Can Market Power be controlled by Regulation of Core Prices alone?: An Empirical Analysis of Airport Demand and Car Rental Price

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Abstract

Many firms offer "core" and "side" goods in the sense that side-good consumption is conditional on core-good consumption. Airports are a common example where the supply of runway and terminal capacity is the core good and the supply of various concession services (for example, car rental services) is the side good. While side-good supply can be responsible for a major share in total revenue, monopoly regulation typically concentrates on the control of core-good prices ("core prices" in short). Whether market power can indeed be effectively controlled by the regulation of core prices alone then depends on whether core-good consumption is a function of the price for side goods. This study empirically shows that a one-dollar increase in the daily car rental price reduces passenger demand at 199 US airports by more than 0.36 percent. A major implication of our findings is that for the case of airports, the effective control of market power may require regulation of both prices for core and side goods.

Keywords: Core goods; side goods; airport; monopoly; car rentals.
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1.   Introduction

Over the last thirty years, the airport industry has faced two striking trends: First, there is growing importance of "concession revenues," which include revenue from retailing, advertising, car rentals, car parking, and land rentals (e.g., Zhang and Zhang, 1997 and 2003, Forsyth, 2004, and Thompson, 2007), as compared to the traditional aeronautical revenue associated with runways, aircraft parking and terminals. Nowadays, airports worldwide derive as much revenue, on average, from concession services as from aeronautical ones (e.g., Zhang and Czerny, 2012). Second, private airport ownership becomes more prevalent. Starting with the privatization of London airports and other airports in the United Kingdom in 1987, many airports around the world have been, or are in the process of being, privatized (e.g., Oum et al., 2004).[5] Since airports possess a significant amount of monopoly power in many situations, infrastructure charges of privatized airports are often subject to economic regulation. Such regulation has nevertheless focused on aeronautical services only, with airport concession services being generally left unregulated.

The present paper investigates the question of how the price of side goods, such as airport concession goods and services, can affect the demand for core goods and services (traveling activities). As discussed in more detail in the following, a good understanding of this relationship is fundamental for the design of regulatory regimes for airports. While the present study mainly reverts back to the airport industry as an example, the insights are also useful for other transport industries. For example, in the (passenger) rail industry, the supply of rail tracks and stations can be considered as the core good of rail infrastructure providers, while the supply of various concession services at train stations can be considered as the side good. Thus, the same question emerges for rail infrastructure providers as for airports: Can monopoly market power be effectively controlled by regulation of the core prices alone?

It seems directly plausible that concession revenues change the incentives for private, profit-maximizing airport infrastructure pricing, because they are closely linked to passenger quantities.

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[5] One may argue that these two developments are related to, and may in effect reinforce, each other. As compared to public airports, privatized airports have a greater incentive to explore and expand concession revenues due, at least in part, to the fact that, as discussed in more detail below, usually concession activities are unregulated and hence are more profitable. At the same time, the growing revenues generated from concession activities allow airport privatization politically feasible and attractive. For example, a government could fetch a large (lump-sum) amount of money when selling its airports to private hands, or receive continuous payments from the privatized airports as a landlord, or both.

Theory, however, shows that there are two possibilities, which depend on whether the passenger quantity is independent, or a decreasing function, of airport concession prices.[6] Independence may occur because buying the air tickets and car rental services can be separated in time (e.g., Zhang and Zhang, 1997 and 2003).[7] On the other hand, experienced travelers, e.g., business passengers, may well decide upon traveling based on the entire trip costs for both the tickets and (for example) car rentals. A reduction in the car rental price may therefore increase traveling activities of business passengers.

The policy implications of these two scenarios for private airport pricing are significant. If traveling activities are independent of concession prices, concession businesses may unambiguously exert downward pressure on the private aeronautical charge (e.g., Zhang and Zhang, 1997). The intuition is that airports reduce the private aeronautical charge in order to increase the passenger quantity and thus the demand for airport concession services and profit derived from the supply of airport concession services. Starkie (2001) proposes completely abolishing private airport regulation because of this effect.

However, the opposite may be true if an increase in prices for concession services reduces the amount of traveling. In this scenario, a reduction in the prices for concession services can be considered as an increase in airport "quality," which increases travel demand (Czerny and Lindsey, 2014). Czerny (2006) provides a numerical example, where the private aeronautical charge with airport concession services is *higher* than the private aeronautical charge in the absence of such services. He further shows that it can be welfare-optimal, in the sense of Ramsey (1927), to charge car rental services at marginal costs and cover infrastructure costs only using revenue from aeronautical charges when airport subsidy payments are unavailable. Note that a reduction in the car rental charge reduces the price elasticity of airport infrastructure demand (Czerny and Lindsey, 2014), and since Ramsey-optimal prices are inversely related to the price elasticities of demands, this provides an intuition for the welfare-optimality of such pricing

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[6] See Flores-Fillol et al. (2014) for a unifying approach where consumer foresight is determined by a continuous variable and the associated extreme values capture the scenarios with perfect consumer foresight (analogue to Czerny, 2006) or no consumer foresight at all (analogue to Zhang and Zhang, 1997 and 2003) respectively.

[7] Braccaglia et al. (2014) usefully point out that the increasing use of online booking and the fact that airport car rental or car-parking services are offered at the time of air ticket purchase may have increased consumer foresight relatively to earlier days.

structures.[8] As pointed out by Czerny (2006), marginal cost pricing for car rental prices may be difficult to implement through the regulation of infrastructure charges alone; thus, whether airport market power can be effectively controlled by the regulation of infrastructure charges alone depends crucially on whether travel activities are a function of concession prices or not.

Whether travel activities are a function of concession prices or not is an empirical question. Here, some empirical insights can be derived from the literature. Van Dender (2007) analyzes the effects of airline market structure on revenues that airports derive from airlines and passengers. In line with some of the literature mentioned above (e.g., Zhang and Zhang, 2003), he estimates a regression model where passenger quantities are used as an explanatory variable for average concession revenues, but abstracts away from the possibility that concession prices can explain passenger volumes. He finds that an increase in the passenger quantity reduces average concession revenues, which is consistent with the idea that a reduction in prices for concession goods and services can increase traveling activities. Choo (2014) finds that an increase in the share of revenues derived from concession businesses (and hence a decrease in the share of aeronautical revenues) is associated with a reduction in the aeronautical charge. This is consistent with the basic idea that a reduction in aeronautical charges can lead to a reduction in aeronautical revenues. Compared to these two studies, Ivaldi et al. (2014) directly test the effect of airport concession prices on passenger demand. They treat airport car parking prices as exogenous and find a negative effect of an increase in airport car parking prices on passenger demand.

While these three studies concentrated on US airports, other studies analyzed European airports. Analysis of European airports is of special interest because airport privatization is common in Europe, while almost all US airports are under public ownership. Thus, consideration of European airports captures private airport pricing behavior and economic regulation. Here the evidence is mixed. Bel and Fageda (2010) find that airlines pay higher aeronautical charges at private and unregulated airports relative to public or private and regulated airports. On the other hand, Bilotkach et al. (2012) find that aeronautical charges can be a decreasing function of private involvement in airport management. As pointed out by Bilotkach et al. (2012), this may

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[8] Czerny (2006) did not consider airport congestion. See Yang and Zhang (2011), Czerny (2013), D'Alfonso et al. (2013) and Czerny and Zhang (2014) for analyses of airport concession services when airports are congested.

be because private airport operators are more capable in developing concession businesses, which in turn may exert a stronger downward pressure on the private aeronautical charge if private involvement in operations increases. Since the consumption of concession services is not obligatory for the use of airport infrastructure, we can interpret these services as add-ons to the primary good traveling (Czerny and Lindsey, 2014). Here, Brueckner et al. (2013) find that the price for primary goods, "airfares" in their case, can fall when the price for add-ons, "checking a bag" in their case, increases. This may indicate that an increase in the prices for concession goods can reduce the demand for traveling.

Most of these empirical studies have not directly tested the relationship between passenger travelling and concession prices, however. This is understandable, as such empirical testing is not part of their main objectives. The study that is closest to ours because of its capturing of airport concession prices as an explanatory variable for passenger demand is the one by Ivaldi et al. (2014). However, Ivaldi et al. treat airport car parking prices as exogenous.

The main contribution of the present paper is to estimate the effect of airport car rental prices on passenger quantities, with the price for car rental services being treated as an *endogenous* variable. The present study therefore captures that concession service providers and airport operators may take advantage of a high demand for concession services by an increase in the price for concession services. The analysis is based on a sample of 199 large US airports with approximately 60,000 or more annual passengers in order to estimate the effect of car rental prices on passenger demand. A major challenge is to identify a valid instrumental variable for car rental prices. To qualify for such an instrumental variable, the variable must (i) have strong explanatory power with respect to car rental prices, and (ii) be exogenous with respect to airport market size in terms of passenger quantities. We find that the presence of Alamo, a car rental firm in our sample, has indeed a strong negative effect on average car rental prices over all the car rental companies and car categories. Based on a theoretical model of entry behavior in horizontally and vertically differentiated markets developed in the present paper, we further find that an increase in the overall market size can increase or decrease the individual incentives for market entry. We therefore assume that Alamo's presence at airports is exogenous to airport size in terms of passenger quantities. Altogether, this qualifies the dummy variable for the presence of Alamo as an instrumental variable for car rental prices. To explain passenger demand, we

develop a base model with one endogenous explanatory variable, car rental prices, and several exogenous variables which control for income, population size, airport competition, and vacation destinations.

We find that an increase in the daily car rental price reduces passenger demand by a minimum of 0.36 percent. Furthermore, we find that the absolute effect of car rental prices on passenger demands is small relative to the effect of ticket prices on passenger demands derived by previous studies when point estimates are considered. This is a sensible result given that only a share of the passengers arriving at an airport rent a car. To test for causality, we further consider average airport infrastructure revenue as another endogenous explanatory variable for passenger demand. In line with the public ownership structure of US airports, we find that the average infrastructure revenues are determined largely by average airport-operating costs, while average airport-operating costs are not a significant predictor for car rental prices. This leads to the conclusion that the increase in passenger demand associated with a reduction in the car rental prices may not be caused by corresponding reductions in aeronautical charges. This finding is consistent with the idea that car rental prices are causal for changes in passenger demands. Until this point, the analysis abstracts away from airport congestion. In a final step, we show that, for this reason, our regression results provide conservative estimates of the effect of car rental prices on passenger demand because congestion softens the effect of car rental prices on passenger demand.

This paper is organized as follows. The next section describes the data sources and the data itself. It further discusses the potential estimation bias of ordinary-least squares (OLS) estimations and how instrumental variable (IV) estimations can lead to consistent coefficient estimations. A theoretical model is used to discuss the number of car rental companies and the presence of a specific car rental company as candidates for instrumental variables for car rental prices. Section 3 presents the estimation results and discusses the order of magnitude of the estimation results relative to demand effects of air ticket prices. Causality and the effects of aeronautical charges on the regression results are analyzed in Section 4. This section also contains the discussion of congestion effects. Conclusions and avenues for future research are provided in Section 5.

2. Data Description and Econometric Model

2.1. Data description

This study analyzes 199 large US airports with more than 60,000 annual passengers. (The full list of the 199 airports is given in Appendix A.) The data was collected from several publicly available sources in the year 2005. The database of the US Bureau of Transportation Statistics (BTS) and especially the T-100 Segment (All Carriers) was used to collect information on passenger arrivals. The City-data website was used to collect information on airport aeronautical revenues and operating expenses. Car rental prices and identities of all car rental firms present at an airport had been collected from Orbitz and Expedia websites, as well as from individual firms. The car rental firms include eight major national firms (Avis, National, Hertz, Thrifty, Dollar, Enterprise, Alamo, and Budget) and several regional firms such as Fox, U-Save, Payless, and others. The price information was collected in March 2005 two weeks in advance and for five car types: Economy, Compact, Midsize, Standard, and Full. Specialty vehicles, such as minivans and SUVs were excluded because these tended to be available in only a few markets. Demand and cost factors for airports and car rental firms came from the database of Census, Bureau of Economic Analysis (BEA), Bureau of Labor Statistics (BLS), and Compustat.

The list of variables describing each airport is in Table 1. Variables are separated into three categories: namely, endogenous, instrumental, and exogenous variables. The table further indicates that some variables are considered as "potential" endogenous or instrumental variables. The consideration of these candidate variables will be helpful in analyzing the data and providing insights on the robustness of the approach and causal relationships, although they will ultimately not be used to determine the effect of car rental prices on passenger demand.

The average airport size in terms of passenger quantities is around 3.4 million passengers in 2005, which is quite low relative to Atlanta, the largest airport, with more than 80 million passengers. The average car rental price at an airport ($56.38 in Table 1) is calculated as average one-day price over all car categories and car rental firms; thus, all categories and firms are attached with the same weight, which is due to the fact that car rental quantities are not available to us.[9] Khan et al. (2009) found little evidence for quantity discounts based on the length of the rental period.

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[9] Our main estimation results are robust with respect to the use of alternative definitions of car rental prices. For instance, they are largely independent of whether averages are calculated for specific car-categories, i.e., whether car rental prices refer to the average Economy, Standard, Midsize, and Full car-type rental prices.

Thus, if passengers rent a car for a period of four days, average car rental expenditures reach more than US$225 per trip.[10] Compared to the average expenditure for air tickets of US$155 for the period between 1998 and 2002 found by Van Dender (2007), car rental expenditures are therefore a major share of the overall individual traveling expenditures for some passengers.

Table 1. Descriptive statics for sample comprising the 199 largest US airports in 2005

Variable	Brief explanation	Natural units		Units in the model			
		Mean		Mean	Std. dev.	Min.	Max.
(Potential) Endogenous							
log(*passengers*)	Arriving passengers	3,349,094.000	passengers	13.557	1.727	11.045	17.570
crprice	Average daily car rental price	56.377	US$	56.377	10.200	33.542	93.200
(*charge*)	Average aeronautical revenue per passenger	9.699	US$	9.699	8.629	2.274	83.403
(Potential) Instruments							
(*competition*)	Number of car-rental firms	7.096	firms	7.096	2.392	1.000	17.000
alamo	Presence of Alamo	0.799	dummy	0.799	0.402	0.000	1.000
(log(*cost*))	Airport operating cost per passenger	0.100	US$	0.100	0.042	0.009	0.315
Exogenous							
airports	Number of airports in county	1.166	firms	1.170	0.435	1.000	3.000
log(*gdp*)	County-level GDP	35633.810	US$	10.460	0.210	9.820	11.523
log(*population*)	Population	710,656.600	inhabitants	12.680	1.200	9.161	16.070
log(*poverty*)	Povertyratio	0.122	share	0.122	0.043	0.030	0.326
holiday	Vacation destination	0.156	dummy	0.155	0.363	0.000	1.000

Two candidates for the instrumental variables of rental price will be discussed in detail below: (i) the number of car rental firms present at an airport, and (ii) the presence of Alamo, a car rental firm in our sample, which will be chosen for our regression analysis. Alamo is present at 159 of our 199 airports and seems to target primarily leisure travelers. It, together with National, another car rental company in our sample, belonged to Vanguard, the third-largest car-rental company in the US in terms of the number of cars in service in the sample year 2005. While our main regression model abstracts away from aeronautical revenues, the analysis of aeronautical revenues is used to derive some insights on the causes for changes in passenger quantities. More specifically, we will use average aeronautical revenues as a proxy for airport infrastructure

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[10] In 2013, Scott Sider presented evidence that average car rental length in the US was 4.3 days for leisure customers and 3.6 days for commercial customers for car rental company Hertz, which is present at almost all airports in our sample.

charges, and discuss the use of average per-passenger operating cost as an instrument for average aeronautical revenues.

The set of exogenous variables includes the number of airports in the county in order to control for airport competition. Information about GDP, population, poverty, and vacation destinations (e.g., Las Vegas and Miami) is used to control for demand conditions.

2.2. Econometric model

Consider a regression in which the relationship between passenger demand and car rental prices is characterized as follows:

$$\log(passengers_i) = \alpha + \beta \cdot crprice_i + X_i \cdot \gamma + \varepsilon_i, \tag{1}$$

where i is an airport index with $i = 1, \ldots, 199$, $\log(passengers_i)$ is the log of annual passenger arrivals, $crprice_i$ is the average car rental price, X_i is a vector that contains all exogenous variables (i.e., $airports_i$, $\log(gdp_i)$, $\log(population_i)$, $\log(poverty_i)$, $holiday_i$), and the noise term ε_i (with mean zero and standard deviation σ_ε) captures the unobserved effects on passenger demands. Our main interest is to derive a better understanding of the sign and magnitude of the coefficient for the average car rental price, β.

A straightforward start is to run a simple OLS regression. However, it seems intuitive that car rental prices are a function of market size in terms of passenger volume for two alternative reasons. First, an increase in passenger demand will most likely lead to an increase in the demand for car rentals as well. Given that airport car rental companies are profit-oriented, a high demand for car rentals will lead to a relatively high price for car rental services under most circumstances.[11] On the other hand, taking into account that US airports are all publicly owned and operate under strict airport-cost recovery conditions, a second story may apply: Typically, airports operate under increasing economies of scale, which means that a high number of passengers reduces unit costs of airports and airport-cost recovery may therefore be less of a burden for larger airports. (This point will be discussed in more detail in Section 4.) Furthermore, US airports follow the "residual cost" or the "compensatory" pricing system (Oum et al., 2004). The first implies that aeronautical revenues cover the difference between the total cost and

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[11] More specifically, a positive shift in demand will lead to an increase in the monopoly price if demand is sufficiently concave.

revenues derived from, for example, concession businesses, while aeronautical revenues must fully cover aeronautical cost under the second pricing system. Thus, especially under the compensatory pricing system high passenger numbers may be associated with low unit cost, low aeronautical charges and low concession cost for airport car rental providers (e.g., the airport's charge to rental companies for their use of airport space). Since prices are usually an increasing function of cost, the low concession cost may therefore lead to low car-rental prices. Altogether, the car rental prices may be a function of passenger quantities and unobserved factors that are captured by the error term:

$$crprice_i = \psi + \phi \cdot \log(passengers_i) + \upsilon_i,$$ (2)

where the sign of ϕ can, as discussed above, be positive or negative in sign, and the noise term υ_i (with standard deviation σ_v) is assumed to be independent of ε_i. In this situation, the probability limit of the OLS estimate for β, denoted as $\hat{\beta}$, can be written as

$$\text{plim}\,\widehat{\beta} = \beta + \frac{\text{cov}(crprice_i, \varepsilon_i)}{\text{var}(crprice_i)}$$ (3)

with

$$\frac{\text{cov}(crprice_i, \varepsilon_i)}{\text{var}(crprice_i)} = \frac{\phi}{1 - \phi\beta} + \frac{1}{\phi(1 - \phi\beta)}\frac{\sigma_\upsilon^2}{\sigma_\varepsilon^2}$$ (4)

for $\phi \neq 0$ and $\phi\beta < 1$, where the latter condition ensures that expected car rental prices are non-negative. The right-hand side of equation (4) is negative in sign when an increase in the passenger demand reduces the car rental price. In this situation, OLS estimates would overestimate the absolute effect of car rental prices on passenger demand. On the other hand, the right-hand side of (4) is positive in sign under the alternative hypothesis that an increase in passenger demand is associated with an increase in the car rental price. In this scenario, it may therefore be more difficult to detect the effect of car rental prices on passenger demand, because the OLS estimate of β is conservative.

To deal with the simultaneity, we make use of an instrumental variable estimator. Letting z_i denote the instrumental variable with standard deviation σ_z, the probability limit of the instrumental variable estimator, denoted $\hat{\beta}_{IV}$, can be written as:

$$\text{plim } \hat{\beta}_{IV} = \beta + \frac{corr(z_i, \varepsilon_i)}{corr(z_i, cprice_i)} \cdot \frac{\sigma_\varepsilon}{\sigma_z}. \tag{5}$$

The right-hand side of (5) shows that two conditions must be satisfied to ensure that the instrumental variable estimator is consistent: (i) the instrumental variable must be uncorrelated with the error term ε_i, and (ii) the correlation between the instrumental variable and car rental prices must sufficiently strong. If condition (i) is not satisfied, while condition (ii) is satisfied, the IV estimate is clearly biased. However, even if condition (i) is satisfied and the numerator of the second term on the right-hand side of (5) is small, the second term can still be significantly high in magnitude if the denominator is small in magnitude. Thus, to derive useful results both conditions (i) and (ii) should be satisfied.

In the following, we discuss two candidates for the instrumental variable: (i) the number of car rental companies present at an airport, denoted n, and (ii) the presence of a specific car rental company.[12] These two candidates qualify as potential instrumental variables because both may have a significant impact on the level of car rental prices. This seems obvious in the case of the number of car rental companies because competition, and thus downward pressure on car rental prices, would be increasing in the number of car rental companies present at an airport. The presence of a specific car rental company may also have a strong explanatory power with respect to the level of car rental prices if this car rental company can be qualified as a "tough competitor." For instance, it has been shown for the airline industry (e.g., Dresner et al., 1996, Morrison, 2001) that the presence of a single airline such as Southwest can exert a significant, strong downward pressure on ticket prices in the market and the effect is stronger than that exerted by other airlines.

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[12] We also tested whether information about the utilization of public transport services or the distance between the airport and the city center could serve as instruments for car rental prices. It turned out that these variables had no significant effect on car rental prices and therefore did not qualify as the instrument.

Figure 1. Market size and entry
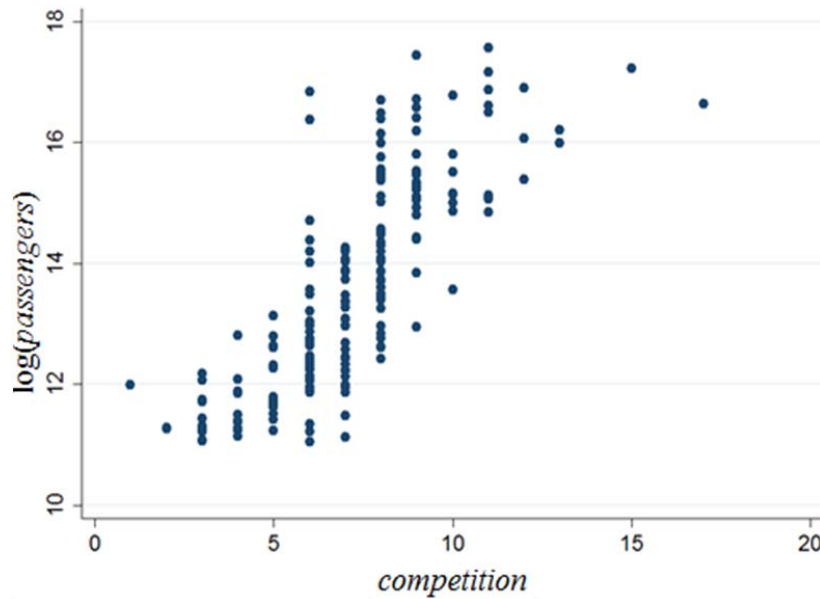
More specifically, consider a free-entry equilibrium with a large number of identical potential entrants, where firms decide upon entry in the first stage and play an oligopoly game in the output market in the second stage.[13] Let n denote the number of firms in the market and $\pi(n)$ denote the individual firm's profit. The necessary and sufficient conditions for a free-entry equilibrium are that firms cannot increase profit by entering the market, i.e., $\pi(n) = 0$, and that the individual firm's profit is a decreasing function in the number rival firms, i.e., $\pi'(n) < 0$. Market size is captured by parameter a with $\pi(n) = \pi(n;a)$ and $\partial \pi(n;a)/\partial a > 0$, which means that individual profits are an increasing function of the market-size parameter when the number of firms is given. Totally differentiating the zero-profit condition, $\pi(n;a) = 0$, reveals that an increase in the market-size parameter a increases the number of firms present in the market, i.e., $dn/da > 0$. Figure 1 displays a scatter plot of the log of passenger quantities and the number of car rental companies present, showing that a positive relationship between the two variables can indeed be observed in our data. Similarly to the above, one can show that the relationship between market size in terms of passenger quantities and entry can lead to a positive relationship between the number of car rental companies and the error term ε_i, i.e.,

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[13] This is analogue to the free-entry equilibrium model considered by Mankiw and Whinston (1986).

$corr(competition_i, \varepsilon_i) > 0$. Since we further expect a negative sign for the correlation between the number of car rental companies and car rental prices, i.e., $corr(competition_i, crprice_i) < 0$, the instrumental variable estimator would overestimate the (negative) effect of car rental prices on passenger demand. Since we prefer conservative estimates, we therefore abstain from using the number of car rental companies as an instrumental variable for car rental prices.

What about the presence of a "tough competitor" as an instrumental variable for car rental prices? The qualification as a tough competitor mentioned earlier indicates that there is a significant effect of the presence of this firm on car rental prices. The question however is whether market size can influence the incentives of a differentiated company to enter a market. To see that this is not necessarily the case, suppose there is a differentiated company with profit $\tilde{\pi}$ given that it enters the market. Furthermore, profit $\tilde{\pi}$ is a function of the number of competitors in the market, n, and the market size of the rival companies' market, a, i.e., $\tilde{\pi} = \tilde{\pi}(n, a)$. The effect of market size measured by a on the differentiated firm's profit can then be described by

$$\frac{d\tilde{\pi}(n,a)}{da} = \frac{\partial\tilde{\pi}(n,a)}{\partial a} + \frac{\partial\tilde{\pi}(n,a)}{\partial n}\frac{\partial n}{\partial a}. \tag{6}$$

The right-hand side of (6) shows that a change in market size has a direct and an indirect effect on the profit of the differentiated firm. The direct effect captures how an increase in the rivals' market size, a, affects competition between the rivals and the differentiated company when the number of competitors is given. The second effect captures the impact of changes in market size on the number of rival firms in the market. Appendix B presents an example with an endogenous number of n identical firms that compete in quantities a la Cournot among one another as well as against the differentiated company. In this example, both the direct and the indirect effects of an increase in the market-size parameter on the differentiated firm's profit are negative. The reason why the direct effect is negative is that, in this model, the parameter a can be considered as a quality parameter. Thus, an increase in a means that the quality of the n firms' product becomes higher, which has two consequences: first, the market increases in terms of aggregate equilibrium customer quantities. Second, business stealing of the form discussed by Mankiw and Whinston (1986) becomes more difficult for the differentiated firm, which makes market entry less attractive for the differentiated firm. This shows that one cannot directly infer from the aggregate size of a market the individual incentives to enter a market. Based on these insights we

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conclude that the presence of a tough competitor can indeed be used as an instrumental variable for car rental prices.[14]

3. Empirical Results

In this section we start with the discussion of the first-stage results, which will show that the presence of the car rental company Alamo can be considered as a sufficiently strong instrument for car rental prices. As mentioned earlier, Alamo primarily targets leisure travelers and is, as a result, differentiated from other car rental companies. We then discuss potential issues arising from heteroscedastic errors and compare the OLS estimation results and IV estimation results in the second stage. We also discuss the order of magnitude of the estimation results and compare them with the estimation results derived for air ticket prices.

The first-stage IV regression results are displayed in Table 2. Since the Pagan-Hall test for heteroscedasticity indicates the presence of homoscedastic noise terms, we abstain from consideration of robust standard errors.[15] The results show that the presence of Alamo at an airport has a highly significantly negative effect on average car rental prices.[16] Furthermore, the dummy variable *alamo* qualifies as a strong instrument. More specifically, the F-test of excluded instruments yields an F-value of 11.66. Using the critical values of the Stock-Yogo weak identification (ID) test for single endogenous regressors (Stock and Yogo, 2005), the F-value of 11.66 means that the bias of the IV estimator relative to the bias of the OLS estimator is between 10 and 15 percent. Thus, the presence of Alamo is a sufficiently strong instrumental variable in the sense that it is more likely to produce valid estimation results relative to OLS estimates.[17]

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[14] Comparing airport sizes in terms of log passenger quantities reveals that the mean airport size of airports where Alamo is present, 13.875, is not statistically different from the mean airport size over all airports, 13.775. But, airports where Alamo is not present are with mean 12.291 significantly smaller than airports where Alamo is present. Since we will conclude that Alamo exerts significant downward pressure on car rental prices, which increases passenger demand, these observations are consistent with idea that market entry of Alamo is independent of airport market size in terms of passenger quantities.

[15] The Pagan-Hall general test statistic can be used to test for homoscedastic noise terms in the case of IV regressions, and based on its results we accept the null hypothesis of homoscedastic noise terms in the case of the IV regression. More specifically, the Pagan-Hall test leads to a χ^2-value of 8.989 and a corresponding P-value of 0.174.

[16] More precisely, the first-stage regression results lead to a coefficient estimate that is significantly different from zero at the 0.1 percent level of significance. With this, the presence of Alamo showed the strongest absolute effect on average car rental prices relative to all other car rental companies in our sample.

[17] If instead the null hypothesis of homoscedastic errors would be rejected, the Pflueger-Wang weak identification test developed by Montiel and Pflueger (2013) may be used. The results of this test cast some doubts on the strength of our instrument variable *alamo*. In this respect, the estimation results should be considered with caution.

Table 2. First-stage IV regression results

Dependent variable: crprice		
	Coefficient	Std. Err.
alamo	−6.233	1.825
log(*gdp*)	7.568	4.211
log(*population*)	2.446	0.707
log(*poverty*)	−4.166	2.458
holiday	1.068	2.102
airports	−1.002	1.825
constant	−56.816	40.434
R^2	0.141	
F test of excluded instruments	11.66	

The OLS estimation results and the results of the second-stage IV regression results are displayed in Table 3.[18] Consider the OLS estimate of the coefficient for *crprice*$_i$, which is positive in sign. Given the discussion in the previous section, this is consistent with the idea that an increase in the passenger demand is associated with a relatively high car rental price, i.e., car rental companies will charge a high price if the passenger demand and the corresponding demand for car rental services is high. But, it also indicates that the OLS estimates suffer from endogeneity problems. This is further confirmed by the Wu-Hausman test for endogeneity, where the null hypothesis that all explanatory variables are exogenous can be rejected at the 0.5 percent level of significance. The IV estimate of the coefficient for *crprice* is negative and significantly different from zero at the 3.9 percent level of significance, while all other IV estimates have the expected signs and all of them are statistically significant.

The IV estimation results in Table 3 indicate that an increase in the daily car rental price by 1 US$ leads to a reduction in passenger demand of 7.1 percent. Note that an increase in the daily rate of 1 US$ is associated with an average increase in car rental expenditures of 4 US$ for an average car rental period of 4 days, which explains the seemingly high absolute value of the point estimate. Furthermore, the 95 percent-confidence interval suggests that there is a lower limit for the effect of daily car rental prices, which is given by 0.36 percent.

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[18] To control for heteroscedasticity, the table reports the robust standard errors in the case of the OLS regression. Based on the Breusch-Pagan / Cook-Weisberg test for heteroscedasticity, the null hypothesis of a constant variance can be rejected for the OLS regression at the 1 percent level of significance.

Table 3. Passenger demands as a function of endogenous car rental prices[*]

Dependent variable: log(*passengers*)

	OLS		IV	
	Coef.	Std. Err.	Coef.	Std. Err.
crprice	0.003	0.009	−0.071	0.035
log(*gdp*)	1.528	0.506	2.094	0.561
log(*population*)	1.054	0.068	1.183	0.100
log(*poverty*)	−0.653	0.289	−0.834	0.296
holiday	1.207	0.226	1.267	0.249
airports	−0.405	0.192	−0.462	0.215
constant	−17.089	4.834	−20.795	5.061
R^2		0.744		

[*] In the case of OLS, robust standard errors are reported.

It is insightful to compare these estimates with the effect of ticket prices on passenger demand. To do this, we repeat the IV regression analysis with log of car rental prices (the full set of coefficient estimates is relegated to Appendix C). The coefficient is then given by −4.271. We divide this number by 4 to account for the fact that cars are, on average, rented for 4 days. This yields a point estimate of the demand elasticity of passengers with respect to car rental prices equal to −1.067 with a lower limit of the corresponding 95 percent-confidence interval of −0.037. On the other hand, the demand elasticity in airline ticket prices is −1.4 at the route level (Smyth and Pearce, 2008). Estimates are not distinct in the statistical sense, since 95 percent-confidence intervals are overlapping, but the point estimates are less for car rental prices than for ticket prices. This is a sensible result since typically only a share of passengers will rent a car at airports (while almost all passengers will need to buy a ticket, of course). Thus, the point estimate for the coefficient for car rental prices falls within a reasonable negative range in particular if the lower limit for the 95 percent-confidence intervals is considered.

4. Robustness Checks

4.1. Aeronautical charges

The question is whether the change in car rental prices is indeed causal for the corresponding change in passenger demand identified and discussed in the previous section. One alternative explanation, which may create doubts on the direct effect of car rental prices on passenger demand, would be that a change in the car rental prices is associated with a change in the aeronautical charges in the same direction. In this situation, it would be unclear whether the

change in the car rental prices is causal for the change in passenger demand because the latter may have been caused by the corresponding change in the aeronautical charge. To test for causality, we use the average aeronautical revenue, i.e., the variable *charge*, as a proxy for aeronautical charges. Furthermore, since US airports operate under public ownership and must raise sufficient revenue to cover their costs, we consider the airport average operating cost per-passenger as an instrumental variable for the average aeronautical revenue per passenger determined by the variable *charge*.

Table 4. First-stage IV regression results with aeronautical revenues

Dependent variable:	crprice		charge	
	Coef.	Std. Err.	Coef.	Std. Err.
alamo	−5.700	1.869	−0.442	1.458
cost	22.077	17.250	98.339	13.459
log(*gdp*)	7.409	4.206	10.105	3.281
log(*population*)	2.562	0.711	1.081	0.555
log(*poverty*)	−4.519	2.469	−0.124	1.927
holiday	1.352	2.110	−1.915	1.647
airports	−0.996	1.807	−2.019	1.410
constant	−59.409	44.350	−113.803	31.535
R^2		0.149		0.276
F-test of excluded instruments		6.67		28.66

The problem here is that average operating cost is independent of airport size in terms of passenger volume because airports typically operate under increasing returns to scale.[19] Thus, it is likely that there is a negative relationship between the cost variables and the noise terms in the demand functions, which means that the second-stage IV regression results for the airport passenger demand functions are likely to produce biased estimation results (therefore, they are not shown). However, to test for the direct effect of car rental prices on passenger demand it is sufficient to consider the first-stage IV regression results, which are displayed in Table 4. As expected, the results show that unit cost, *cost*, is a highly significant predictor for average

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[19] To test for economies of scale in airport operations one needs information about the average per-passenger cost, passenger volume, and a suitable instrumental variable for passenger demand. While our data set covers information about cost and passenger volumes, the third ingredient, the suitable instrumental variable, is lacking in our data. To see this, note, first, that the number of airports in the county may be related to population, GDP, and the presence of the holiday destination. Second, one may expect that costs are higher in more populated counties, if the GDP is relatively high or the poverty ratio is low.

aeronautical revenues, *charge*. This confirms that aeronautical charges are largely determined by cost-recovery considerations. On the other hand, car rental prices, *crprice*, are statistically independent of average operating costs, which indicates that the choice of car rental prices follows a different rationale. Altogether, these findings are consistent with the idea that a change in the car rental price has a direct effect on passenger demand.[20]

4.2. Airport congestion

More than twenty percent of airline flights in the US were delayed between 2000 and 2007, and a major source of delays in the US is the volume of traffic relative to airport capacity (e.g., Ball et al., 2010, Zhang and Czerny, 2012).[21] Ball et al. (2010) studied the economic impact of air travel delays in the US. They found that, in 2007, congestion increased operating costs of airlines due to increased expenses for crew, fuel, and maintenance, among others by about 8.3 billion US$, while 16.7 billion US$ have been borne by passengers due to, for example, delayed flights, flight cancellations, and missed connections. The question therefore arises that how our estimation results are affected by congestion effects.

To see this, let congestion denote the per-passenger congestion delay and expand the demand function in (1), which yields

$$pax_i = \alpha + \beta \cdot crprice_i + \psi \cdot congestion_i + X_i \cdot \gamma + \varepsilon_i \tag{7}$$

with $\psi < 0$, which is a measure for the passengers' time valuations,

$$congestion_i = \eta + \lambda \cdot pax_i + \mu_i. \tag{8}$$

where $\lambda > 0$, which is a measure for airport capacity, e.g., the number of runways and passenger terminals and where μ captures unobserved factors such as weather conditions or shortages in air-space capacity. With these specifications, the demand function can be rewritten as

$$pax_i = \tilde{\alpha} + \tilde{\beta} \cdot crprice_i + X_i \cdot \tilde{\gamma} + \tilde{\varepsilon}_i \tag{9}$$

with

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[20] Also the discussion of the OLS estimations in Table 3 indicated that car rental prices are positively related to demand and thus unrelated to the average operating cost.

[21] A flight is considered as delayed when the actual arrival time exceeds the scheduled arrival time by more than 15 minutes. The on-time performance is even worse for the major US and international airports (Lin and Zhang, 2015).

$$\tilde{\alpha} = \frac{\alpha + \psi\eta}{1 - \psi\lambda}, \quad \tilde{\beta} = \frac{\beta}{1 - \psi\lambda}, \quad \tilde{\gamma} = \frac{\gamma}{1 - \psi\lambda}, \quad \tilde{\varepsilon}_i = \frac{\psi\mu_i + \varepsilon_i}{1 - \psi\lambda}. \tag{10}$$

Comparing the coefficients β and $\tilde{\beta}$ shows that $\beta > \tilde{\beta}$. Furthermore, since the analysis in Section 3 abstracts away from congestion effects, the estimation results in Section 4 correspond to estimates of the value $\tilde{\beta}$, which is a conservative estimate of the true effect of car rental prices on passenger demand determined by β.
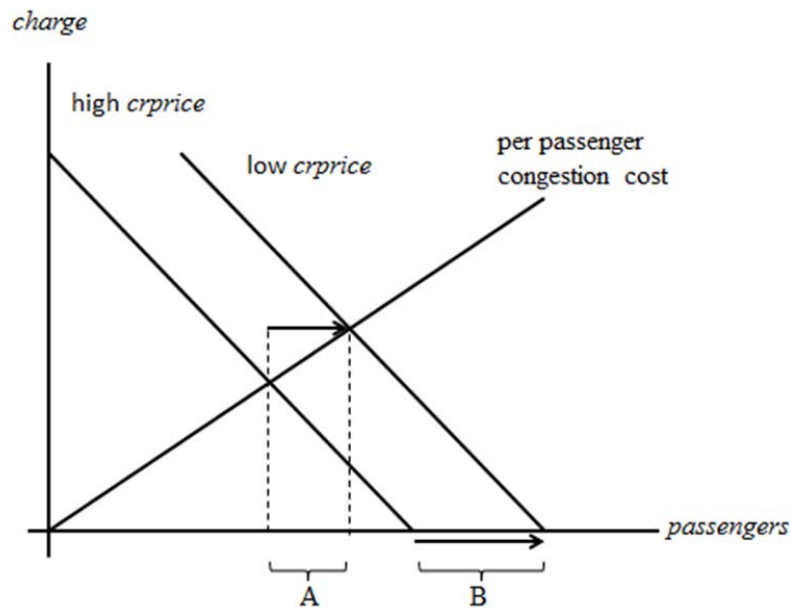
Figure 2. Congestion effects

Figure 2 illustrates the effect of congestion on the relationship between car rental prices and demand. The number of passengers is determined on the horizontal axes, while the vertical axes determines the per-passenger aeronautical charge. The two downward sloping lines depict inverse the passenger demands for high and low car rental prices respectively. Suppose that the congestion cost and the aeronautical charge are both zero. In this situation, a reduction of the car rental price from high *crprice* to low *crprice* leads to an increase in passenger volume equal to B. The picture changes if per-passenger congestion costs are positive and increasing in the passenger volume. In this situation and with zero aeronautical charges, a reduction of the car

rental price from high *crprice* to low *crprice* leads to an increase in passenger volume equal to A, with A < B. Thus, congestion softens the demand effect of a change in the car rental price because changes in the passenger volume have a direct effect on the congestion cost, and therefore the regressions would yield conservative estimations of the effect of car rental prices if congestion were ignored.

Note that the total congestion cost is the product of per-passenger costs and the passenger quantity. Although the congestion specification in (8) is linear, the total congestion cost is quadratic in the passenger volume; thus, non-linear effects are captured by the current specification.

5.   Concluding Remarks

This study has used an IV regression analysis to show that airport car rental prices can have a direct negative effect on passenger demand. This is a relevant insight for airport managers and especially regulators because it indicates that airport market power cannot be controlled by the regulation of aeronautical charges alone. More specifically, our results indicate that airports can abuse market power by an increase in the prices for concession goods and services when airport aeronautical charges are regulated.

There are several avenues for future research, which could help to derive a more precise understanding of the demand effects of airport car rental services and airport concession services in general. While our data set relied on car rental prices posted on the internet, it would be interesting to analyze a data set with transacted car rental prices and thus observations that capture, for example, price bonuses due to loyalty programs provided by car rental companies. Furthermore, the estimations could greatly benefit from information about the number of passengers that rent a car at an airport (hence the percentage of car rental passengers out of the total passengers) and the rental periods because this can be used to derive a much better understanding of the overall importance of airport car rental services for passengers. Since a large share of airport concession revenues are derived from sources other than car rental services such as the supply of car-parking spaces, it would also be helpful to integrate (endogenous) prices of car parking and other airport concession services into the analysis. Finally, it would be helpful to incorporate more information on airport runway and capacity supply as well as congestion delays into the present analysis.

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Appendix

A. Airport Sample

The airport sample contains data from 199 of the largest US airports in 2005 in terms of passenger numbers.[22]

Table 5. Airport sample in alphabetical order

ABE	BHM	CLE	EKO	GNV	ITH	MAF	MYR	RDM	SLC
ABI	BIL	CLL	ELM	GPT	ITO	MBS	OAJ	RDU	SMF
ABQ	BIS	CLT	ELP	GRB	JAC	MCI	OAK	RIC	SNA
ACK	BLI	CMH	ENA	GRR	JAN	MCO	OKC	RNO	SPI
ACT	BMI	CMI	ERI	GSO	JAX	MDT	OMA	ROC	SRQ
ACV	BNA	COS	EUG	GSP	JFK	MDW	ONT	RST	STL
AEX	BOI	CPR	EVV	GTF	KOA	MEM	ORD	RSW	SUN
AGS	BOS	CRP	EYW	HHH	LAN	MFR	PBI	SAN	SWF
ALB	BRO	CRW	FAI	HLN	LAS	MGM	PDX	SAT	SYR
AMA	BTV	DAB	FAR	HOU	LAX	MKE	PFN	SAV	TLH
ATL	BUF	DAL	FAT	HPN	LBB	MLB	PHL	SBN	TOL
ATW	BUR	DAY	FAY	HSV	LFT	MLI	PHX	SBY	TPA
AUS	BWI	DCA	FLL	HVN	LGA	MLU	PIA	SCE	TRI
AVL	BZN	DEN	FNT	IAD	LGB	MOB	PIT	SDF	TUL
AVP	CAE	DFW	FSD	IAH	LIH	MOT	PNS	SEA	TUS
AZO	CAK	DHN	FSM	ICT	LIT	MQT	PSP	SFO	TVC
BDL	CHA	DLH	FWA	IDA	LNK	MSN	PVD	SGF	TYR
BFL	CHO	DRO	GEG	ILM	LRD	MSO	PWM	SHV	TYS
BGM	CHS	DSM	GFK	IND	LSE	MSP	RAP	SJC	VPS
BGR	CID	DTW	GJT	ISP	LWS	MSY	RDD	SJT	

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[22] Cincinnati airport (CVG) is deleted from the sample although the passenger quantity exceeds the critical value of 60,000 passengers per year. This is because there is an extreme outlier in terms of squared residuals derived from IV estimations associated with this observation (the squared residual is more than four times as high as the second-largest value of the squared residual).

B. Differentiated View on Market-size and Entry

There are *n* identical firms and one firm, which we call the differentiated firm, that provides a good that is differentiated from the goods of its *n* rival firms. Let q_i with $i = 1, \ldots, n$ denote the individual quantity of one of the *n* firms, *q* denote the aggregate quantity of the *n* firms with $q = \sum_i q_i$ and $\tilde{q}$ denote the quantity of the differentiated firm. The representative customer's utility function is denoted *B* with $B = B(q, \tilde{q})$. To distinguish between market sizes of the *n* firms and the differentiated firm, consider the following variation of the Dixit (1979) type utility function:

$$B(q, \tilde{q}) = aq + \tilde{q} - \frac{1}{2}\left(q^2 + \tilde{q}^2\right) - kq\tilde{q} \tag{11}$$

with $a > 0$ and $k \in (0,1)$. The parameter, *k*, determines the degree of horizontal product differentiation between the *n* companies and the differentiated company; the range of *k* ensures that goods are substitutes and equilibrium quantities are non-negative. On the other hand, the parameter *a* determines the degree of vertical product differentiation between firms. To see this, consider the partial derivatives of the benefit function in (11) with respect to *q* and $\tilde{q}$, which yields the inverse demand for the *n* companies, denoted as *P*, and the differentiated company, denote as $\tilde{P}$, with $P = a - q - k\tilde{q}$ and $\tilde{P} = 1 - \tilde{q} - kq$, respectively. Suppose that the *n* firms and the differentiated firm sell the same amount, i.e., $q = \tilde{q}$; then the *n* firms' customers are willing to pay a premium determined by the difference between the choke prices, $1 - a$, which can be positive or negative in sign. If this difference between choke prices is positive, the differentiated firm provides a high quality good relative to the *n* firms and vice-versa if the difference is negative. The choke price *a* therefore implicitly determines the degree of vertical product differentiation between the *n* companies and the differentiated company.

To concentrate on market entry, we normalize the production costs of all firms to zero. Individual profits of the *n* firms, denoted as π_i, and the differentiated firm, denoted as $\tilde{\pi}$, can then be written as $\pi_i = q_i P$ and $\tilde{\pi} = \tilde{q}\tilde{P}$, respectively. Firms compete in quantities a la Cournot. For a given number of firms *n*, the equilibrium quantities can be derived by using symmetry between the *n* firms and the first-order conditions

$$\frac{\partial \pi_i}{\partial q_i} = a - (n+1)q - k\tilde{q} = 0, \ \frac{\partial \tilde{\pi}}{\partial \tilde{q}} = 1 - 2\tilde{q} - kq = 0, \tag{12}$$

which yields individual equilibrium quantities (indicated by superscript *N* for Nash):

$$q_i^N = \frac{2a - k}{2n - (n-1)k^2}, \tilde{q}^N = \frac{n - (n-1)ak}{2n - (n-1)k^2}. \tag{13}$$

The right-hand sides of the first-order conditions (12) are decreasing functions of $\tilde{q}$ and q, respectively, which implies that quantities are strategic substitutes in the sense that best responses are decreasing in the rivals' quantities. Furthermore, the first right-hand side in (12) is an increasing function of the choke price *a*, which means that best responses are increasing in the quality supply the *n* firms. Consider the right-hand sides in equations (13). The denominators are positive by the assumption that $k < 1$, and the numerators can be ensured to be positive by assuming that $a \in (1/2, n/(n-1))$ and $n > 2$.[23] Equilibrium quantities in (13) show that quantities, q_i^N, are increasing in own choke price *a*, while the differentiated company's equilibrium quantity, $\tilde{q}^N$, is decreasing in the rivals' choke price. This is because quantities are strategic substitutes and own best responses are increasing functions of own quality supply. Thus, companies are stronger competitors if they provide a relatively high quality. Plugging equilibrium quantities in eqs. (13) into profit π_i yields equilibrium profit for a given number of carriers *n*, denoted as π_i^N. Assume that market entry incurs fixed costs $g > 0$ to each company $i = 1, \ldots, n$. Solving equilibrium profit for the market entry condition $\pi_i^N = 0$ yields:

$$n = k^2 + \frac{1}{\sqrt{g}} \frac{2a - k^2}{2 - k^2}, \tag{14}$$

where the right-hand side is an increasing function of the choke price *a* and a decreasing function of market entry cost *g*. To ensure that the equilibrium quantity *n* exceeds 2, assume that the choke price *a* is sufficiently high, i.e., $a \geq \left(k + \sqrt{(16 - 8k^2 + k^4)g} \right)$.

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[23] The second derivatives of individual profit with respect to own quantity is negative, which ensures the existence of unique best responses for the *n* firms and the differentiated firm.

Using equilibrium quantities in (13) and equilibrium market entry in (14), we can now plot the equilibrium profit of the differentiated firm as a function of the choke price a (for $g = 1/40$):

Figure 3. Profit of the differentiated company with equilibrium market entry in the rivals' market
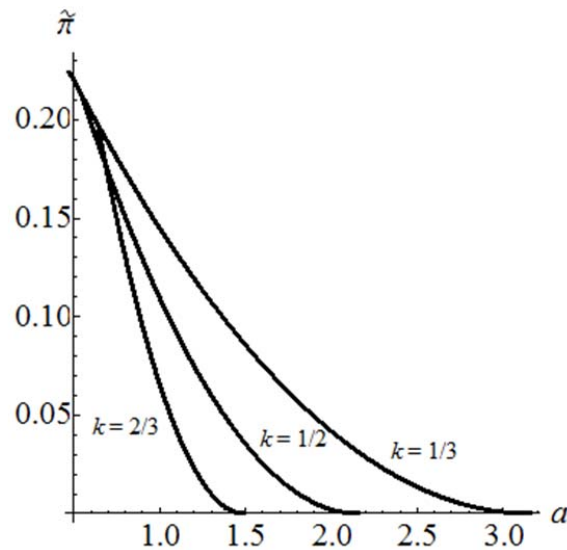

Figure 3 shows for different degrees of horizontal product differentiation, i.e., $k = 1/3, 1/2, 2/3$, that not only the equilibrium quantity but also equilibrium profit of the differentiated company is a decreasing function of the rivals' choke price a. Since the choke price a also determines the size of the n firms' market, this leads to:

Proposition 1: *For the differentiated firm, the incentives to enter the market are increasing in its own market size and decreasing in the rival firms' market size.*

For an intuitive explanation, note that the firms' incentives for market entry depend on the potential for "stealing business" from the incumbent firms in the sense that an entrant causes incumbent firms to reduce output (Mankiw and Whinston, 1986). If the incumbent firm produces a high quality relative to the new entrant, this makes business stealing more difficult for the new entrant and therefore entrance becomes less attractive for the differentiated firm. A consequence is that it is difficult to infer the individual incentives for market entry from aggregate market size.

C. Supplementary Table

Table 6 displays the IV regression results when the logs of car rental prices are used to explain passenger demand. Taking logs is useful because the coefficient estimates for the log of car rental prices can have the interpretation of the elasticity of passenger demand with respect to car rental prices. These estimates can then be compared with the known elasticity of passenger demand with respect to air ticket prices in order to evaluate whether the magnitude of coefficient estimates fall within a sensible range. Note that the estimate for the elasticity of passenger demand with respect to car rental prices must be corrected for the average car rental period in order to ensure that it can be compared with the elasticity of passenger demand with respect to air ticket prices. For an average car rental period of 4 days, the point estimate for the elasticity of passenger demand with respect to car rental prices is −1.067, which is small relative to the point estimate of passenger demand on the route level of −1.4. Since not all passengers rent a car at airports, this is a sensible result.

Table 6. Passenger demand depending on log car rental prices

Dependent variable: log(*passengers*)		
	Coefficient	Std. Err.
log(*crprice*)	−4.271	2.105
log(*gdp*)	2.154	0.586
log(*population*)	1.195	0.105
log(*poverty*)	−0.831	0.301
holiday	1.201	0.252
airports	−0.476	0.219
constant	−8.392	6.514
F test of excluded instruments	10.561	