A duopoly of transportation network companies and traditional radio-taxi dispatch service agencies

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Abstract

Transportation network companies commonly enter the market for taxi ride intermediation and alter the market structure. In many cities, these companies compete with traditional radio-taxi dispatch service agencies. Transportation network companies increase fleet sizes and serve more customers with lower fares than cooperatively organized radio-taxi dispatch service agencies, when the fixed costs of an agency are relatively small. In an asymmetric equilibrium of one cooperatively organized taxi dispatch agency and one transportation network company, the fleets of both are even larger. Due to larger fleets, fares decline and consumer rents rise.

JEL:
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1 Introduction

Especially in large cities, taxi rides are an important part of public transportation. Not only private people order taxicabs, but also businesspeople, tourists, sick people, pupils and other groups use taxi services. People demand taxi services because they are convenient and fast, they may not have a driving license, they can disembark without searching for parking, or do not have access to a private car. The market for taxi rides can be divided into three submarkets (Schaller, 2007). The first is the cab stand market found, for example, at railway stations or city centers, where taxicabs are waiting for customers in a line. In Germany, about 30-40 percent of the taxi rides start at cab stands. The second market is the street hail market where customers in cities flag down taxicabs driving in the streets. In German cities, only around ten percent of taxi rides are initiated in this way. In some American and Asian cities, this share is notably higher. The most important market, with a share of around 50-60 percent is the dispatch market. Customers order taxicabs by contacting a taxi firm or radio-taxi dispatch service agency (RDS) by phone or app. These agencies then select a cab for the customers. There are mostly only a few RDSs in each city, so that monopolistic, duopolistic or oligopolistic market structures predominate. An analysis of the largest German cities showed that, for example, in Munich and Cologne, nearly all taxi drivers and companies use the service of two large radio-taxi dispatch service agencies. In Stuttgart and Nuremberg, only one RDS is present (see Figure 1).

RDSs can be organized privately or cooperatively and the two types pursue different objectives. Cooperatively organized agencies distribute their revenues among all members and aim to maximize the average profit of each driver, while private firms take into account only the owner’s profit.

The market for taxi rides is characterized by some specifics that should be noted for analytical purposes. The demand for taxi services is not only determined by the price of a ride. The waiting time plays an important role, because it creates a negative externality. When a customer occupies a taxicab, all other potential customers have to wait longer than before (Orr, 1969; Cairns and Liston-Heyes, 1996). Contrariwise, there are economics of density; doubling trips and taxicabs
reduces waiting time (Arnott, 1996). In a market without regulation, neither externality is internalized in the market price. This is one reason why the market for taxi rides is regulated in the most countries. The fares taxi drivers should charge, the number of taxicab licenses and minimum standards for vehicles are often regulated. But regulation can be inefficient as well. Many economists share the view that rent-seeking plays a large role in taxi market regulation (Barrett, 2003; Cetin and Eryigit, 2013), because taxi firms are able to capture the regulatory process and ensure regulation that corresponds to their objectives (regulatory capture). At the agency level, the market is often slightly regulated, although the market for radio-taxi dispatch services is highly concentrated. However, if licenses and fares
are regulated, there is only minimal leeway to abuse market power. Information asymmetries, another argument in favor of regulation, are not important in the dispatch market, because customers can choose a particular company to order a taxi ride. The firms therefore aim at a stable customer relationship and repeat purchases, so they do not exploit uninformed customers, but have an incentive to satisfy them. Furthermore, bad reviews could deter other customers.

Over the last few years, digitization has enabled new business models to earn money in the market for taxi rides, especially in the dispatch market. Customers can order a taxi service with the help of a smartphone app like Uber or Lyft and the app operator allocates a driver nearby to the requester. The ride route and the fare are usually set by the operator of this transportation network company (TNC) which earns a fixed share of the driver’s revenue. When fares are not regulated, Uber adjusts the fare with using a so-called “surge pricing” algorithm to balance supply and demand (Hall et al., 2015). Cramer and Krueger (2016) show that joining Uber increases capacity utilization and thus the productivity of taxi drivers, by reducing empty drives and idle time. App operators like Uber have developed techniques to lower the waiting time, thereby improving quality and raising customer willingness to pay. Apps claim that they serve as an interface where taxi drivers and taxi customers meet, but in fact, by fixing the product (route) and the price (fare), they act as an ordinary taxi firm. These TNCs can compete with the present radio-taxi dispatch service agencies in each town.

From a theoretical point of view, the question arises as to what a taxi dispatch market, including transportation network companies like Uber or Lyft, looks alike. There has been some research on modeling the market for taxi rides. While for example Douglas (1972) and Cairns and Liston-Heyes (1996) generated aggregated models for the street hail market, Häckner and Nyberg (1995) developed an aggregated model for an oligopolistic dispatch market and showed that cooperatively organized RDSs are relatively less efficient than privately owned RDSs. Another large group of studies integrated the spacial structure of taxi services into street

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1This terminology was introduced by the California Public Utilities Committe in 2013 to classify Uber-like companies.
Yang and Wong (1998) developed a network model to analyze taxi movements in cities. The model has been extended to consider demand elasticity and road congestion (Wong et al., 2001), market competition and regulation (Yang et al., 2002), multi-period dynamic taxi services with endogenous service intensity (Yang et al., 2005), multiple user classes and vehicle modes (Wong et al., 2008) and nonlinear pricing (Yang et al., 2010a). Wong et al. (2005) and Yang et al. (2010b) introduced mathematical models to consider the bilateral-searching behaviour of vacant taxis and customers in the street hail market through meeting functions. These models were further enhanced to analyze the equilibrium properties (Yang and Yang, 2011) and deal with congestion effects (Yang et al., 2014). He and Shen (2015) included the presence of an e-hailing platform in a network model and Wang et al. (2016) generated the pricing strategies of a taxi-hailing platform using the meeting function. In their model, taxi drivers are free to use the e-hailing platform or to do roadside hailing. The model most closely related to ours is the one of Zha et al. (2016). They investigate the market impacts of a monopoly ride-sourcing service like Uber and of a duopoly of ride-sourcing services in an aggregated model. They state that regulated competition may not necessarily lead to lower prices and higher social welfare than in a regulated monopoly. We include transportation network companies in the taxi dispatch market model of Hackner and Nyberg (1995). In contrast to Zha et al. (2016), we compare the market outcomes of a duopoly of TNCs with the ones of a duopoly of traditional radio-taxi dispatch service agencies. Additionally, we consider an asymmetric duopoly of one cooperatively organized RDS and one TNC and the regime of regulatory capture.

In our two-stage game, companies first choose the number of taxicabs for their fleet and then compete on price. We compare the market outcomes of four different regimes: The first is a symmetric duopoly of cooperatively organized RDSs, that try to maximize the average profit of each driver, because they distribute their revenues among all members (Regime 1). By contrast, privately organized RDSs attempt to maximize the overall profit of each company/RDS (Regime 2). The next regime is a duopoly of transportation network companies, where each TNC charges taxicab drivers a fraction of the revenue and therefore tries to maximize
revenue (Regime 3). Finally, we add the regime of regulatory capture. We analyze full regulatory capture by assuming in this regime, that two cooperatively organized RDSs collude and are able to capture the regulatory process, so that the price and the number of taxicabs are set to maximize their aggregated profits (Regime 4).

Market entry, and even the principle of revenue sharing in the radio-taxi dispatch market fosters competition and serves the customers well. We can show that the largest fleet sizes emerge in the regime of two privately organized RDSs (Regime 2). Furthermore, fleet sizes are larger and fares are smaller in a duopoly of transportation network companies (Regime 3) than in the duopoly of cooperatively organized RDSs (Regime 1), if the fixed costs of an intermediary are small. If the fares and number of licenses are regulated and the regulation is captured by the taxi firms (Regime 4), this leads to the smallest fleet sizes of all regimes. In an asymmetric duopoly of one cooperatively organized RDS and one TNC, both increase their fleet sizes compared to a symmetric duopoly.

2 The Model

Similarly to Häckner and Nyberg (1995), we consider a duopoly of firms that serve as an intermediary for taxi rides. Each RDS or TNC has \( f_i \) affiliated taxicabs as a fleet and offers taxicab services to customers with fares that are linear in the quantity \( q \) of (homogenous) taxi rides consumed.

Consumer utility depends on taxi rides and a composite good \( y \). Utility increases at a decreasing rate with the number of trips \( q \) and waiting time decreases at an increasing rate. To simplify the analysis, we assume a specific utility function of a representative consumer that single-homes with taxi intermediary \( i \):

\[
U = y_i + (w - \alpha q_i)q_i - \frac{\beta Q_i}{f_i}q_i. \tag{1}
\]

The marginal utility of the first taxi trip is assumed to be \( w \). We assume that this utility exceeds the variable costs of a ride \( (w > c) \), because otherwise, there would be no supply of taxi services. The diminishing marginal utility of additional trips
is parameterized by $\alpha$. Waiting time depends on the quotient of demand $Q_i$ of firm $i$ and their fleet size $f_i$. The technical ability to match customers and taxicabs to reduce idle and waiting time is denoted by $\delta$. The marginal disutility of the first second of waiting time is zero, but the marginal disutility increases when more trips are demanded and waiting time rises, which is parameterized by $\beta$.

Facing a budget constraint of $I = y_i + p_i q_i$, where the composite good $y_i$ is the numeraire, the utility maximizing consumption of taxi rides is

$$q_i = \frac{w - p_i - \beta/\delta Q_i/ f_i}{2\alpha}.$$  \hfill (2)

If the number of consumers is normalized to one, the aggregate demand for firm $i$ is $Q_i = q_i m_i$ where $m_1 = m$ is the market share of firm 1 and $m_2 = 1 - m$ is the market share of firm 2. Consumers search for the best combination of price and waiting time, but if both firms are operating in the market customers must be indifferent between the two, i.e., the indirect utilities have to be identical: $V(p_1, Q_1, I) = V(p_2, Q_2, I)$, which means that

$$p_1 + \frac{\beta}{\delta} \frac{Q_1}{f_1} = p_2 + \frac{\beta}{\delta} \frac{Q_2}{f_2}.$$  \hfill (3)

Solving this equation for the market share $m$ leads to

$$m = \frac{f_1 (2\alpha \delta f_2 (p_1 - p_2) + \beta (p_1 - w))}{\beta (f_1 p_1 + f_2 p_2 - (f_1 + f_2)w)}.$$  \hfill (4)

This value of the market share determines the aggregated demand $Q_i$ of company $i$. In the two-stage game of this model, firms first choose the number of taxicabs of their fleet and then compete on price. In this paper, we consider and compare different types of firms. RDSs can be organized cooperatively or privately. Moreover, a duopoly of transportation network companies can be considered, or a regime of regulatory capture, so that firms collude and maximize their aggregated profits.

We assume that operating a taxi intermediary costs $K_r$ independently of the number of taxicabs and customers using the service. A taxicab bears fixed costs of $K_c$ plus variable costs of $c$ per trip.
2.1 Price Competition

We begin with the analysis of a duopoly of cooperatively organized RDSs. Aggregate demand $Q_i$ leads to a profit at the second stage of the game of each cooperatively organized RDS $i$ that bears variable costs of $c$ per taxi trip of

$$\bar{\pi}_i = \frac{\delta f_i(p_i - c)(2\alpha \delta f_j(p_j - p_i) + \beta(w - p_i))}{\beta(\beta + 2\alpha \delta (f_i + f_j))}.$$  \hfill (5)

The firms maximize their profit with respect to prices, so that the reaction functions $p_i(p_j)$ can be derived and the equilibrium prices $\hat{p}_i^e(f_i, f_j)$ are

$$\hat{p}_i^e = \frac{c(\beta + 2\alpha \delta f_i)(\beta + 3\alpha \delta f_j) + \beta(\beta + \alpha \delta(2f_i + f_j))w}{2\beta^2 + 6\alpha^2 \delta^2 f_i f_j + 4\alpha \beta \delta (f_i + f_j)}$$ \hfill (6)

and the equilibrium quantities are

$$\hat{Q}_i^e = \frac{\delta f_i(\beta + \alpha \delta(2f_i + f_j))(\beta + 2\alpha \delta f_j)(w - c)}{2(\beta + 2\alpha \delta (f_i + f_j))(\beta^2 + 3\alpha^2 \delta^2 f_i f_j + 2\alpha \beta \delta (f_i + f_j))}.$$ \hfill (7)

The corresponding profit of each RDS at the second stage (without taking into account the fixed costs $K_r$ of the RDS) is

$$\bar{\pi}_i^e = \frac{\beta \delta f_i(\beta + \alpha \delta(2f_i + f_j))^2(\beta + 2\alpha \delta f_j)(c - w)^2}{4(\beta + 2\alpha \delta (f_i + f_j))(\beta^2 + 3\alpha^2 \delta^2 f_i f_j + 2\alpha \beta \delta (f_i + f_j))^2}.$$ \hfill (8)

A taxi firm that is organized as a TNC behaves differently. First of all, by matching only customers and taxicabs, the firm does not bear the variable costs of an additional trip. On the other hand, the TNC only receives a share $\gamma_i$ of the fares charged. Therefore, at the second stage, the TNC maximizes

$$\hat{\pi}_i = \gamma_i \frac{\delta f_i p_i(2\alpha \delta f_j(p_j - p_i) + \beta(w - p_i))}{\beta(\beta + 2\alpha \delta (f_i + f_j))}.$$ \hfill (9)

The two TNCs maximize their profit with respect to prices and the equilibrium prices $\hat{p}_i^e(f_i, f_j)$ are

$$\hat{p}_i^e = \frac{\beta(\beta + \alpha \delta(2f_i + f_j))w}{2\beta^2 + 6\alpha^2 \delta^2 f_i f_j + 4\alpha \beta \delta (f_i + f_j)}$$ \hfill (10)

with $\partial \hat{p}_i^e / \partial f_i < 0$ and the equilibrium quantities are

$$\hat{Q}_i^e = \frac{\delta f_i(\beta + \alpha \delta(2f_i + f_j))(\beta + 2\alpha \delta f_j)w}{2(\beta + 2\alpha \delta (f_i + f_j))(\beta^2 + 3\alpha^2 \delta^2 f_i f_j + 2\alpha \beta \delta (f_i + f_j))}. \hfill (11)
The corresponding profit of each TNC at the second stage is
\[ \hat{\pi}_i^e = \gamma_i \frac{w^2}{(e-w)^2} \bar{\pi}_i. \] (12)

Therefore, we can state

**Proposition 1** If the fleet sizes in a duopoly of cooperatively organized RDSs are as large as the fleet sizes in a duopoly of transportation network companies, taxi fares are lower in the duopoly of TNCs.

### 2.2 Fleet sizes

We now analyze the maximization at the first stage. Taxi intermediaries can determine the number of taxicabs of their fleet \( f_i \). A cooperatively organized RDS maximizes profits per taxicab
\[ \bar{\pi} = \bar{\pi}_i^e - K_c - \frac{K_r}{f_i}. \] (13)

with a first-order condition
\[ \frac{\partial \bar{\pi}}{\partial f_i} = \frac{\partial \bar{\pi}_i^e/\partial f_i}{f_i^2} f_i - \frac{\bar{\pi}_i^e}{f_i^2} + \frac{K_r}{f_i^2} = 0, \] (14)

which holds if
\[ \frac{\partial \bar{\pi}_i^e}{\partial f_i} = \frac{\bar{\pi}_i^e}{f_i} - \frac{K_r}{f_i}. \] (15)

Furthermore, because RDSs are only profitable if \( \bar{\pi}_i^e - K_c f_i \geq K_r \), \( \partial \bar{\pi}_i^e/\partial f_i \geq K_c \) has to hold. For the comparative statics of the equilibrium of cooperatively organized RDSs, see H"ackner and Nyberg (1995) or the Appendix.

A TNC charges taxicab drivers a fraction \( \gamma_i \) of the revenue. Each taxi driver has to bear the variable costs and the fixed cost of entry \( (K_c) \) in this regime, so that the profits of a TNC are
\[ \hat{\pi}_i = \hat{\pi}_i^e - K_r. \] (16)

For cooperatively organized RDSs, it can be shown that \( \partial f_i/\partial f_j > 0 \). In this case, the fleet sizes are strategic complements. The opposite is true for the TNCs. The
Figure 2: Best response functions and equilibria

Parameter values are: $\alpha = 1.4, \beta = 0.05, \delta = 1, c = 0.1, K_c = 0.05, w = 2$ and $K_r = 0.05$. $A$ is the equilibrium of TNC 2 and C-RDS 1, and $B$ the equilibrium of TNC 1 and C-RDS 2.

The reaction function of the fleet size has a negative partial derivative with respect to the fleet size of the other TNC $j$ ($\partial f_i / \partial f_j < 0$). In this case, the fleet sizes are strategic substitutes (see Figure 2).

At the first stage, the TNC fixes the share $\gamma_i$ it claims from the taxicab drivers. Then taxicab drivers decide to enter the market and to join a TNC. At the equilibrium, taxicab drivers who have to pay the fixed cost of entry $K_c$, the variable costs of $c\hat{Q}_i^e / f_i$ and receive a share of $1 - \gamma_i$ of revenue $\hat{\pi}_i^e$, continue to enter the market until their profit is zero:

$$\Psi(\gamma_i, f_i) = \frac{(1 - \gamma_i)}{\gamma_i} \hat{\pi}_i^e - c\hat{Q}_i^e - K_c f_i = 0.$$  

The transportation network company can anticipate the reaction of the taxicab drivers who wish to join the TNC if they change the revenue share. The revenue share as a function of the fleet sizes $\gamma_i(f_i)$ can be determined from the equation

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above (see Appendix). It is shown in the Appendix that the impact of the fleet size on the revenue share is negative \((\partial \gamma_i/\partial f_i < 0)\) and vice versa. If the TNC claims a higher share of revenue, fewer taxicab drivers join the TNC. Because this relationship is bijective, the TNC determines one of the strategy variables \(\gamma_i\) or \(f_i\), and then the other one is determined as well. Whereas in reality, the TNC determines \(\gamma_i\), we can analyze the behavior by assuming that the TNC determines \(f_i\).

The transportation network company maximizes

\[
\hat{\pi} = \hat{\pi}_i^e - K_r
\]  

which is maximized if

\[
\frac{\partial \hat{\pi}}{\partial f_i} = \frac{\partial \gamma_i}{\partial f_i} \frac{w^2}{(c - w)^2} \hat{\pi}_i^e + \gamma_i \frac{w^2}{(c - w)^2} \frac{\partial \hat{\pi}_i^e}{\partial f_i} = 0.
\]  

In the appendix, it is shown that the fixed costs \(K_r\) of the TNC and \(K_c\) of a taxi cab have no effect on the fleet sizes of the TNCs. \(K_r\) are sunk costs for the TNC. Furthermore, the drivers bear the fixed costs \(K_c\) of a taxicab, so that they do not influence the revenue maximization of the TNC operator. A rise in variable costs \(c\) leads to higher prices and lower quantities in this regime, while the demand parameter \(w\) has a positive effect on the quantity.

To compare the fleet sizes of the cooperatively organized RDSs (C-RDSs) and the fleet sizes of the TNCs, we look at the marginal profit of the C-RDS

\[
\frac{\partial \bar{\pi}}{\partial f_i} = \frac{\partial \bar{\pi}_i^e/\partial f_i}{f_i} - \frac{\bar{\pi}_i^e}{f_i^2} + \frac{K_r}{f_i^2}
\]  

at the profit maximizing TNC fleet size \(f_1 = f_2 = \hat{f}^*\). The first-order condition \(19\) at the profit maximum of the TNC can be transformed into

\[
\bar{\pi}_i^e = -\gamma_i \frac{\partial \bar{\pi}_i^e/\partial f_i}{f_i}.
\]  

and therefore

\[
\frac{\partial \bar{\pi}}{\partial f_i | f_i = \hat{f}^*} = \frac{\partial \bar{\pi}_i^e}{\partial f_i | f_i = \hat{f}^*} \frac{1}{\hat{f}^*} + \frac{\gamma_i}{(\hat{f}^*)^2} \frac{\partial \bar{\pi}_i^e}{\partial f_i | f_i = \hat{f}^*} \frac{1}{(\hat{f}^*)^2} + \frac{K_r}{(\hat{f}^*)^2}.
\]  

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which is negative, if
\[ K_r < - \frac{\partial \bar{\pi}^e}{\partial f_i | f_i = \hat{f}_i} \left( \hat{f}_i^* + \frac{\gamma_i(\hat{f}_i^*)}{\partial f_i} / \partial f_i \right) = \hat{K}_r. \] (23)

In this case, the fleet sizes of the TNCs are larger than those of the C-RDSs. The opposite is true if \( K_r \) is larger than \( \hat{K}_r \). For the TNCs \( K_r \) are fixed costs that do not influence the determination of the fleet sizes. The C-RDS maximizes the average profit of each taxi driver. Each driver has to bear a portion of \( K_r \), which depends on the number of taxicabs in the C-RDS. If an additional driver joins the C-RDS, each driver bears less of \( K_r \). In the case of a high \( \hat{K}_r \) the C-RDS has an incentive to increase the fleet size, so as to split costs between more taxicabs. Transportation network companies optimize without considering variable taxi costs and therefore operate with lower prices, which usually implies larger taxicab fleets. If \( \hat{K}_r \) is large, the incentive for C-RDSs to split costs overcompensates for the price competition effect and C-RDS fleet sizes become larger than TNC fleet sizes. In reality, the fixed costs of a RDS or TNC are similar to those of a taxicab.

**Proposition 2** In a duopoly of TNCs, the fleet sizes are larger than in the duopoly of cooperatively organized RDSs, if and only if \( K_r < \hat{K}_r \).

In this case, the fares are smaller in the duopoly of transportation network companies than in the duopoly of cooperatively organized RDSs.

Now consider a duopoly of RDSs comprising privately owned firms that maximize their profits by determining the fleet size. At the second stage of the game they follow the same strategy as a cooperatively organized RDS. However, in the first stage, they do not maximize the average profit of a taxicab, but the aggregate profit
\[ \bar{\pi}_i = \bar{\pi}_i^e - f_i K_c - K_r = f_i \bar{\pi}. \] (24)

The first-order condition is
\[ \frac{\partial \bar{\pi}}{\partial f_i} = f_i \frac{\partial \bar{\pi}}{\partial f_i} + \bar{\pi}^e = 0. \] (25)

\[ \text{This holds because } \frac{\partial \bar{\pi}}{\partial f_i} < 0 \text{ and the the TNC fares are already smaller if fleet sizes are similar.} \]
At the optimal fleet sizes of the TNCs \( f_1 = f_2 = \hat{f}^* \), marginal profit is positive, because, by using equation 21 we obtain

\[
\frac{\partial \bar{\pi}}{\partial f_i |_{f_i = \hat{f}^*}} = f_i \frac{\partial \bar{\pi}^e_i}{\partial f_i |_{f_i = \hat{f}^*}} - \frac{\partial \gamma_i}{\partial f_i |_{f_i = \hat{f}^*}} \left( \hat{f}_i^* - \frac{\gamma_i(\hat{f}_i^*)}{\partial \gamma_i / \partial f_i |_{f_i = \hat{f}^*}} \right) \quad (26)
\]

Using the first-order condition (19), we know that \( \partial \bar{\pi}^e_i / \partial f_i \) is positive at \( \hat{f}^* \). Because \( \partial \gamma_i / \partial f_i \) is always negative, \( \partial \bar{\pi} / \partial f_i \) is positive at \( \hat{f}^* \) and therefore

**Proposition 3** In a duopoly of profit maximizing RDSs, the fleet sizes are larger than in the duopoly of transportation network companies.

The profit maximizing RDS receives all the marginal profits an additional taxicab generates, whereas the TNC only receives a fraction of it and has therefore a smaller incentive to increase fleet sizes. For the comparative statics of the equilibrium of privately organized RDSs, see H"ackner and Nyberg (1995) or the Appendix.

In the previous regimes, the two firms compete with each other and are able to set prices and fleet sizes. In most countries, the fares and the number of taxicabs are determined by a regulatory authority. Because of that, we also consider a regime with regulation. It is possible that the regulatory authority does not serve the interests of society as a whole, but is captured by special interest groups (Stigler, 1971; Barrett, 2003; Cetin and Eryigit, 2013). In Germany, for example, fare increases in cities are often initiated by the local RDSs. Political bodies then mostly authorize the applications for fare increases by these firms. We analyze full regulatory capture, by assuming that two cooperatively organized RDSs collude and are able to capture the regulatory process so that the price and the number of taxicabs are set to maximize their aggregated profits. Because the firms are symmetric, we set \( p_i = p_j = p \) and \( q_i = q_j = q \). Each RDS has half of the total number of taxicabs, so that \( f_i = f_j = f \). The market shares of the two identical firms are 1/2, so that in this case, \( Q_i = 1/2 \cdot q \). The utility maximizing consumption (equation 2) then changes to

\[
q = \frac{2(w - p) \delta f}{4 \alpha \delta f + \beta} \quad (27)
\]
The resulting average profit of a taxi driver, depending on the price and the fleet size, is

\[ \pi = \frac{\delta f (p - c)(w - p)}{\beta + 4\alpha \delta f} - K_c - K_r f. \]  

(28)

The maximization of the profit with respect to the price \( \partial \pi / \partial p = 0 \) leads to an equilibrium price of

\[ \bar{p}^* = \frac{c + w}{2}. \]  

(29)

The price in this regime is influenced only by the parameters \( w \) and \( c \). The maximization with respect to the fleet size \( \partial \pi / \partial f = 0 \) results in an equilibrium fleet size of

\[ \bar{f}^* = \frac{\beta K_r}{\delta (w - c) \sqrt{\alpha K_r - 4\alpha \delta K_r}}. \]  

(30)

Under the assumptions of the model, this fleet size \( \bar{f}^* \) is positive if \( 0 < K_r < \frac{(w - c)^2}{(16\alpha)} \) holds. An increase in the parameters \( w \) and \( \delta \) reduces the fleet size. If the willingness to pay of the customers or the technical ability to match customers and taxicabs rise, the RDSs will c.p. reduce their fleet size to maximize the aggregated profits. In contrast, the equilibrium fleet sizes rise in the cost parameter \( c \) and \( K_r \) and in the parameter \( \beta \). The RDSs choose higher fleet sizes to spread the costs over a larger number of drivers. If the disutility accruing to customers from waiting time is high, the RDSs choose a greater fleet size as well, to reduce the average waiting time (see Appendix).

To compare the results with the duopoly of cooperatively organized RDSs, we consider the partial derivative, in this case \( \partial \pi / \partial f \) at the profit maximizing fleet size of the capture regime \( \bar{f}^* \). This is positive and leads to the following result:

**Proposition 4** In a duopoly of cooperatively organized RDSs, the fleet sizes are larger than in the captured regime.

In the last few years, transportation network companies have entered (or tried to enter) the market still served by traditional RDSs, which is an asymmetric oligopoly of cooperatively organized RDSs competing with TNCs. If we analyze the asymmetric oligopoly of one C-RDS and one TNC (see equilibria A and B in Figure 2), the companies increase their fleets to a size larger than those in the
the symmetric equilibriums. All drivers would prefer to be member of the coop-
ernatively organized RDS, but only a limited number is accepted. Furthermore,
whether or not cooperatives can survive the competition with TNCs depends not
only on operating costs, which may be similar, but also on the technique of match-
ing drivers and customers and changing prices according to demand. Available
empirical evidence (Cramer and Krueger, 2016; Peck, 2017) supports the notion of
more efficient TNCs, which may result in an exit of cooperatively organized RDSs
and the emerge of a duopoly or monopoly of transportation network companies.

3 Conclusion

The number of taxi rides that are ordered via transportation network companies
increases day by day. Especially in cities where Uber and Lyft are free to operate,
TNCs serve a large part of the dispatched taxi rides which were previously served
by one or a few radio-taxi dispatch service agencies, organized either cooperatively
or privately.

We can demonstrate that the largest fleet sizes emerge in the regime of two
privately organized RDSs. In a duopoly of transportation network companies, fleet
sizes are larger and fares are smaller than in a duopoly of cooperatively organized
RDSs, if the fixed costs of an intermediary are small. If the fares and the number
of licenses are regulated, and the regulation is captured by the taxi firms, this leads
to smaller fleet sizes than in the duopoly of cooperatively organized RDSs. The
agencies try to maximize the profit per taxicab and therefore reduce their fleet size
and raise fares. In an asymmetric oligopoly of one cooperatively organized RDS
and one TNC, both increase their fleet size beyond those in the TNC equilibrium.

Under the assumption that the taxi market is perfectly well regulated in the
status quo, market entry by TNCs which do not comply with the current regula-
tion of fares, licenses etc. reduces welfare and should be not allowed. Under the
assumption that the regulation is captured by the incumbent taxi firms, liberaliza-
tion and the market entry of new firms fosters competition and increases welfare.
But even if the second assumption holds, there are some parts of the story that
our theoretical model does not tell. TNCs often claim that they are an intermediary between customers and taxi drivers. However, competing taxi drivers who are allowed to use an app to fix the fares may abuse market power. TNCs are usually not an anti-competitive coordination device for taxicab drivers. Because they determine the fare, the product (quality and route) and the number of taxicabs, they act as a taxi firm. However, by claiming not to be a firm, some try to avoid compliance with social legislation, tax legislation, minimum wages and other legal worker rights. When the law that regulates taxi services do not include a category of “intermediary”, as in Germany, it has to be included before the market entry of transportation network companies, and price fixing through RDSs should be allowed.

Furthermore, there are economies of scale in dispatching taxi ride services. Waiting time is a cost component for customers and an RDS or TNC with more taxicabs c.p. reduces waiting time. This tendency towards a natural monopoly, combined with the freedom to set prices in a liberalized market, and extensive information about customers, raises the danger of an abuse of market power. Only the future will reveal whether competition in the market for dispatching taxi services or competition by such other modes of transport as shuttle services, lift services, car sharing or public transport can prevent the abuse of monopolistic market power by TNCs, or whether governmental action is required.
Appendix

Solving equation 17 for $\gamma_i$ leads to

$$
\gamma_i(f_i) = 1 - \frac{2\rho(2(\beta + 2\alpha\delta(f_i + f_j))K_c\rho + c\delta w(2\alpha\delta f_j + \beta)(\alpha\delta(2f_i + f_j) + \beta))}{\beta\delta w^2(2\alpha\delta f_j + \beta)(\alpha\delta(2f_i + f_j) + \beta)^2}
$$

(31)

with $\rho = \beta^2 + 3\alpha^2\delta^2 f_i f_j + 2\alpha\beta\delta(f_i + f_j)$ and therefore

$$
d\gamma_i = -\frac{2\alpha(24\alpha\beta^4\delta(f_i + f_j)K_c + \alpha\beta^3\delta^2(12\alpha(4f_i^2 + 10f_if_j + 5f_j^2)K_c + cf_j w))}{\beta w^2(2\alpha\delta f_j + \beta)(\alpha\delta(2f_i + f_j) + \beta)^3}
$$

$$
-\frac{2\alpha(4\beta^5K_c + 6\alpha^4\delta^5 f_j^2(6\alpha f_i(2f_i^2 + 3f_if_j + 2f_j^2)K_c + cf_j(2f_i + f_j)w))}{\beta w^2(2\alpha\delta f_j + \beta)(\alpha\delta(2f_i + f_j) + \beta)^3}
$$

$$
-\frac{2\alpha(2\alpha^2\beta^2\delta^3(2\alpha(8f_i^3 + 48f_i^2f_j + 57f_if_j^2 + 20f_j^3)K_c + cf_j(f_i + 3f_j)w))}{\beta w^2(2\alpha\delta f_j + \beta)(\alpha\delta(2f_i + f_j) + \beta)^3}
$$

$$
-\frac{2\alpha(\alpha^3\beta\delta^4 f_j(12f_i(4f_i + f_j)(8f_i^2 + 13f_if_j + 4f_j^2)K_c + cf_j(10f_i + 11f_j)w))}{\beta w^2(2\alpha\delta f_j + \beta)(\alpha\delta(2f_i + f_j) + \beta)^3}
$$

< 0

(32)

Comparative statics

Duopoly of cooperatively organized RDSs

It can be shown that for cooperatively organized RDSs, the marginal utility of the first taxi trip $w$ has a negative impact on the fleet sizes. The variable costs $c$ and the fixed costs of an intermediary $K_r$ have a positive effect on the fleet sizes and the fixed costs of a taxicab $K_c$ have no effect on the fleet sizes:

$$
\frac{\partial^2 \bar{\pi}}{\partial f_i \partial w} < 0, \quad \frac{\partial^2 \bar{\pi}}{\partial f_j \partial c} > 0, \quad \frac{\partial^2 \bar{\pi}}{\partial f_i \partial K_r} > 0, \quad \frac{\partial^2 \bar{\pi}}{\partial f_i \partial K_c} = 0.
$$

(33)

The price of a taxi ride rises, if the parameter $w$ increases ($d\bar{p}/dw > 0$). This is true because

$$
\frac{d\bar{p}}{dw} = \frac{\partial p}{\partial f_i} \frac{\partial f_i}{\partial w} + \frac{\partial p}{\partial f_j} \frac{\partial f_j}{\partial w} + \frac{\partial p}{\partial w}
$$

is positive. We assume that a higher fleet size has a negative effect on the price. The effect of $w$ on the fleet size is negative and the direct effect of $w$ on the price is positive, so that the total effect is positive as well. The effects of the other parameters in this regime are indeterminate.
Duopoly of TNCs

It can be shown that for TNCs the marginal costs $c$ have a negative impact on the fleet sizes, and that the fixed costs of an intermediary $K_r$ and the fixed costs of a taxicab $K_c$ have no effect on the fleet sizes:

$$\frac{\partial^2 \hat{\pi}}{\partial f_i \partial c} < 0, \quad \frac{\partial^2 \hat{\pi}}{\partial f_i \partial K_r} = 0, \quad \frac{\partial^2 \hat{\pi}}{\partial f_i \partial K_c} = 0.$$  \hspace{1cm} (35)

In the regime of TNCs, the price is positively influenced by the variable costs $c$.

$$\frac{d\hat{p}}{dc} = \frac{\partial p}{\partial f_i} \frac{\partial f_i}{\partial c} + \frac{\partial p}{\partial f_j} \frac{\partial f_j}{\partial c} + \frac{\partial p}{\partial c}$$ \hspace{1cm} (36)

We assume that a higher fleet size has a negative effect on the price, as shown above. The effect of $c$ on the fleet size is negative and the direct effect of $c$ on the price is zero, because the TNCs do not have to bear these costs. In this case, the total effect is positive.

For the quantity, the effect of $c$ is negative and the effect of $w$ is positive.

$$\frac{d\hat{Q}}{dw} = \frac{\partial Q}{\partial f_i} \frac{\partial f_i}{\partial w} + \frac{\partial Q}{\partial f_j} \frac{\partial f_j}{\partial w} + \frac{\partial Q}{\partial w}$$ \hspace{1cm} (37)

We assume that a higher fleet size has a positive effect on the quantity, as shown above. The effect of $w$ on the fleet size is positive and the direct effect of $w$ on the quantity is positive as well, so that the total effect is positive.

$$\frac{d\hat{Q}}{dc} = \frac{\partial Q}{\partial f_i} \frac{\partial f_i}{\partial c} + \frac{\partial Q}{\partial f_j} \frac{\partial f_j}{\partial c} + \frac{\partial Q}{\partial c}$$ \hspace{1cm} (38)

We assume that a higher fleet size has a positive effect on the quantity, as shown above. The effect of $c$ on the fleet size is negative, and the direct effect of $c$ on the quantity is zero, so that the total effect is negative. The effects of the other parameters in this regime are indeterminate.

Duopoly of privately organized RDSs

We can state for the fleet size, that higher fixed costs $K_c$ lead to a smaller fleet size of privately organized RDSs ($\partial \hat{f}/\partial K_c < 0$) and in this case, $K_r$ does not influence
\( \tilde{f} \). In this regime, the price is positively influenced by the variable costs \( c \):
\[
\frac{d\tilde{p}}{dc} = \frac{\partial \tilde{p}}{\partial f_i} \frac{\partial f_i}{\partial c} + \frac{\partial \tilde{p}}{\partial f_j} \frac{\partial f_j}{\partial c} + \frac{\partial \tilde{p}}{\partial c} \quad (39)
\]
We assume that a higher fleet size has a negative effect on the price, as shown above. The effect of \( c \) on the fleet size is negative and the direct effect of \( c \) on the price is positive, so that the total effect is positive as well.

For the quantity, the effect of \( c \) is negative and the one of \( w \) is positive.
\[
\frac{d\tilde{Q}}{dw} = \frac{\partial \tilde{Q}}{\partial f_i} \frac{\partial f_i}{\partial w} + \frac{\partial \tilde{Q}}{\partial f_j} \frac{\partial f_j}{\partial w} + \frac{\partial \tilde{Q}}{\partial W} \quad (40)
\]
We assume that a higher fleet size has a positive effect on the quantity. The effect of \( w \) on the fleet size is positive, and the direct effect of \( w \) on the quantity is positive as well, so that the total effect is positive.

\[
\frac{d\tilde{Q}}{dc} = \frac{\partial \tilde{Q}}{\partial f_i} \frac{\partial f_i}{\partial c} + \frac{\partial \tilde{Q}}{\partial f_j} \frac{\partial f_j}{\partial c} + \frac{\partial \tilde{Q}}{\partial c} \quad (41)
\]
We assume that a higher fleet size has a positive effect on the quantity. The effect of \( c \) on the fleet size is negative, and the direct effect of \( c \) on the quantity is negative as well, so that the total effect is negative. The effects of the other parameters in this regime are indeterminate.

**Regulatory capture**

In the regime of regulatory capture, the different parameters have the following effects on the fleet size:
\[
\frac{\partial \tilde{f}}{\partial w} < 0, \frac{\partial \tilde{f}}{\partial c} > 0, \frac{\partial \tilde{f}}{\partial K_r} > 0, \frac{\partial \tilde{f}}{\partial \beta} > 0, \frac{\partial \tilde{f}}{\partial \delta} < 0. \quad (42)
\]

\( K_c \) has no effect on \( \tilde{f} \) and the effect of \( \alpha \) depends on the size of the fixed costs \( K_r \). If \( K_r \) is large, it holds that \( \partial \tilde{f} / \partial \alpha > 0 \).

The parameters affect the price of a taxi ride as follows:
\[
\frac{\partial \tilde{p}}{\partial w} > 0, \frac{\partial \tilde{p}}{\partial c} > 0. \quad (43)
\]

\( K_r, K_c, \alpha, \beta, \delta \) have no influence on the price in the regime of regulatory capture.
The demand for the services of each RDS depends on the following two parameters:

\[
\frac{\partial \tilde{Q}}{\partial K_r} > 0, \quad \frac{\partial \tilde{Q}}{\partial \alpha} < 0.
\] (44)

\(c, w, K_c, \beta, \delta\) have no influence on the demand in this regime.
References


Heilker, Thorsten and Sieg, Gernot (2016). How can a revenue-maximizing platform change the taxi business? manuscript.


