Transportation Research Part A 92 (2016) 261–276

Contents lists available at ScienceDirect

Transportation Research Part A

journal homepage: www.elsevier.com/locate/tra

Air transport and high-speed rail competition: Environmental implications and mitigation strategies ☆

Tiziana D'Alfonso [a,c,*], Changmin Jiang [b,c], Valentina Bracaglia [a]

[a] Department of Computer, Control and Management Engineering, Sapienza Università di Roma, Via Ariosto 25, Rome, Italy
[b] Asper School of Business, University of Manitoba, 181 Freedman Crescent, Winnipeg, Manitoba, Canada
[c] Transport Institute, University of Manitoba, 181 Freedman Crescent, Winnipeg, Manitoba, Canada

A R T I C L E   I N F O

Article history:
Available online 5 August 2016

Keywords:
High-speed rail
Airlines
Competition
Environment
Mitigation policies
London-Paris market

A B S T R A C T

We build a duopoly model to shed light on the environmental impact of HSR-air transport competition, capturing the effects of induced demand, schedule frequency and HSR speed. The net environmental effect can be negative since there is a the trade-off between the substitution effect – how many passengers using the HSR are shifted from air transport – and the traffic generation effect – how much new demand is generated by the HSR. We conduct a simulation study based on the London-Paris market where HSR has served 70% of the market. The introduction of HSR is detrimental to LAP, while it is beneficial to GHG emissions. HSR entry increases neither LAP nor GHG emissions when the ratio between HSR and air transport emissions is relatively low. Moreover, competition is more likely to be detrimental to the environment when the weight of the social welfare in HSR objective function is high. Since the magnitude of the environmental friendliness of HSR compared to air transport hinges on the mix of energy sources used to generate the electricity (which is heavily constrained by the country in which HSR operates), regulators should assess the implications of HSR entry taking into account the energy policy and mitigation strategies available to transport modes.

1. Introduction

Protecting the environment and preventing climate change is a strategic priority for the European Union (EU). By 2050, EU leaders have endorsed the objective of reducing Europe's Greenhouse Gas (GHG) emissions by 80–95% compared to 1990 levels. The targets are: 20% GHG emissions reduction by 2020, 40% reduction by 2030 and 60% by 2040. The impact of aviation on the environment is of growing concern, mainly due to the projected increase in demand for air transport. The 37th International Civil Aviation Organization (ICAO) assembly reports a projected 4.7% growth in world revenue passenger kilometers (RPKs) flown between 2010 and 2030[1]. The Committee on Climate Change reports that, under a high growth scenario, in 2050 aviation CO_2 emissions will be 7–8 times their levels in 1990 (Adler et al., 2013). The traffic increase will result in increasing emissions from aircrafts in spite of technological progresses (Socorro and Betancor, 2011). In fact, most studies

☆ Research supported by European Commission in the framework of the BONVOYAGE project (From Bilbao to Oslo, intermodal mobility solutions and interfaces for people and goods, supported by an innovative communication network), funded by EU under the Grant Agreement no 635867.

* Corresponding author at: Department of Computer, Control and Management Engineering, Sapienza Università di Roma, Via Ariosto 25, Rome, Italy.
E-mail address: dalfonso@dis.uniroma.it (T. D'Alfonso).

[1] Evidence shows that several large airports in the EU are currently operating at full capacity (Avenali et al., 2014).

http://dx.doi.org/10.1016/j.tra.2016.06.009
0965-8564/

foresee that the aviation sector will not be able to reduce its emissions by more than 1–1.5% per kilometer flown per annum (Anger, 2010; Morrell, 2007; Scheelhaase and Grimme, 2007).

In this context, air transport and high-speed rail (HSR) substitution has been supported by many for environmental reasons. The EU, for instance, stated that the majority of medium-distance passenger transport should go by rail by 2050, with the length of the existing HSR network to be tripled by 2030 (EC, 2011)[2]. One of the main statements to justify policies for modal shift from air to rail relies on the *greenness* of HSR on a per-seat basis. In fact, some empirical evidences show that the (per-seat) Local Air Pollution (LAP) and GHG emissions (or their economic impact) of airlines are higher than those of HSR (Givoni and Banister, 2006; Givoni, 2007; Janic, 2003, 2011). Nevertheless, the introduction of HSR services does not necessarily lead to overall environmental advantages (D'Alfonso et al., 2015). The net environmental effect can be negative since the introduction of the new transport mode often results in additional demand. In other words, there is a the trade-off between the *substitution effect* - how many passengers using the HSR are shifted from air transport - and the *traffic generation effect* - how much new demand is generated by the HSR.

The existing literature has mainly focused on the market equilibrium of airline-HSR competition (i.e., traffic and price levels) abstracting away from environmental considerations, with empirical approaches (Behrens and Pels, 2012; Dobruszkes, 2011; González-Savignat, 2004; Park and Ha, 2006), game theory settings (Adler et al., 2010) or analytical perspectives (Yang and Zhang, 2012). Some contributions have examined the possibility of airline-HSR cooperation and its potential benefits for airlines and the society. Again, these are mainly empirical papers (Cokasova, 2006; Givoni and Banister, 2006), with only a few works addressing this issue analytically (Jiang and Zhang, 2014; Jiang et al., 2016; Socorro and Viecens, 2013). Some recent contributions have investigated the long-term impacts of high-speed rail competition on air transport studying how the market coverage and the network choice of an airline would respond to HSR competition on origin-destination trunk routes (Jiang and Zhang, 2016).

The environmental impact of air-rail substitution has been mostly object of case studies on specific routes. Part of the debate concentrates on the assessment of the potential per-seat saving in pollution (LAP or GHG emissions) that could be achieved by substituting some short-haul flights with HSR services (Janic, 2011; Givoni and Banister, 2006; Miyoshi and Givoni, 2013). However, all these papers abstract away from the effect on environment of induced demand due to the introduction of a new mode of transport. D'Alfonso et al. (2015) move steps further and derive an analytical framework to evaluate the impact of modal competition between air transport and HSR on the environment and social welfare while pointing out the effect of induced demand. Their results show that competition between the two modes may be detrimental to the environment depending on market expansion, modal shift, market size and modal heterogeneity on emission rates.

In this paper, we build a duopoly model to study the impact of air transport and HSR competition on the environment when new travel demand is induced. The operators decide simultaneously on the number of passengers and the frequencies of service; HSR is also allowed to change train speed. We conduct a simulation study based on the London-Paris market, where HSR market share is 70% (Barrón et al., 2009). Such an exercise is necessary from a policy perspective. On the one hand, the debate around the impact of air-rail competition on the environment may have led to a bias amongst policy makers when considering future transport policies. On the other hand, HSR introduction can involve substantial investments, therefore a better understanding of its impact is necessary and timely. So far the partial substitution of short-haul flights with HSR services, either through modal competition or cooperation, has already taken place at major airports like Frankfurt Main, Paris CDG, Madrid Barajas or Amsterdam Schipol, which are all connected to the Trans-European High-Speed-Rail Network. China, the UK, Italy, Belgium and South Korea have successfully launched HSR lines. Many others, like Brazil, India, Russia, Turkey and the US are evaluating the options of investing in HSR.

Our paper shows similarities with D'Alfonso et al. (2015) but contributes on two counts.

First, we examine the effects on the environment of induced demand, schedule frequency and HSR speed simultaneously: we examine a single scenario in which air transport decides the traffic quantity and schedule frequency while HSR decides traffic quantity, schedule frequency as well as train speed. Conversely, D'Alfonso et al. (2015) build up three separate scenarios, each focusing on one aspect. What is missing in the framework of D'Alfonso et al. (2015) is that, when frequency and speed are both strategic variables for the HSR, the operator may have incentives to increase the speed of the vehicle and reduce the frequency accordingly, if this strategy is less costly than increasing the frequency of the service. On the one hand, this may be beneficial to the environment, since the number of HSR rides may reduce. On the other hand, this may be detrimental for the environment since pollution from HSR depends on the energy consumption of the rolling stock (CfIT, 2001), which increases with the speed of the train (Kemp, 2004; Garcia, 2010; Andersson and Lukaszewicz, 2006; Bousquet et al., 2013).

Second, through the numerical analysis, we measure the implications of HSR's introduction on LAP and GHG, while no simulation study is present in D'Alfonso et al. (2015). In doing so, we are able to disentangle the impact of air transport/HSR competition on LAP and climate change. This simulation study is also a base for discussing different mitigation strategies available to the two transport modes and EU policy measures – which might jointly affect the ratio between HSR and air transport emissions in the long run.

[2] Similarly, outside the EU, the National Environmental Policy Act (NEPA) underlines the importance of comparing the environmental impact of alternative modes in the United States (US). As highlighted in the Passenger Rail Investment and Improvement Act (PRIIA), US rail plans are to address a broad spectrum of issues, including an analysis of rail environmental impacts compared to air.