Welfare and environmental effects of short-haul flights bans*

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Abstract

This paper explores the efficacy of short-haul flights bans in reducing environmental external costs and its effects on welfare. Recently implemented by several European countries, the ban policy assumes that the air traffic lost will be diverted to rail giving environmental gains. A model where users are also allowed to use private car and account for all transport external costs is proposed to check this measure. The ban will provoke a shift in the modal split and affect total traffic levels. Rail prices will rise, users surplus and net welfare will fall. External costs are not necessarily reduced. Finally, an ex-ante assessment is done finding that environmental costs only decrease in the Madrid-Barcelona corridor, increasing in the Madrid-Valencia one. Social welfare net of all external costs decreases by 14.8% and 4.7% respectively. Thus, a case-by-case approach for implementing short-haul flights bans would be advisable.

Keywords: Environmental external costs, HSR, short-haul flight ban.

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1 Introduction

With the purpose of reducing greenhouse gas (GHG) emissions and respond to climate change challenges, several European countries (Austria, France, The Netherlands) are recently implementing short-haul flights bans on Origin- Destination (OD) routes when there is a rail alternative. Although the aviation industry and organizations such as International Air Transport Association (IATA) and International Civil Aviation Organization (ICAO) are very concerned and are devoting their efforts to limit the climate impact of travel, bans are not welcomed. One of the rationales of the ban policy is that it will provoke a shift in the transport modal split in favor of a more environmentally friendly mode such as rail and, in particular, the high-speed rail (HSR). However, a proportion of users may react to the short-haul flights ban by increasing the number of trips by private cars, which is a transport mode alternative that generates higher external costs than air transport.[1] Therefore, before adopting a ban policy in a given OD transport market, it is important to carefully assess their effects on the overall account of external costs and also the welfare consequences generated on users due to the reduction in competition.[2]

Air traffic has exponentially grown in the last two decades, 86% between 2000 and 2019 (European Commission, 2021). This tendency accelerates the increasing environmental pressure of transport activity (28.5% of global GHG emissions in the EU-27). Within the transport sector, civil aviation is responsible for 13.4% of GHG emissions (148 Mt CO2 equivalent) while rail accounts for 4% of GHG emissions (4.1 Mt CO2 equivalent) (European Commission, 2021). Besides CO2 emissions, aviation emits other air pollutants, which are estimated to represent half of the climate warming effects (Boschmans et al., 2021). Considering the overall

[1] According to the US Environmental Protection Agency, rail supposed 2.1% in the breakdown of transportation-related GHG emission in the United States in 2020. Commercial Aircraft accounted for 5.6%, while cars reached 37.8%, that is, six times more (OTAQ, 2022).

[2] Cantos-Sánchez et al. (2009) also consider the effect of external costs in the analysis of optimal pricing in interurban passenger routes.

environmental costs in monetary terms, external costs of short-haul flights is estimated at 4.3 €-cent/pkm. The high environmental costs have positioned aviation in the spotlight of the climate change debate. Public authorities and organizations are bringing to the table new policy instruments that reduce air transport activity towards more environmentally friendly modes like HSR, the external costs of which are three times lower than short-haul flights (1.3€-cent/pkm), see European Commission (2020).[3] For instance, pricing policies, technology standards, infrastructure measures, or banning domestic short hauls. Proposals to substitute shorter flights by rail were expressed in the 2011 European Commission's White Paper (Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system). To illustrate, the flight route between Vienna-Salzburg, the Amsterdam-Brussels and Paris Orly-Lyon routes are examples of such ban policy. This scheme was also considered by the Spanish Government who recommended banning short-haul flights in the following years (ONPE Gob.España, 2021) and has been discussed in Germany, Italy and the UK (see Dobruszkes et al., 2022).

To reduce emissions and limit climate change in aviation, much of the literature has studied proposals ranging from taxes to emission reductions schemes and changes in travel behaviour. Thus, Gössling et al. (2019) discuss the perceived necessity of flights and implications for a cleaner aviation system. For Switzerland, Wild et al. (2021) survey the effects of market-based measures and other governmental policies to reduce CO2 emissions. They conclude that flight tax programs are weakly effective, and may even generate additional transport traffic. Using synthetic control methods, Kang et al. (2022) provide an ex-post evaluation showing that the policy change in the EU Emission Trading System will reduce flight frequency, increase load factors and significantly impact low-cost and regional carriers and short-haul routes. A review of papers on the challenges for mitigating the climate impact of aviation is given by Lai et al. (2022).

[3] The EU average costs are averages for the selected EU-airports that may not be representative for all EU airports.

A more general view concerning CO2 reduction measures is required and should look at modal interactions – see Jiang et al. (2021) for a survey on the environmental implications of the interplay between HSR, air and road transport. Note that HSR traffic is diverted from other modes and that the introduction of HSR may generate new travel demand (Givoni and Dobruszkes, 2013). In this regard, collaboration between airlines and HSR may be environmentally beneficial since HSR travel is certainly attractive for trips in the range of 300-700 km and less polluting than air travel (see Sun et al. (2017), and Zhang et al. (2019) for surveys on air-HSR competition). D'Alfonso et al. (2015, 2016) conclude that the competition between air transport and HSR may be detrimental for the environment as compared with monopoly. The paper by Jiang (2021) theoretically studies an integrated policy consisting of taxing air transport while subsidizing the railway. Abstracting from environmental issues, Álvarez-SanJaime et al. (2020) study the scope of inter-modal cooperation in a transport network noting that welfare gains can be significant.

Only some recent contributions explicitly investigate the effects of policies that ban short-haul flights. For the case of intra-European flights and HSR, Avogadro et al. (2021) analyze route substitutability finding that banning domestic short-to-medium haul flights, where alternative connections are feasible, is positive in terms of CO2 savings, yet the benefits are not equally distributed across Europe. In contrast, Dobruszkes et al. (2022) argue that a ban policy should consider absolute emissions and not just look at the substitution effects towards a more efficient travel mode. These authors conclude that short-haul flights bans have limited effects on emissions reduction as the share of fuel burnt in such type of flights is barely 5.9% of the total despite they account for 27.9% of departures in 31 European countries. Finally, Reiter et al. (2022) offer a quantitative analysis of the effects that would follow from substitution of short-haul flights with rail services for a number of travel corridors in Germany. Their estimates point at significant reductions in CO2 emissions – between 2.7% and 22%. We complement this line of research by providing a formal setting that accounts for modal interactions between air, HSR and private car transport to conveniently consider all demand effects. An empirical application to two Spanish corridors allows for an informed assessment of the impacts of a short-haul flights ban on external costs, user surplus and social welfare.

Therefore, our objective here is to evaluate the effects of banning short-haul flights (a no-flights policy) when transport services are performed on routes where mode substitution is possible. We consider OD routes where trips can be made by air, HSR and road (users have the option to use their private car). The assessment of the proposed market-based measure involves not only looking at its effects on user surplus and company profits, but also on the level of external costs, including environmental damages, derived from the shift in the modal split.

The paper is structured into two parts. In the first part a formal model is used to obtain the equilibrium corresponding to two different scenarios. Firstly, the benchmark scenario (the duopoly equilibrium) characterizes the equilibrium when the three modes of transport are available to passengers. An HSR operator and an airline compete by setting prices. The equilibrium prices determine the modal split of passengers for train, air and road transport that allows us to calculate user surplus, firms profits and external costs. The latter are obtained as a weighted sum of passengers, where the weights are the per unit external costs per mode of transport. Secondly, the short-haul flights ban scenario (the monopoly equilibrium) corresponds to the case where only the HSR operator sets the equilibrium price. As in the former scenario, a modal split for passengers is obtained that allows us to find conditions for the short-haul flights ban (the no-flights policy) to be detrimental for society. In the second part, we provide an empirical application that consists of a calibration of the model for the two most important OD markets in Spain: the Madrid-Barcelona and the Madrid-Valencia corridors.

Our results show that when the per unit external cost of road transport is sufficiently large, the implementation of a no-flights policy turns out to be detrimental to society as it generates larger external costs. Considering that the per unit external cost of air transport is larger than that of HSR services, the condition on the external cost of road transport becomes weaker the larger the preference of users for the rail upon the air transport, as well as the better substitutes transport modes are for the symmetric case. Finally, we find that the no-flights policy increases HSR service price which leads to an increase in HSR profits, but to a decrease in user surplus and total profits for the symmetric case.

The model is calibrated for the two largest corridors in Spain in terms of total traffic: Madrid-Barcelona and Madrid-Valencia. The former is dominated by the HSR mode, while the latter by private car use. Then we may simulate the effects of a short-haul flights ban in these corridors. The simulations confirm the results put forward in the theoretical analysis, that is, an increase in HSR prices that implies increases in HSR profits and user losses, a fall in welfare and an increase in external costs (damages) follow in a no-flights setting. Our empirical analysis shows that welfare gross of external costs may slightly decrease (by 0.8%) in the Valencia-Madrid corridor or notably decrease (by 10.6%) in the Madrid-Barcelona corridor. From a transportation viewpoint it is relevant to distinguish between all external costs and those associated with the environment. Regarding the latter, we find that they may be smaller (10.9%) when removing air transport in the corridor where it carries quite air traffic. However, total external costs always increase, the size of which is in the range of 1.9-13.3%. We also find that users suffer a loss of between 0.7% and 19.7%. Altogether, social welfare net of all external costs is lower under the no-flights policy – the impact is stronger in the Madrid-Barcelona corridor (14.8%) than in the Madrid-Valencia corridor (4.7%). Finally, it is remarkable to note that the ban would induce an increase in environmental external costs of 12.3% in the Madrid-Valencia corridor.

We also discuss what happens when the degree of product differentiation between modes changes. The above noted results remain qualitatively valid. In particular, when modes become more similar the increase in total external costs (between 10.38% and 14.83%) and the welfare decrease (between 4,71% and 12.68%) appear to be more significant. A final robustness check is carried out considering competition in HSR services. The size of the negative effects that arise under no HSR competition are lessened.

The paper is organized as follows. Section 2 presents the model. Different subsections describe equilibria of different scenarios; the benchmark scenario where HSR and airlines compete for passengers (subs. 2.1), as well as the short-haul flights ban scenario (subs. 2.2). Subsection 2.3 offers the effects of the no-flights policy. The empirical application is given in Section 3. Finally, we conclude with some remarks and policy recommendations in Section 4.

2 The model and analysis of equilibria

Consider an OD market connecting two cities where a high-speed-rail (HSR) operator is competing with an airline and users have the option to use their private car. Thus, three differentiated transport modes are competing for passengers. In order to model demand, we define the following Spence-Dixit representative user utility function (see Dixit, 1979):

$$U(q_t, q_a, q_c) = y + \sum_{i=t,a,c} \alpha_i q_i - \frac{1}{2} \sum_{i=a,t,c} \beta_i q_i^2 - \gamma(q_t q_a + q_t q_c + q_a q_c) \tag{1}$$

The representative user's budget constraint is defined by $I = p_t q_t + p_a q_a + r_c q_c + y$; where subscript t stands for rail transport, a for air transport and c for car, q_i denotes the number of trips and α_i the maximum willingness to pay for travelling by mode i, for $i = t, a, c$. Similarly, p_t and p_a are the HSR and airline prices, while r_c is the cost of private car use (fuel, depreciation, maintenance and repair, etc.), I is the user's income and y stands for the numeraire of the economy. Services become less differentiated as γ tends to $\beta' s$.[4] A system of inverse demand functions is obtained from the maximization of the utility function in (1) subject to the

[4]In fact, the ratio $\frac{\gamma^2}{\beta_i \beta_j}$ expresses the degree of product differentiation between modes i and j. Then, less differentiation implies ratios closer to one.

budget constraint as follows:

$$p_t(q_t, q_a, q_c) = \alpha_t - \beta_t q_t - \gamma(q_a + q_c), \tag{2}$$

$$p_a(q_t, q_a, q_c) = \alpha_a - \beta_a q_a - \gamma(q_t + q_c), \tag{3}$$

$$r_c = \alpha_c - \beta_c q_c - \gamma(q_a + q_t). \tag{4}$$

The two first equations above correspond to the inverse demand functions for the HSR and airline transport services, while (4) is the condition that defines the optimal use of private car. Since r_c is parametric but affects the operators' decisions, we solve for q_c in (4), substitute back in (2) and (3) and then solve for p_t and p_a leading to the following inverse demand system:

$$p_t(q_t, q_a) = a_t - b_t q_t - d q_a, \tag{5}$$

$$p_a(q_t, q_a) = a_a - b_a q_a - d q_t. \tag{6}$$

Note that $q_c = \frac{\alpha_c - r_c - \gamma(q_a + q_t)}{\beta_c}$, with $\alpha_c > r_c$, and $a_k = \alpha_k - \frac{\gamma(\alpha_c - r_c)}{\beta_c}$; $b_k = \frac{\beta_k \beta_c - \gamma^2}{\beta_c}$ for $k = t, a$ and $d = \frac{\gamma(\beta_c - \gamma)}{\beta_c}$.[5] The benchmark scenario features a duopoly situation, where the HSR operator and the airline choose the profit-maximizing prices. Then, a short-haul flights ban is implemented and there is just HSR service. Since we assume that firms compete in prices, the demand system derived from (5)-(6) is:

$$q_t(p_t, p_a) = \frac{b_a a_t - d a_a - b_a p_t + d p_a}{b_t b_a - d^2}, \tag{7}$$

$$q_a(p_t, p_a) = \frac{b_t a_a - d a_t - b_t p_a + d p_t}{b_t b_a - d^2}. \tag{8}$$

The HSR operator and the airline have the following operating profits:

$$\pi_t = (p_t - c_t) q_t(p_t, p_a), \tag{9}$$

$$\pi_a = (p_a - c_a) q_a(p_t, p_a). \tag{10}$$

where marginal (operating) cost per passenger by train and air are denoted by c_t and c_a, respectively.

[5] All a_k are assumed positive, that is $min\{\alpha_t, \alpha_a\} > \frac{\gamma}{\beta_c}(\alpha_c - r_c)$. Also, it happens that $b_k > d$ because $\beta_i \beta_j > \gamma^2$ for all $i, j = t, a, c, i \neq j$.

We are concerned with the external costs transport modes are imposing to society. These costs are proportional to the number of users and each mode has a different negative impact. Given that, we define the damage function as $D = \sum_i \delta_i q_i$, for $i = t, a, c$ where δ_i is interpreted as the per unit damage imposed by mode i . Finally, define the (gross of damages) social welfare function (SW) as the sum of consumer surplus (CS) and industry profits (Π),

$$\begin{aligned} SW &= CS + \Pi = U - p_t q_t - p_a q_a - r_c q_c + \pi_t + \pi_a \\ &= (\alpha_t - c_t - \frac{\beta_t}{2} q_t) q_t + (\alpha_a - c_a - \frac{\beta_a}{2} q_a) q_a + (\alpha_c - r_c - \frac{\beta_c}{2} q_c) q_c \\ &- \gamma(q_t q_a + q_t q_c + q_a q_c). \end{aligned} \tag{11}$$

The effect on society of the policy analyzed will be assessed as the difference in the sum of SW and damages D that such a policy will induce.

2.1 The benchmark scenario: the duopoly equilibrium

Consider that the HSR operator and the airline compete in prices, so each operator chooses p_t and p_a to maximize its corresponding profits in (9) and (10). The solution of the system $\frac{\partial \Pi_t}{\partial p_t} = 0$ and $\frac{\partial \Pi_a}{\partial p_a} = 0$ and the equilibrium condition $q_c = \frac{1}{\beta_c}(\alpha_c - r_c) - \frac{\gamma}{\beta_c}(q_a + q_t)$, where superscript d stands for duopoly, yields

$$p_t^d = a_t - \frac{b_t(2b_a(a_t - c_t) + d(a_a - c_a))}{4b_t b_a - d^2}, \tag{12}$$

$$p_a^d = a_c - \frac{b_a(2b_t(a_a - c_a) + d(a_t - c_t))}{4b_t b_a - d^2}. \tag{13}$$

Once the equilibrium prices are obtained, the equilibrium outputs read,

$$q_t^d = \frac{b_a((2b_t b_a - d^2)(a_t - c_t) - b_t d(a_a - c_a))}{(4b_t b_a - d^2)(b_t b_a - d^2)}, \tag{14}$$

$$q_a^d = \frac{b_t((2b_t b_a - d^2)(a_a - c_a) - b_a d(a_t - c_t))}{(4b_a b_t - d^2)(b_t b_a - d^2)}, \tag{15}$$

$$q_c^d = \frac{\alpha_c - r_c}{\beta_c} - \frac{\gamma}{\beta_c}(q_t^d + q_a^d). \tag{16}$$

Let us define $R = \frac{a_t - c_t}{a_a - c_a}$. This ratio can be interpreted as the relative premium of the willingness to pay net of marginal costs between HSR and air transport services. The term premium meaning, as indicated in the definitions of a_t and a_a, the advantage of each mode over the net willingness to pay for private car use. Then, $R > 1$ is interpreted as a relative preference for the HSR service over air travel. Equilibrium quantities are required to be positive, which translates to the following restriction on R, $\frac{b_t d}{2b_t b_a - d^2} < R < \frac{2b_t b_a - d^2}{b_a d}$; and $q_t^d + q_a^d < \frac{\alpha_c - r_c}{\gamma}$.

2.2 The short-haul flights ban scenario: The monopoly equilibrium

Suppose now that a no-flights policy is implemented so that the airline can no longer operate this route. The HSR maximizes profits taking into account that now users' equilibrium condition for the car use becomes $q_c = \frac{\alpha_c - r_c - \gamma q_t}{\beta_c}$ and the HSR inverse demand function in (5) now reads $p_t(q_t) = a_t - b_t q_t$. The equilibrium quantities in this case are

$$q_t^m = \frac{a_t - c_t}{2b_t}, \tag{17}$$

$$q_c^m = \frac{\alpha_c - r_c}{\beta_c} - \frac{\gamma}{\beta_c} q_t^m. \tag{18}$$

2.3 The effects of the no-flights policy

In this section we first find the condition for the no-flights policy to imply higher damages and then its effect on the gross of damages social welfare. Remind that $D^d = \delta_t q_t^d + \delta_a q_a^d + \delta_c q_c^d = (\delta_t - \frac{\gamma}{\beta_c}\delta_c) q_t^d + (\delta_a - \frac{\gamma}{\beta_c}\delta_c) q_a^d + \frac{\alpha_c - r_c}{\beta_c}\delta_c$, while $D^m = \delta_t q_t^m + \delta_c q_c^m = (\delta_t - \frac{\gamma}{\beta_c}\delta_c) q_t^m + \frac{\alpha_c - r_c}{\beta_c}\delta_c$. The effects of a no-flights policy on damages will be negative if $D^m > D^d$. The condition for $D^m > D^d$ can be written as follows,

$$\delta_c > \frac{\beta_c}{\gamma} \left(\Gamma_a(R)\delta_a - \Gamma_t(R)\delta_t \right) \tag{19}$$

where $\Gamma_a(R) = \frac{2b_t^2((2b_a b_t - d^2) - b_a d R))}{H}$, $\Gamma_t(R) = \frac{d(2b_a b_t^2 - d(3b_t b_a - d^2)R)}{H}$ and $H = 2b_t^2(2b_a b_t - b_a d - d^2) - (2b_a b_t^2 - 3b_a b_t d + d^3) d R$. Note that, $\Gamma_a(R) > 0$ while $\Gamma_t(R) > 0$ only if $R < \frac{2b_t^2 b_a}{d(3b_t b_a - d^2)} < \frac{2b_t b_a - d^2}{b_a d}$.

Condition (19) imposes a sufficiently large δ_c for the no-flights policy to imply a larger damage. Considering $\delta_a > \delta_t$, this condition is weaker, i.e. the right-hand side of (19) is smaller, the larger R, that is, the larger the relative premium of the HSR upon the air transport. Similarly, condition (19) is weaker the larger b_a if $R < \frac{b_t}{d} < \frac{2b_t b_a - d^2}{b_a d}$ and the smaller b_t if [6] $\frac{b_t d}{2b_t b_a - d^2} < r^- < R < \frac{2b_t b_a - d^2}{b_a d}$.

To give a simpler condition we assume symmetry as follows. Firstly, symmetry in the HSR and air modes, which entails, $a_a = a_t = a = \alpha - \frac{\gamma}{\beta}(\alpha_c - r_c)$, and $c_a = c_t = c$; this implies that $q_t^d = q_a^d = q^d$ and $R = 1$. Also symmetry in substitution across modes, that is $\beta_t = \beta_a = \beta_c = \beta$. Then, condition (19) now simplifies to,

$$\delta_c > \frac{\beta}{\gamma}\left(\frac{2(\beta+\gamma)^2\delta_a - \beta\gamma\delta_t}{2\beta^2 + 3\beta\gamma + 2\gamma^2}\right) \tag{20}$$

The above condition is weaker when modes are better substitutes for $\delta_a > \delta_t$. Finally, a sufficient condition for the no-flights policy to imply larger damages is obtained by setting $\delta_t = 0$,

$$\frac{\delta_c}{\delta_a} > \frac{\beta\left(2(\beta+\gamma)^2\right)}{\gamma\left(2\beta^2 + 3\beta\gamma + 2\gamma^2\right)} > 1 \tag{21}$$

Then, if the relative per unit damage of the road and air modes is sufficiently larger than one, the no-flights policy will induce damages. This requirement decreases with the degree of substitution across modes. For instance, in case $\gamma = \beta$, that is, users view modes as perfect substitutes, the no-flights policy induces larger damages when $\frac{\delta_c}{\delta_a} > \frac{8}{7}$.

Consider now the effect on SW. First note that in the case of symmetry, i) $q_c^d = \frac{\alpha_c - r_c}{\beta} - \frac{\gamma}{\beta}(q_t^d + q_a^d)$, $q_t^d = q_a^d = q^d = \frac{\beta(\beta+\gamma)(a-c)}{(\beta-\gamma)(2\beta+\gamma)(\beta+2\gamma)}$, and ii) $q_c^m = \frac{\alpha_c - r_c}{\beta} - \frac{\gamma}{\beta} q_t^m$, $q_t^m = q^m = \frac{\beta(a-c)}{2(\beta^2-\gamma^2)}$. Therefore, it happens that $q^d < q^m < 2q^d$ which implies that the modal split changes to more train users ($q_t^m > q_t^d$) and more traffic on the road ($q_c^m > q_c^d$). Besides, total traffic decreases, $2q^d + q_c^d > q^m + q_c^m$. This shift on the modal split leads to a reduction in SW. The SW expressions that correspond

[6] Note that r^- is the lower root for R of expression $4b_a^2 b_t^3 - d\left(12b^2 b_a^2 - 9bb_a d^2 + 2d^4\right)R + (3b_a^2 b_t d^2 - 2b_a d^4)R^2 = 0$. In case of symmetry, $R = 1$ and r^- <1 iff $0.761\beta < \gamma < \beta$.

to each situation are obtained from (11) and read,

$$SW^d = \frac{(\alpha_c - r_c)^2 + 4(\beta(\alpha - c) - \gamma(\alpha_c - r_c))q_d - 2(\beta - \gamma)(\beta + 2\gamma)q_d^2}{2\beta}, \quad (22)$$

$$SW^m = \frac{(\alpha_c - r_c)^2 + 2(\beta(\alpha - c) - \gamma(\alpha_c - r_c))q_m - \left(\beta^2 - \gamma^2\right) q_m^2}{2\beta}, \quad (23)$$

where it can be easily shown that (22) is larger than (23) for all $\beta > \gamma$.[7]

If quantity competition among the HSR and the airline is assumed, a similar condition to that in (19) can be obtained. Considering full symmetry, the corresponding condition to (20) is $\delta_c > \frac{2\beta(\beta+\gamma)\delta_a - \beta\gamma\delta_t}{\gamma(2\beta+\gamma)}$, which is more demanding, so a larger δ_c is needed. A sufficient condition for larger damages under the no-flights policy becomes $\frac{\delta_c}{\delta_a} > \frac{2\beta(\beta+\gamma)}{\gamma(2\beta+\gamma)}$, which is decreasing in γ and larger than one, being $\frac{\delta_c}{\delta_a} > \frac{4}{3}$ when $\gamma = \beta$.

3 An empirical application to Spain

Spain ranks first in Europe in terms of HSR network length, with 3,622 km in 2021, and second globally after China (40,474 km). Spanish HSR services provide speeds of up to 300 km/h with short travel times, multiple frequencies and stations in the city center. This represents a significant improvement in service quality and puts competitive pressure on air transport for distances between 300 and 700 km. Since the official opening of the first lines, they have had a significant substitution effect on the air transport mode for medium to long distance routes, leading to a modal re-distribution of passenger transport. HSR is an important tool for meeting the commitments made to reduce GHG emissions from passenger transport in the European Union. Spain is therefore a good example to ex-ante evaluate the effects of banning short-haul flights.

We present the calibration of effects of bans in two OD markets. The first one is the Madrid-Barcelona corridor, the most important OD market with 9.40 mil-

[7] The sign of the difference $SW^d - SW^m$ is the same as the sign of $20\beta^3 + 28\beta^2\gamma + 5\beta\gamma^2 - 6\gamma^3$, which is definitely positive for $\beta > \gamma$.

lion travelers in 2018 (8.24 million in the period 2005-2018). The two cities have Spain's two largest airports, there is a highway connecting the two cities and a HSR service has been in operation since February 2008. It is important to note that the modal split in 2018 was 45.7 % HSR, 26.3% air, 23.6% private car. This means that the market is dominated by HSR, a situation that has been reached from an initial dominance of air transport of 43.4% in 2008, which indicates an important modal shift in favor of HSR. The second market is the Madrid-Valencia corridor, which links the first and third Spanish cities in terms of population. It is the second OD market with 9.24 million travelers in 2018 (8.72 million in the period 2005-2018). Valencia has a major international airport, there is a highway connecting both cities and a HSR service has been operating since December 2010. However, in 2018 the Madrid-Valencia market was dominated by private car, 66.2%, followed by HSR, 26.2% and by air, 3.9%. Since the HSR started operating, the shares of air and private car have decreased from 11.1% and 76.0%, respectively. Therefore, we present two OD examples where the HSR has been important in reducing air transport, but this mode is dominant only in the former market. This difference will prove important in explaining the impact of the short-flights ban on society. Information of these two corridors for 2018 are shown in Table 1.

We proceed to calibrate the model following the methodology employed in Álvarez-SanJaime et al. (2020, 2021). In this exercise we will apply a more general version of the utility function in (1), where cross parameters between transport modes will be different. To find values for the parameters in the utility function, values on prices, traffic levels and price elasticities have been used as a reference. Values for own and cross price elasticities are displayed in Table 2.

The values for elasticities are borrowed from different references. The literature obtains similar values for own price elasticities, where clearly air transport is price elastic, with values slightly higher than one, HSR presents a price elasticity around (-0.6,-0.7) and car transport is the more inelastic mode. Regarding cross-elasticities there is a higher dispersion in the values. Ortega-Hortelano

Table 1: Data for Madrid-Barcelona and Madrid-Valencia OD markets, year 2018

	Madrid-Barcelona	Madrid-Valencia
HSR		
Kms by HSR	506	303
Price (euros)	80	55
Traffic (pass. per day and direction)	5,879	3,321
Air		
Kms by air	487	293
Price (euros)	100	85
Traffic (pass. per day and direction)	3,382	495
Private transport (car)		
Kms by car	617	356
Price (euros)	60	40
Traffic (pass. per day and direction)	3,041	8,386

Source: AENA, RENFE, DG. of Transport, Ministry of Works and own elaboration.

Table 2: Own and cross price elasticities

	HSR	Air transport	Car transport
HSR	-0.65	0.39	0.21
Air transport	0.39	-1.22	0.25
Car transport	0.21	0.25	-0.50

Source: Ortega-Hortelano et al. (2016); Martín and Nombela (2008) and Román et al. (2010).

et al. (2016) estimate a higher cross sensitivity than Martín and Nombela (2008) and Román et al. (2010). We have opted to consider a mean value for the cross-elaticities, and a sensitivity analysis will be undertaken in order to provide more robustness to our results. In particular, the values obtained for the parameters of the utility function for both corridors are in Table 3. Note that in the Madrid-

Barcelona corridor the different parameter types are more similar across modes, indicating that this corridor closer to the symmetric case in the theoretical model. Regarding operating transport costs, we employ data for the cost per passenger by HSR and air in both corridors, which are displayed in Table 4.

Table 3: Calibrated utility function parameters

	Madrid-Barcelona	Madrid-Valencia
β_t	0.016	0.039
β_a	0.019	0.362
β_c	0.032	0.036
γ_{ta}	0.0091	0.083
γ_{tc}	0.0093	0.028
γ_{ac}	0.0103	0.096
α_t	261.83	500.31
α_a	250.02	1359.57
α_c	226.67	474.11

Finally, in order to incorporate the external costs in our model we will use the definition of external costs and the estimates employed in the Handbook elaborated by the EU (see "Handbook on the external costs of transport", version 2019 – 1.1).[8] In particular, we will follow two approximations. In the first one we con-

[8]The total external costs for road, rail, inland waterway transport, aviation and maritime in 2016 amounted to €987 billion, which corresponds to 6.6% of the total GDP in EU28. Road trans-

Table 4: Operating costs per transport mode and OD market

	Madrid-Barcelona	Madrid-Valencia
Operating costs HSR	65	45
Operating costs air	80	65

Source: Own elaboration from Campos and De Rus (2009) and Swan and Adler (2006).

sider only external costs of environmental type. In this case we take into account the effects of pollution, climate change, well-to tank and congestion. We assume that congestion not only results in more travel time and energy consumption, but also causes pollution, decreases productivity and imposes costs on society.[9] In the second approximation we include all the external costs provoked by transport. Then we add to the former costs, the external costs in terms of accidents, noise and habitat damage. Table 5 displays the values of these external costs in cents of € per passenger-km.

Table 5: External costs per transport mode in cents of € per pass-km

	HSR	Air (short-haul)	Car transport
Air pollution	0.0	0.30	0.7
Climate	0.0	2.39	1.2
Congestion	0.0	0.00	4.2
Well-to-Tank	0.3	1.06	0.4
External environm. costs	**0.3**	**3.75**	**6.5**
Accidents	0.1	0.04	4.5
Habitat damage	0.6	0.03	0.5
Noise	0.3	0.46	0.6
Total external costs	**1.3**	**4.28**	**12.1**

Source: EC DG for Mobility and Transport "Handbook on the external costs of transport", 2019.

Results for the simulation for both corridors are reported in Table 6. Note that there are two columns for each OD market, one for the case where air transport competes with HSR and car, and another one where air transport is banned. In

port is by far the mode that causes most external costs, 83% of the total costs (out of this 83% a 69% is due to passenger transport). Aviation causes 10%, while rail transport 1.8%.

[9]During congestion, vehicles spend more time on the road, idling or crawling, and undergo numerous acceleration and deceleration events that may lead to an increase in emissions, see Smit et al. (2008).

Table 6: Simulated effects of the no-flights policy for Madrid-Barcelona and Madrid-Valencia OD markets

	MADRID-BARCELONA		MADRID-VALENCIA	
	HSR+Air	Flights Ban	HSR+Air	Flights Ban
HSR price	111.54	128.87	93.33	95.37
		15.54%		2.19%
Air price	99.46		98.50	
HSR traffic	5,879	6,152	3,321	3,375
		4.64%		1.63%
Air traffic	3,382		495	
Car traffic	3,041	4,047	8,386	9,686
		33.08%		15.50%
Total traffic	12,302	10,199	12,202	13,061
		-17.09%		7.04%
HSR operat. profits	273,609	392,928	160,504	167,000
		43.61%		5.92%
Airline operat. profits	65,814		14,023	
User surplus	980,261	786,747	2,829,055	2,810,061
		-19.74%		-0.67%
Gross Social Welfare	1,319,683	1,179,675	3,003,582	2,980,060
		-10.61%		-0.78%
Ext. environ. costs	192,655	171,661	350,407	393,616
		-10.90%		12.33%
Total external costs	333,236	339,523	656,566	743,680
		1.89%		13.27%

the case of Madrid-Barcelona (columns two and three), note that banning short-haul flights would suppose an increase in HSR price by 15.5% and by 4.6% in rail traffic. This is explained by the elimination of a direct competitor for the HSR. At the same time the removal of air transport would lead to a rise by 33.0% in the use of private car. Note that car traffic behaves as a competitive mode and the cost of private car use keeps fixed not reacting to the removal of air transport, but it becomes relatively cheaper than HSR service. There is a modal redistribution from air to HSR and, specially, to car use, although total traffic falls by 17.1%, following the elimination of short-haul flights. It is clear that the HSR operator will improve her profits with the air transport ban, but user surplus will notably fall by 19.4%, and gross social welfare also falls by 10.6%. Regarding external costs, when only external environmental costs were considered the banning of flights would reduce the environmental damages by 10.9%, which is a positive result. However, if we took into account all external costs there would be a small increase by 1.9%. The reason for this result is that total external cost per pass-km of car is almost three times the total external cost of air; note that external costs due to accidents are particularly large for the car mode. Therefore, if total external costs were taken into account, these would increase with the banning of the air transport leading to net social welfare losses. Indeed, even with the most restrictive definition of external costs, the net social welfare is considerably reduced by 10.6% were short-haul flights banned, reaching 14.8% when all external costs are included.

Regarding results for Madrid-Valencia (columns four and five), we must first stress that in this corridor the presence of the air transport is much lower than in Madrid-Barcelona. In particular and considering only the largest modes of transport, HSR, air and car; the market share for air transport in Madrid-Barcelona was 29.0%, while the corresponding market share for air in Madrid-Valencia was 4.2%. In this corridor the increase in HSR price is very small (2.2%), and the increase in the HSR traffic is also very modest (1.6%). However, there is a notable rise in car traffic (around 15.5%), which is the worst mode in terms of total external costs. Therefore, there is a small substitution effect towards HSR and a notable one towards car use, yielding a 7.0% increase in total traffic, which is in contrast with what happens with Madrid-Barcelona. In this case user surplus is reduced, but in a very small amount (only by 0.7%). Also gross social welfare falls by a small amount (0.8%). But now environmental external costs and total external costs are clearly higher with respect to the benchmark scenario. The increase in dominance of car transport is the main reason that explains that external costs are always higher after the banning of the air transport, which inevitably results in welfare losses net of external cost of 4.7%.

3.1 Robustness analysis

Results presented in Section 2 emphasize the relevance of the degree of product differentiation between transport modes in assessing the welfare effects and damages stemming from a short-haul flights ban. Tables A.1 and A.2 in the Appendix show the results when the three γ parameters in Table 6 used in the calibration are changed by $\pm$ 7.5%. In the Madrid-Barcelona corridor, when they are increased by 7.5%, that is, transport modes are more similarly perceived by users, the reduction in external environmental costs is smaller than in Table 6 (the decrease is 2.9%). When we consider total external costs, the 10.4% rise is now higher relative to the case in Table 6. Regarding net social welfare, the elimination of air transport produces a reduction in net social welfare of 12.7%. If instead, the γ parameters are reduced by 7.5%, the reduction in external environmental costs is higher, a decrease by 12.5%, while total external costs barely increase (0.13%). In any case net welfare always falls. The above comments remain fundamentally valid for the Madrid-Valencia corridor. *We can conclude that when the modes are more substitutes, banning short-haul flights will be more detrimental in terms of external costs*.

One wonders whether the increase in availability of a more environmental friendly mode may reverse our main conclusions. It is therefore worth analyzing the effects of a second HSR competitor. In 2018 this was not possible, because only the incumbent operator (RENFE) offered HSR services. However, as of 2022, some new private operators (OUIGO and Iryo) have entered in Madrid-Barcelona and Madrid-Valencia corridors. Consequently, using the parameter values in Table 3 we have simulated the existence of a duopoly in the HSR service assuming that HSR companies are symmetric and that the degree of differentiation between HSR services is lower than across modes.[10] The results for the two corridors are in Table A.3 in the Appendix. Focusing on the corridor Madrid-Barcelona, the removal of flights would lead to a lower increase in HSR prices and car traffic, a larger increase in HSR traffic, and a larger reduction in external environmental costs with respect to the situation of only one HSR operator. However, if all the external costs are considered the removal of flights would lead to a small decrease in total external costs, the reason being that HSR competition leads to lower prices for air and rail transport, thus the share of car traffic is lower as compared to the case with only one HSR service. Also, a ban on flights induces a lower increase in car use and a larger increase of HSR traffic with respect to Table 6. Besides, the reduction in the user surplus would be very much lower than that produced in the rail monopoly situation. The reason is that users suffer less after a flights ban when there is competition in HSR services because HSR prices increase by less. In terms of profits, HSR duopolists capture the foregone profits of air transport. Finally, net social welfare decreases by less. Regarding the Madrid-Valencia corridor, in the case that there are two HSR companies the results are very similar to the case of the rail monopoly. User surplus is hardly affected due to the relative low market share of air transport. The removal of flights will lead to a relevant increase in the environmental and all the external costs and ultimately in a lower net social welfare loss than in the case of no HSR competition.

[10]The introduction of a second HSR operator will reduce equilibrium prices, this effect is larger the lower the degree of differentiation between HSR operators.

4 Concluding remarks and policy implications

The fact that global air transport significantly affects climate change has prompted scholars to develop studies that evaluate policy measures towards a greener modal split. One such measure is the promotion of rail above air travel, which emits less greenhouse gases per passenger. This is a possibility in short distance routes where rail and air transport effectively compete. Our paper has formally explored the welfare and external environmental consequences of a short-haul flights ban, a market-based policy that is being implemented or planned in several European countries. The analysis carefully considers the demand effects between air, rail and private car transport while taking into account a number of external costs associated to each mode. The main conclusion from our theoretical analysis is that, provided that the per unit external cost of road transport is sufficiently large, a no-flights policy is detrimental to society as it generates larger external costs. The simulation results for two Spanish corridors suggest that, although there may be less external environmental costs in the route with more air traffic, there are always losses to society; users are worse off and total external costs increase. Increases in environmental external costs cannot be ruled out. The size of such losses is found to depend on the degree of differentiation between modes and the existence of competition in rail services.

Some relevant policy implications can be drawn from our analysis regarding the desirability of a short-haul flights ban. Firstly, in view of our results, a blanket approach for such a policy should not be adopted; we propose a careful case-by-case study. Secondly, complementary measures would be advisable. One of them would be to encourage more fuel efficient cars to lessen the negative effects of the policy. Another complementary measure is to use short-haul flights as the means to extent the adoption of SAF (sustainable aviation fuel) on aviation via subsidies; this will enhance the use and improvement of such technology by moving forward on the learning-by-doing curve. Finally, an alternative policy would consists of the improvement of HSR service quality to make it relatively more attractive to users. This would provide for a better initial setting in which to consider policies that limit short-haul flights.

The consideration of travel time issues, the effect of variation in frequency of HSR services, and of course, the effects on connecting passengers are extensions worth analyzing in future work.

Appendix: Tables for the robustness analysis

Table A.1: Sensitivity analysis for the Madrid-Barcelona OD market

	γ parameters 7.5% larger		**γ parameters 7.5% smaller**	
	HSR+Air	Flights Ban	HSR+Air	Flights Ban
HSR price	109.67	133.60	115.31	131.46
		21.82%		14.01%
Air price	95.84		102.15	
HSR traffic	5,879	6,049	5,879	6,167
		2.89%		4.90%
Air traffic	3,382		3,382	
Car traffic	3,041	4,435	3,041	3,968
		45.84%		30.48%
Total traffic	12,302	10,199	12,302	10,135
		-14.78%		-17.62%
HSR operat. profits	262,615	414,961	295,772	409,859
		58.01%		38.57%
Airline operat. profits	53,571		74,911	
User surplus	1,360,790	1,126,260	901,780	757,402
		-17.23%		-16.05%
Gross Social Welfare	1,676,976	1,541,221	1,272,464	1,166,901
		-8.10%		-8.30%
Ext. environ. costs	192,655	187,051	192,655	168,489
		-2.91%		-12.54%
Total external costs	333,236	367,840	333,236	333,669
		10.38%		0.13%

Table A.2: Sensitivity analysis for the Madrid-Valencia OD market

	γ **parameters 7.5% larger**		γ **parameters 7.5% smaller**	
	HSR+Air	Flights Ban	HSR+Air	Flights Ban
HSR price	82.86	82.90	102.48	106.54
		0.05%		3.96%
Air price	79.41		115.32	
HSR traffic	3,321	3,323	3,321	3,385
		0.06%		1.93%
Air traffic	495		495	
Car traffic	8,386	9,828	8,386	9,581
		17.20%		14.25%
Total traffic	12,202	13,151	12,202	12,966
		7.78%		6.26%
HSR operat. profits	125,733	125,941	190,891	208,313
		0.17%		9.13%
Airline operat. profits	8,841		18,552	
User surplus	2,928,230	2,920,830	2,729,880	2,699,540
		-0.25%		-1.07%
Gross Social Welfare	3,046,772	3,046,772	2,939,324	2,907,853
		-0.52%		-1.07%
Ext. environ. costs	350,407	399,196	350,407	389,399
		13.92%		11.13%
Total external costs	656,566	753,908	656,566	735,871
		14.83%		12.08%

Table A.3: Simulated effects of the no-flights policy for Madrid-Barcelona and Madrid-Valencia OD markets with two symmetric HSR operators

	MADRID-BARCELONA		**MADRID-VALENCIA**	
	HSR+Air	Flights Ban	HSR+Air	Flights Ban
HSR price	93.96	101.44	78.53	79.62
		7.96%		1.39%
Air price	85.51		90.84	
HSR traffic per firm	5,009	5,469	2946	3004
		9.18%		1.97%
Air traffic	2,666		420	
Car traffic	2,072	2,661	6,543	7,5890
		28.43%		16.00%
Total traffic	14,756	13,599	12,855	13,598
		-7.84%		5.78%
HSR op. profits per firm	145,061	199,290	98,779	103,998
		37.38%		5.28%
Airline operat. profits	14,690		10,853	
User surplus	1,252,517	1,125,497	2,942,117	2,930,266
		-10.14%		-0.40%
Gross Social Welfare	1,557,328	1,524,078	3,150,529	3,138,263
		-2.14%		-0.39%
Ext. environ. costs	146,973	123,303	279,008	313,531
		-16.10%		12.37%
Total external costs	271,053	265,040	532,982	603,154
		-2.22%		13.17%

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