2: Anticipated congestion is calculated with previous probabilities estimated and thanks to equation (17).

Step 3: The two repeated models are estimated again but with anticipated congestion as an explanatory variable.

Step 4: Visiting probabilities are recalculated to implement anticipated congestion.

Steps 5: Models are reestimated until convergence is reached (system of equations (19)).

At the Nash equilibrium, every individual probability of participating and individual probability of visiting a site depend on other individuals probabilities. This equilibrium is the result of a system of simultaneous equations but in a discrete choice context. The fixed point calculation *via* the iterative procedure permits to take into account this simultaneity of choices.

Table 4 shows the results of this procedure of estimation..

Table 4: Result of models estimated with anticipated congestion

	Tourists			Residents		
	Coef.	**Std Dev.**	**Pr.> |t|**	**Coef.**	**Std Dev.**	**Pr.> |t|**
No participation choice						
No go constant	1,1809***	0,1809	<,0001	1,8624 ***	0,1598	<,0001
Reason sea	0,0865	0,0716	0,227			
Planning	0,0415	0,1166	0,7222			
Length of stay	-0,4006***	0,0793	<,0001			
Holidays	-0,2491*	0,1376	0,0703	-0,5855***	0,102	<,0001
Bac+2	0,1241	0,0779	0,111	-0,2185**	0,1067	0,0406
Farmer	0,3234	0,4056	0,4252	0,1919	0,4422	0,6644
Craftsman	0,5984***	0,1958	0,0022	0,206	0,2465	0,4033
Intermediate	-0,0683	0,1022	0,5038	0,0789	0,1578	0,6171
Executive	-0,006701	0,1027	0,948	0,0994	0,1591	0,5321
Worker	0,1639	0,1659	0,3231	-0,0941	0,1859	0,6126
Employee	0,3769***	0,1073	0,0004	0,5924	0,137	<,0001
Unemployed	0,1813	0,13	0,1629	0,7807	0,1682	<,0001
Household	0,0723***	0,0256	0,0047	0,1181***	0,0417	0,0046
Rain	0,3598***	0,0758	<,0001	0,263***	0,102	0,0099
Bathing	-0,7895***	0,0856	<,0001	-1,1162***	0,1124	<,0001
Hiking	-0,2553***	0,0941	0,0067	-1,096***	0,1316	<,0001
Week-end	-0,2581***	0,0713	0,0003	-0,3568***	0,0952	0,0002
Temp20	-0,001458	0,0721	0,9839	-0,0773	0,0975	0,4276
High income	-0,1584	0,1317	0,2289	0,0425	0,229	0,8528
Inclusive value nogo	1	0		1	0	
Inclusive value site choice	0,0536***	0,0142	0,0002	0,1459***	0,0312	<,0001
Site choice						
Travel cost	-0,3625***	0,009359	<,0001	-0,3304***	0,0127	<,0001
Quality x family	-2,0195***	0,0722	<,0001	-3,0113***	0,1702	<,0001
Congestion	-0,2134***	0,0366	<,0001	-0,0754***	0,0267	0,0048
Distpark	0,003647***	0,000124	<,0001	0,001124***	0,000287	<,0001
Distpark x beach	-0,00751***	0,000682	<,0001	-0,003631***	0,000932	<,0001
Camps	0,1723***	0,0147	<,0001	0,1422***	0,021	<,0001
Anchorage	-1,1552***	0,1502	<,0001	-0,6725***	0,1919	0,0005
Urban environment	0,1093	0,076	0,1506	-0,094	0,1074	0,3812
Restaurant	0,5583***	0,0576	<,0001	0,6887***	0,0746	<,0001
Natural environment	-0,555***	0,0578	<,0001	-0,1276	0,0834	0,1257
Access	-0,3777***	0,0858	<,0001	-0,5121***	0,1347	0,0001
Games x family	-0,8996***	0,117	<,0001	-0,4967***	0,1762	0,0048
ρ^2	0,2342			0,2733		

***, **, *Parameters significance at the 1%, 5% et 10% respectively.

We observe the quality of adjustment is quite good: Mc Fadden's pseudo R^2 equals to respectively 0,2342 for the tourist model and 0,2733 for the resident's. It is important to note that, given the structure of the repeated model, this is the no participation decision which is modelled. Then, a negative impact on the no participation choice means a positive impact on the participation decision.

Some of explanatory variables of the no participation decision are specific to tourists. Among these variables, only the length of stay relies positively and significantly to the participation decision. Variables representing the professional status are mainly insignificant. Choosing to hike or to bath instead of fishing has a positive impact on participation decision. Expectedly, variables "holidays" and "week-end" influence positively the participation choice. On the contrary, "rain" leads to a decrease of participation.

Hopefully, travel costs has a negative and significant impact on site choice for both populations. More surprising, the distance to park area relies positively to site choice for land ends and cliffs whereas its impact is negative for beaches. But, hiking is the main activity practiced in cliffs and land ends. Generally, the way from the park area to the point of view is part of the pleasure. The presence of an anchorage near the site is negatively felt by individuals. The most important parameter for our purpose is the utility effect of congestion, which is negative and significant for both populations. So, this equilibrium is unique and stable. But it is important to note the congestion impact on utility is more negative for tourists than for residents. We observe social differences (in income, professional status...) that can explain this heterogeneity.

Most of studies explain recreation by an observed congestion measure without ensuring the consistency with the Nash equilibrium. In our study, it leads to biased estimates. Congestion parameter has a positive and significant effect on utility, whereas its impact becomes significantly negative when the consistency with the Nash equilibrium is achieved. We observe that a bad measure of congestion leads to bias on other parameters like the coefficient of urban environment for residents. Here it is significantly negative whereas it was insignificant in the previous estimation. In the same way, the effect of the variable "anchorage" becomes more negative than previously. In the tourist model, there is the same phenomenon: the impact of "urban environment" becomes significantly negative whereas it was insignificant in the model at the equilibrium.

At the beginning of this process, we used a congestion measure resulting from a model with omitted congestion. We also try to do the same iterative procedure but using the observed congestion measure as a starting point of iterations. At the end of the iterations, we reach the same equilibrium but the convergence is longer to achieve. This result is linked to the result of Bayer and Timmins (2005): equilibrium is unique when the parameter of congestion, estimated at the equilibrium, is negative.

6 Simulating policy alternatives

We use now the two models estimated at the equilibrium of congestion to simulate regulation policies. Using models estimated with equilibrium of congestion as an explanatory variable leads to more realistic simulations. In fact, the introduction of an access fee for instance has a negative impact on individual utility by increasing the access cost to the site. Because individual utility decreases, probability of visiting this site drops also. Then, this site becomes less crowded. If the congestion effect on utility is negative, it rises utility. The negative effect on utility is weakened by the positive impact of congestion. In most of studies with congestion, equilibrium is not calculated (Berman et al., 1997; Lin et al., 1996; Hansen et al., 1999; Yen and Adamowicz, 1994; Schuhman and Schwabe, 2004; Salanié, 2006). As a result, the positive impact of congestion is ignored.

The procedure for conducting simulations proceeds as follows. We begin by determining each individual surplus under the status quo period according to the inclusive value at the equilibrium:

$$\text{Surplus}_i = \frac{I_{iGt}}{|\delta|} = \frac{\ln\left(\sum_j e^{U_{ijt}/\rho}\right)}{|\delta|} \tag{20}$$

To convert expected utility per choice occasion in euros, the inclusive value is divided by the absolute value of the travel cost parameter, δ.

Next we change a variable, for instance we increase travel costs to simulate a tax and recalculate the equilibrium congestion for each of the alternatives of the choice set. This yields to a new vector of anticipated congestion, from which we compute new values of surplus per choice occasion, so as to conduct every simulation at the Nash equilibrium. The expected tax profit is added to the individual surplus per choice occasion to compute a measure of collective welfare: it is the tax included surplus.

Setting of a tax at the most popular site

The "pointe du Raz", 19^{th} site of our study, is a famous land end is France. It belongs to the Great Site network. These site are protected by the French law of 1930 concerning "the protection of natural monuments and sites of artistic, historic, legendary or picturesque character". They enjoy very great fame. The attendance of the "pointe du Raz" is about one million visitors a year (Vourc'h, 1999). Its parking is not free, which is an exception for a site belonging to the "Conservatoire du littoral"[3]. During the survey, the parking fee was about 6 euros whatever long you stay.

In our simulation, this fee is varied from 0 to 9 euros, by stages of 3 euros. Table 5 shows these changes have little impacts on probability of participating. The effect is much more important on the probability of visiting this site ($p_{19|G}$).

Table 5: Changes on probabilities after a variation of the parking ticket

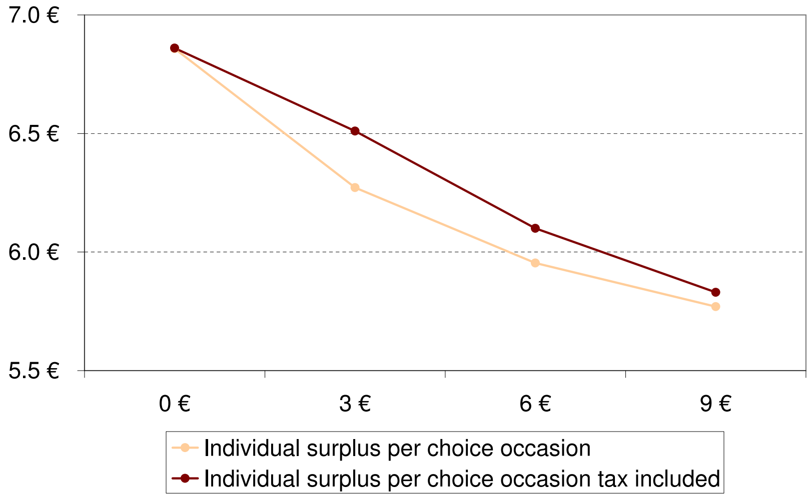
Value of fee	0 €	3 €	6 €	9 €
Probability of participating				
Residents	32%	32%	32%	31%
Tourists	45%	45%	45%	44%
Conditional probability of visiting the "pointe du Raz"				
Residents	6,8%	3%	1,2%	0,2%
Tourists	29,2%	16,8%	8,5%	1,3%

[3]The "Conservatoire du littoral" is a public administrative body with the responsibility of conducting appropriate land-use policies for the protection of threatened natural areas. To ensure the definitive protection of outstanding natural areas on the coast, banks of lakes and stretches of water, this institution purchases these sites.

We use the formula (20) to calculate every surplus, tax included or excluded, for each scenario of tax. It leads to the figure 3.

Figure 3 illustrates welfare variations on the whole sample due to a change on parking fee.

Figure 3: Effect of a change of the parking ticket on the individual surplus per choice occasion



The individual surplus per choice occasion always decreases as the parking fee increases even if the tax profit is included. It can seem surprising but Leplat and Le Goffe (2009) show that introducing congestion leads to two external effects in a repeated logit model: a first effect of "repartition" and a second of "participation". If a tax is set up at only one site, people will visit substitute sites where access is free. Then, congestion decreases at the restricted access site ($p_{19|G}$ drops) but it increases everywhere else because the probability of participating remains stable. So, the introduction of a tax at only one site leads to a decrease of the welfare if substitution effects are taken into account. To improve the welfare, the two external effects need to be internalized in order to reduce congestion in the entire area.

To resolve this problem, we simulate now a taxation on every sites of the study area.

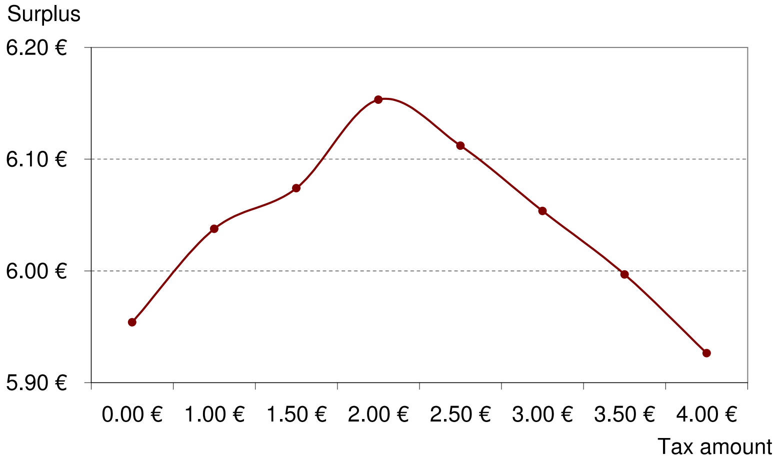
Taxation of every site: to the optimal tax?

To ration access to the study area, access is submitted to a uniform tax.

First, the tax amount is fixed to 1 euro for each site. This amount is progressively increased. We want to know which amount of tax maximizes the sum of the individual surplus per choice occasion and the expected tax profit *i.e* the individual surplus per choice occasion tax included[4]. Figure 4 shows this simulation impact on individual surplus per choice occasion tax included.

[4]It measures the collective welfare.

Figure 4: Variation of the individual tax included surplus per choice occasion after changes on uniform tax



A tax of 2 euros maximizes the tax included surplus. Because tourists and residents behave differently, we can also calculate the amount of optimal tax for each population. This is an interesting data if managers want to set up a discriminating management. Optimal tax is about 1,50 euros for residents and 2 euros for tourists.

For this optimal tax, the predicted resident probability of participation decreases from 31,6%to 21,6% . For tourists, with a predicted rate of participation of 41,6%, this drop is about 3,5 points. This difference is explained by the different sensibility to congestion. The uniform tax has two effects: a "price" direct effect which entails a decline of the participation rate and a positive indirect effect: congestion goes down. Because tourists are more averse to congestion, the setup of a tax impacts less their participation.

Because this measure aims to reduce congestion, we look at predicted congestion incurred by the policy. We observe that it is not at the more congested site that crowding decrease the most. The 48th site remains the most congested site after the policy. These simulations results show that the introduction of a uniform tax is not a satisfying policy. This measure permits to internalize the two external effects, repartition effect and participation effect. However an optimal policy must regulate the absolute level of congestion and reduce the too high visitation at popular site *i.e.* the relative congestion. On optimal scheme of taxation must set up different taxes in accordance with the crowding already recorded.

A third policy has been simulated: a policy mix combining taxes and long-walk-in measures. Because the distance from parking to site has a positive impact on utility for land ends and cliffs, these sites are excluded from this policy. Moreover, the most crowded sites are mainly beaches. An entrance fee is imposed on eighteen beaches and the distance between park area and site is increased by 300 meters for eight beaches.

This policy leads to a rise of congestion on sites excluded from the device. In average, crowding increases about 50% and cliffs and land ends. The policy leads to a decrease of congestion on beaches but like previously, it is not beaches which are the most crowded which are the most impacted by the measure. For instance, sites n°48, 50 and 56 are insufficiently concerned by the regulation. A device of regulation where fragile sites like cliffs and land ends are excluded entails a new repartition of visits which can be damaging for some sites. It is the case in this simulation. For instance the visitation of the "pointe de Castel Meur" rises of 53% whereas this site, close to the "pointe du Raz" is particularly fragile. It cannot support all these additional visitors.

All simulations conducted aim to ration access to sites of the study area. Estimating a model where congestion is an omitted variable allows us to calculate individual surplus per choice occasion according to these models. As a result, in every simulation the loss of individual surplus per choice occasion is overestimated (by between 30% and 40% depending on simulations).In fact, the objective of these policies is to reduce congestion. But, when congestion is omitted, this positive effect is not taken into account. This result is similar to Timmins and Murdock (2007) and O'Hara (2007).

7 Conclusion

In this application, we develop an iterative procedure inspired by Bayer and Timmins (2007) and O'Hara (2007) to estimate a repeated RUM where congestion is a result of a Nash equilibrium. This methodology is available when the endogeneity of congestion is not a concern, which seems to be the case here. Following this procedure, we find congestion has a negative impact on utility.

Next, an iterative procedure is used to conduct simulations of regulation policies at the equilibrium of congestion. Whereas Leplat and Le Goffe (2009) calculated optimal taxes to maximize collective welfare in a two sites RUM, this calculation was too computationally challenging here. Measures simulated aims to improve welfare, not to maximize it. First, a tax at the most popular site of the study is simulated, secondly every sites are taxed and finally a policy mix is tested. These three simulations are run at the equilibrium of congestion. These simulations permits to confirm our previous theoretical results: a tax at only one site reduces the collective welfare because of substitutions effects. Yet, congestion leads to an externality of "repartition" and an externality of "participation" (Leplat and Le Goffe, 2009). Then, every sites of the study area must be targeted by the policy to internalize these two externalities.

However, the taxation scheme proposed here is a little bit caricatural because each site is impacted in the same way by the policy, even if sites attract people differently. It would be interesting to modulate the tax according to popularity of sites, in order to really take into account the externality of "repartition". It was the goal of the policy mix but the proposed modulation is not satisfactory. This model could be improved by introducing correlation between choice occasions and /or heterogeneity in preference for congestion inside categories of populations as Lavin and Hanemann (2008) did.

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A Congestion: an omitted variable

Table 6: Estimation of the model where congestion is omitted

	Tourists			Residents		
	Coef.	**Std Dev.**	**Pr.> |t|**	**Coef.**	**Std Dev.**	**Pr.> |t|**
No participation choice						
No participation constant	1,1915***	0,1808	<,0001	1,8777***	0,1602	<,0001
Reason sea	0,0883	0,0716	0,2173			
Planning	0,0425	0,1165	0,7155			
Length of stay	-0,4022***	0,0792	<,0001			
Holidays	-0,2497*	0,1375	0,0694	-0,5856***	0,1019	<,0001
Bac+2	0,1237	0,0778	0,1119	-0,219**	0,1067	0,0401
Farmer	0,3251	0,4051	0,4222	0,1926	0,4422	0,6631
Craftsman	0,5987***	0,1956	0,0022	0,2063	0,2465	0,4026
Intermediate	-0,0674	0,1021	0,5095	0,0802	0,1578	0,6112
Executive	-0,008005	0,1026	0,9378	0,1001	0,159	0,5289
Worker	0,1657	0,1657	0,3175	-0,0928	0,1859	0,6176
Employee	0,376***	0,1072	0,0005	0,593***	0,137	<,0001
Unemployed	0,1827	0,1299	0,1594	0,7806***	0,1682	<,0001
Household	0,0715**	0,0255	0,0051	0,1175***	0,0417	0,0049
Rain	0,3579***	0,0757	<,0001	0,2613***	0,1019	0,0103
Bathing	-0,7894***	0,0855	<,0001	-1,1153***	0,1123	<,0001
Hiking	-0,2548***	0,094	0,0067	-1,0961***	0,1316	<,0001
Week-end	-0,2563***	0,0712	0,0003	-0,3559***	0,0951	0,0002
Temp20	-0,001145	0,072	0,9873	-0,0771	0,0975	0,4291
High income	-0,1586	0,1315	0,228	0,0425	0,2289	0,8528
Inclusive value nogo	1	0		1	0	
Inclusive value site choice	0,0545***	0,0144	0,0001	0,1463***	0,0316	<,0001
Site choice						
Travel cost	-0,3588***	0,009284	<,0001	-0,3271***	0,0126	<,0001
Quality x family	-1,999***	0,0722	<,0001	-3,0051***	0,1703	<,0001
Distpark	0,003689***	0,000126	<,0001	0,001163***	0,000285	<,0001
Distpark x beach	-0,007536***	0,000689	<,0001	-0,003533***	0,000935	0,0002
Camps	0,1796***	0,0149	<,0001	0,1502***	0,021	<,0001
Anchorage	-1,1181***	0,1497	<,0001	-0,659***	0,1916	0,0006
Urban environment	-0,0155	0,0743	0,8347	-0,1569	0,1055	0,1371
Restaurant	0,4781***	0,0548	<,0001	0,6914***	0,0746	<,0001
Natural environment	-0,5266***	0,0567	<,0001	-0,1426*	0,083	0,0858
Access	-0,3235***	0,0854	0,0002	-0,4797***	0,1343	0,0004
Games x family	-0,7413***	0,1141	<,0001	-0,4464**	0,1758	0,0111
ρ^2	0,23			0,27		
ρ_c^2	0,14			0,17		
Number of observations	4534			3005		
Mean surplus by choice occasion	5,46 €			7,24 €		

***, **, * parameters significance at the 1%, 5% et 10% level respectively.

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