Governmental platform intermediation in two-sided automobile markets

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Abstract

Many governments promote green technological innovation within the automobile sector as a mean to combat climate change. Buyer’s premiums and governmental investment in service infrastructure are widely used. This paper arises the question of adequate market intervention. Thereby, it takes the two-sided market character of the automobile market into account. It shows that network effects, competition effects triggered by further automobile users and decreasing marginal utilities of further service stations determine the welfare efficient extent of governmental intervention. The analysis indicates that governmental promotion of service infrastructure is reasonable, while governments should be careful with buyer’s premiums.

1 Introduction

To reduce greenhouse gas emissions in the transport sector many governments promote alternatives to the present dominant drive-train technology, namely the internal combustion engine. The British and the French government are paying buyer’s premiums for low carbon vehicles, for example. Both also invest in new service infrastructure for electric vehicles. The German government, however, holds back with such measures to promote alternative driven vehicles until now.
Against this background the work addresses the question of adequate market intervention to promote alternative drive-train technologies. Thereby, it argues that the automobile market is a two-sided one.

The work is driven by earlier analysis of the automobile market. In the network literature it is widely recognized that the automobile market owns network effects (see Katz and Shapiro (1985), Arthur (1989), Foray (1997) and Church et al. (2008), for example). Indirect network effects arise because complement products are consumed. Automobiles need fuel, and a compatible service infrastructure is necessary for the area-wide use. Therefore, if innovations are not compatible with the established service station network, they face huge entry barriers. Path dependency and technological lock-in are the consequences. Furthermore, due to network effects the market might be a multi-sided one. In this case platform intermediation is necessary to enable different market sides to interact with each other. Within the automobile market there is such a platform in terms of a common drive-train standard enabling the interaction of at least two market sides, namely automobile users and service station owners.

Recent literature (Armstrong (2004), Armstrong (2006) or Rochet and Tirole (2006), for example) states that usually a platform intermediary has market power and is able to determine a strategic price setting. Thereby, it internalizes network effects in the market. At present, the automobile market has already reached its maturity. That means the service infrastructure has reached to a certain density and, therefore, no further externalities raise by opening up a further service station. Strategic pricing is not possible any more. Platform intermediation without strategic pricing is called open platform by Hagiu (2006). Alternative drive-train technologies that are not compatible with the installed matured service infrastructure are facing a different situation. Here, each new service station generates benefits for the automobile users and rises the numbers of users choosing automobiles with alternative drive-trains. Network effects still need to be taken into account. Up to now, there is no platform intermediary in the market for green drive-train technologies, like electric driven engines, for example. This work asks how a governmental agent, instead of a private intermediary, could intervene to
promote a new standard in the automobile market.

Up to the knowledge of the author this analysis is the first one dealing with governmental platform intermediation. Thereby, it uses a standard approach from the network and two-sided market literature. In a simple framework the effects of private and governmental standard setting are compared. The methodical innovation of the work is to analyze governmental intervention within a two-sided market approach. Especially, competition effects of further vehicles in the market for services and diminishing marginal utilities of further service station for vehicle users are considered. With regards to content it adopts the approach to the automobile market and connects it to transport economics.

2 Simple modelling

2.1 Group setting

The following analysis refers to Armstrong (2006). There are two groups of agents in the market. Both gain benefits from interacting with each other. That means the more members of group two are in the market the higher the benefits of group one and vice versa. This implies positive network effects. Within the automobile sector group one consists of the automobile users and group two are the service station owners. The more people use automobiles the more dense is the service infrastructure and vice versa. For group one the decision of whether to buy a vehicle or not depends on the number of compatible service stations. Therefore, users have preferences for variety and value a dense service station network. It decreases the costs per interaction because it reduces searching and traveling costs. The benefit for a representative individual of using an automobile is defined by the utility function

$$u = \alpha_1 \sqrt{\phi_2(\pi)} + (\beta_1 - c_1).$$  \hspace{1cm} (1)

The utility depends on the number of service stations $\phi_2(\pi) \geq 0$, and the user’s preference for a dense network, $\alpha_1 > 0$, determined by the costs to travel to the next service station. The number of service stations depends on the station
owner’s profit $\pi$. The more service stations are in the market the more users decide to buy the technology and, therefore, more service stations are entering the market. Diminishing marginal network benefits are assumed, via using the root function, because the positive effect of further installed service stations, like reduced searching costs for example, decreases with each installed one. The parameter $\beta_1$ describes the network independent benefit of using the technology determined by the preference for mobility and technology, while $c_1$ are the costs of using the technology.

The case for service station owners is different. Their decision to install additional service stations depends on their profits. The profit for a representative service station owner equals

\[
\pi = (\alpha_2 - C) \phi_1(u) - c_2.
\]  

On the one hand it is determined by the demand for services and, thereby, positively relates to the number of automobiles $\phi_1(u)$. The more matching partners are in the market the higher are the service station owners’ revenues. The number of automobile users itself is determined by the users utility $u$ as defined in equation 1. The parameter $\alpha_2 > 0$ describes the profit of the service station owner from interacting with automobile users. To simplify, it is assumed that the frequency of interaction is equally distributed. That means, each automobile users refuels its vehicle at each service station in equal measure. For this reason linearity could be assumed. On the other hand the revenue depends on the competition in the market for services. As the number of service station owners increases with the number of automobile users the individual revenue decrease. The profit is downsized by $C$, the parameter representing the competition effect. The revenues are finally adjusted downward by the costs of providing the service station, $c_2$. Based on the setting for both groups further calculations are made. The setting implies homogeneous preferences for all members of each group.
2.2 Monopolistic platform setting

To enable interaction with automobiles service stations have to offer services that are compatible to the automobiles in charge. Therefore, both groups have to agree on a certain standard, here the drive-train technology that operates on a certain fuel. They interact with each other because the capacity of vehicle tanks are limited and they need to be refilled after a certain travel distance. As consequence, automobile users buy and service station owners sell fuel. Because the drive-train/fuel standard allows for interaction between buyers and sellers it is called platform in terms of two-sided markets. Platform agents act as sponsors for certain standards. Following the simple approach of Armstrong (2006) the platform agent is monopolist. From this it follows that the platform agent has market power that allows for internalizing the positive network externalities in the market by setting an appropriate price structure. Thereby, it maximizes its profit. Usually, a membership fee $P_i$ is payed by each platform member. Here, it would be payed when buying a vehicle respectively when installing a service station. The revenue functions of both groups are now

$$u = \alpha_1 \sqrt{\phi_2(\pi)} + \beta_1 - c_1 - P_1$$  \hspace{1cm} (3)$$

and

$$\pi = (\alpha_2 - C)\phi_1(u) - c_2 - P_2.$$  \hspace{1cm} (4)$$

Now we can discuss the platform’s maximization problem. If the standard is sponsored by a private agent, it simply maximizes its profit $\Pi$, which is the sum of membership fee multiplied by the number of group members for both groups. This is formulated as

$$\max_{u,\pi} \Pi = P_1 \cdot \phi_1(u) + P_2 \cdot \phi_2(\pi).$$  \hspace{1cm} (5)$$

Based on the platform’s maximizing problem and solving equations 3 and 4 for $P_1$ and $P_2$ the efficient price setting can be determined. The private platform agent maximizes its profit as written in equation 5. The results are calculated by $\frac{\partial \Pi}{\partial u} = 0$ and $\frac{\partial \Pi}{\partial \pi} = 0$. Solving for $P_i$ gives the profit maximizing membership fees.
Lemma 1 For $P_1 = \frac{\phi_1(u)}{\phi_1(u)} - (\alpha_2 - C) \cdot \phi_2(\pi)$ and $P_2 = \frac{\phi_2(\pi)}{\phi_2(\pi)} - \frac{\alpha_1 \cdot \phi_1(u)}{2 \sqrt{\phi_2(\pi)}}$, profit $\Pi$ is maximized.

Proof: See Appendix.

The first term of both price equations in lemma 1 is related to the sensitivity of participating on the platform and is interpreted as monopolistic rent. Due to its market power the monopolistic platform agent is able to set this markup. Rochet and Tirole (2006) have shown that according to Lerner’s index it depends on the price elasticity. The second term of $P_1$ is determined by the network externalities that group one exerts on service station owners and the competition effect for service station owners. As consequence, for $\alpha_2 > C > 0$, the network effect is larger than the competition effect and buyers are paying membership fees smaller than the monopolistic rent. For $0 < \alpha_2 < C$, the membership fee is larger than the rent. The second term of $P_2$ considers the network effect group two exerts on automobile users. Because of diminishing marginal utility of further service stations the term is multiplied by $\frac{1}{2\sqrt{\phi_2(\pi)}}$. Assuming positive network effects, sellers are paying membership fees smaller than the monopolistic rent. But, the relationship is nonlinear because of diminishing marginal benefits from new service stations. To sum up, a monopolistic platform agent sets a price structure which considers the network effects in the market. Due to its market power it can set a markup that depends on the platform participation sensitivity of the groups. Additional effects like the competition in the market for service stations and diminishing marginal gains from further service stations for automobile users determine the final price structure.

2.3 Governmental platform setting

It is also possible that the government provides a standard. Especially, with regard to alternative drive-train Technologies it might be plausible that a governmental agency promotes or even provides a certain standard aiming for faster market development. In opposition to the private monopolist the governmental sponsor could take the buyer and seller surpluses, $v_1(u)$ and $v_2(\pi)$, into account. Thereby, the governmental agent maximizes welfare. Instead of prices the platform agent
sets taxes. The membership fees \( P_i \) in lemma 1 are replaced by the membership taxes \( T_i \). They have to be paid when consumers decide to buy a vehicle respectively when an entrepreneur invests in service stations. As follows, the maximization problem of the governmental platform agent is formulated as

\[
\max_{u, \pi} W_T = T_1 \cdot \phi_1(u) + T_2 \cdot \phi_2(\pi) + v_1(u) + v_2(\pi).
\]

(6)

In case of the infant market for alternative drive-trains the government could sponsor the standard for batterie-driven or hydrogen-driven vehicles, for example. Assuming a welfare maximizing governmental platform agent allows to search for the efficient implementation of alternative standards.

By assumption, the platform provides the standard without any extra costs. Let the aggregate surplus of automobile users be \( v_1(u) \) that satisfies the envelope condition \( v'_1(u) \equiv \phi_1(u) \), and let \( v_2(\pi) \) be the aggregate surplus of service station owners that satisfies the envelop condition \( v'_2(\pi) \equiv \phi_2(\pi) \). For calculations see appendix. The governmental platform maximizes welfare by solving \( \frac{\partial W_T}{\partial u} \big|_T = 0 \) and \( \frac{\partial W_T}{\partial \pi} \big|_T = 0 \) for \( T_i \).

Lemma 2 For \( T_1 = -(\alpha_2 - C) \cdot \phi_2(\pi) \) and \( T_2 = -\frac{\alpha_1 \cdot \phi_1(u)}{2 \sqrt{\phi_2(\pi)}} \), welfare \( W_T \) is maximized.

Proof: See Appendix.

Lemma 2 shows that efficient standard sponsoring depends on the network effects that one market side provides to the other. In case of group one, the automobile users, additionally the competition effect of further vehicles has to be considered. In case of group two, the service station owners, it has to be taken into account that marginal benefits are diminishing. Compared to the price setting of the monopolistic platform agent, the governmental platform agent does not ask for monopolistic rents. This is summarized in proposition 1.

Proposition 1 \( |P_i| > |T_i| \) holds, and the amount of welfare efficient taxes is lower than the one of profit maximizing prices.

Proof: See Appendix.
Having a closer look at the tax paid by automobile users for purchasing a car, there are two opposing effects determining its amount as already discussed in section 2.2. If the positive network effect is larger than the competition effect, governmental platform intermediation means charging automobile users for buying a green car. If the negative competition effect is larger than the network effect, buyers have to be taxed. Maybe both effects are equal. In this case, a governmental platform intermediary does not take any action. Proposition 2 indicates to this non-distinct relation.

Proposition 2  For $\alpha_1 = C$, $T_1 = 0$ holds, and no intervention for buying a car is welfare efficient. For $\alpha_2 > C$, $T_1 < 0$, and buyers are subsidized. For $\alpha_2 < C$, $T_1 > 1$, and buyers are taxed.

The case of service station owners is different. Given the above made assumptions, charging service station owners for installing a network is always welfare efficient. This is shown by proposition 3.

Proposition 3  $T_2 < 0$ holds, and charging service station owners for installing a new service station network is welfare efficient.

In practice, a governmental platform has the opportunity to charge or disburse the agents. When registering their vehicle buyers can be charged, if necessary. Otherwise, purchasing taxes could be adapted to the welfare efficient level. Entrepreneurs could apply for public grants when they plan to invest in new service infrastructure or the government can invest in a public service station network.

3 Conclusion

Motivated by the public discourse about governmental promotion of alternative drive-trains for automobiles, this work stresses the issue of governmental platform behavior. If a government decides to intervene in a two-sided automobile market as promoter of a certain technological standard it has to act as a platform intermediary. Unlike a private platform intermediary a governmental one could pursue the
social interest because no monopolistic rents are sought. A governmental platform sponsor sets efficiently membership fees according to network and competition effects. If marginal revenues are diminishing, it also has to be considered. From this follows that public installation of new service infrastructure is reasonable for promoting alternative drive-train technologies. It also comes out that governmental agents should be careful with paying buyer’s premiums for alternatively driven vehicles. The reason is that new vehicles do not only induce positive network effects but also strengthen competition in the market for services. This effect relativizes the argument of subsidizing the purchase of green vehicles in the early stage of market development.
References


Appendix

Proof of lemma 1

To prove lemma 1 we have to calculate the first derivatives of equation 5. Using equations 3 and 4 gives

$$\frac{\partial \Pi}{\partial u} = (\alpha_1 \sqrt{\phi_2'(\pi)} + \beta_1 - c_1 - u + (\alpha_2 - C) \phi_2(\pi)) \phi'_1(u) - \phi_1(u)$$

$$\Rightarrow P_1 = \alpha_1 \sqrt{\phi_2'(\pi)} + \beta_1 - c_1 - P_1$$

$$\frac{\partial \Pi}{\partial \pi} = \left( (\alpha_2 - C) \cdot \phi_1(u) - C - \pi \right) \cdot \phi'_2(\pi) + \frac{\alpha_1 \phi_1(u) \phi'_2(\pi)}{2\sqrt{\phi_2(\pi)}} - \phi_2(\pi).$$

Now we can prove lemma 1. For $P_1 = \frac{\phi_1(u)}{\phi'_2(\pi)} - (\alpha_2 - C) \cdot \phi_2(\pi)$,

$$P_1 + (\alpha_2 - C) \phi_2(\pi)) \phi'_1(u) - \phi_1(u) = 0$$

$$\Rightarrow \frac{\partial \Pi}{\partial u} = 0,$$

and for $P_2 = \frac{\phi_2'(\pi)}{\phi_2(\pi)} - \frac{\alpha_1 \cdot \phi_1(u)}{2\sqrt{\phi_2(\pi)}}$,

$$P_2 \cdot \phi'_2(\pi) + \frac{\alpha_1 \phi_1(u) \phi'_2(\pi)}{2\sqrt{\phi_2(\pi)}} - \phi_2(\pi) = 0$$

$$\Rightarrow \frac{\partial \Pi}{\partial \pi} = 0,$$

and the profit $\Pi$ is maximized. $\square$

Envelop conditions

Using equation 3 the consumer surplus per automobile user is defined as

$$CS = \int_0^{\phi_2} u(\phi_2) \, d\phi_2 = \phi_2^* (\beta_1 - c_1 - P_1) + \int_0^{\phi_2} \alpha_2 \phi_2 \, d\phi_2.$$  

(13)

The aggregate consumer surplus sums up to

$$v_1(u) = \sum_0^{\phi_1} CS = \phi_1 \cdot CS = \phi_1(u) \cdot \int_0^{\phi_2} u(\phi_2) \, d\phi_2$$

$$= \phi_1(u) \left( \phi_2^* (\beta_1 - c_1 - P_1) + \int_0^{\phi_2} \alpha_2 \phi_2 \, d\phi_2 \right).$$  

(14)
The first derivative with respect to $\phi_2$ gives the optimal value function
\[
\frac{\partial v_1}{\partial \phi_2} = \phi_1(u)(\beta_1 - c_1 - P_1 + \alpha_1 \phi_2) = \phi_1(u) \cdot u(\phi_2). \tag{16}
\]

Solving the optimal value function for the first derivative with respect to $u$ gives
\[
\frac{\partial}{\partial u} = \phi_1'(u)u(\phi_2) + \phi_1(u) \cdot 1. \tag{17}
\]

Using the envelop theorem we get the envelop condition
\[
v_1'(u) \equiv \phi_1(u). \tag{18}
\]

The derivation of $v_2'(\pi) \equiv \phi_2$ is equivalent. □

**Proof of lemma 2**

To prove lemma 2 we have to calculate the first derivatives of equation 6. Using the modified equations 3 and 4 ($P_i = T_i$) and the envelop conditions gives
\[
\frac{\partial W}{\partial u} = (\alpha_1 \sqrt{\phi_2(\pi)} + \beta_1 - c_1 - u + (\alpha_2 - C)\phi_2(\pi))\phi_1'(u) - \phi_1(u) + v_1'(u) = 0 \tag{19}
\]
\[
\frac{\partial W}{\partial \pi} = ((\alpha_2 - C) \cdot \phi_1(u) - C - \pi) \cdot \phi_2'(\pi) + \frac{\alpha_1 \phi_1(u)\phi_2'(\pi)}{2\sqrt{\phi_2(\pi)}} - \phi_2(\pi) + v_2'(\pi) = 0. \tag{20}
\]

Now we can prove lemma 2. For $T_1 = -(\alpha_2 - C) \cdot \phi_2(\pi)$,
\[
(T_1 + (\alpha_2 - C)\phi_2(\pi))\phi_1'(u) = 0 \tag{21}
\]
\[
\frac{\partial W}{\partial u} = 0, \tag{22}
\]
and for $T_2 = -\frac{\alpha_1 \phi_1(u)}{2\sqrt{\phi_2(\pi)}}$,
\[
T_2 \cdot \phi_2'(\pi) + \frac{\alpha_1 \phi_1(u)\phi_2'(\pi)}{2\sqrt{\phi_2(\pi)}} = 0 \tag{23}
\]
\[
\frac{\partial W}{\partial \pi} = 0, \tag{24}
\]
and welfare $W$ is maximized. □
Proof of proposition 1

Since
\[
\left| \frac{\phi_1(u)}{\phi'_1(u)} \right| \geq 0 \tag{25}
\]
\[
\left| \frac{\phi_1(u)}{\phi'_1(u)} - (\alpha_2 - C) \cdot \phi_2(\pi) \right| \geq | - (\alpha_2 - C) \cdot \phi_2(\pi) | \tag{26}
\]
\[
| P_1 | \geq | T_1 | \tag{27}
\]
and
\[
\left| \frac{\phi_2(\pi)}{\phi'_2(\pi)} \right| \geq 0 \tag{28}
\]
\[
\left| \frac{\phi_2(\pi)}{\phi'_2(\pi)} - \frac{\alpha_1 \cdot \phi_1(u)}{2 \sqrt{\phi_2(\pi)}} \right| \geq | - \frac{\alpha_1 \cdot \phi_1(u)}{2 \sqrt{\phi_2(\pi)}} | \tag{29}
\]
\[
| P_2 | \geq | T_2 |. \tag{30}
\]

| P_1 | \geq | T_1 | holds. □

Proof of proposition 2

Let (as in lemma 2) \( T_1 = - (\alpha_2 - C) \cdot \phi_2(\pi) \).

Then, for \( \alpha_2 = C \geq 0 \),

\[
\alpha_2 - C = 0 \tag{31}
\]
\[
-(\alpha_2 - C) \cdot \phi_2(\pi) = 0 \tag{32}
\]
\[
T_1 = 0 \tag{33}
\]

The cases of \( \alpha_2 < C \) and \( \alpha_2 > C \) are calculated equivalent. □
Proof of proposition 3

Let (as in lemma 2) \( T_2 = -\frac{\alpha_1 \cdot \phi_1(u)}{2\sqrt{\phi_2(\pi)}} \)

Then, for \( \alpha_1 \geq 0 \),

\[-\frac{\alpha_1 \cdot \phi_1(u)}{2\sqrt{\phi_2(\pi)}} \leq 0 \quad (34)\]

\[T_2 \leq 0 \quad (35)\]

□