



# Subsidising network technology adoption the case of publishers and E-readers

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**Subsidising network technology  
adoption the case of publishers  
and E-readers:  
Is there a need for vertical  
agreements?**

Matttia de' Grassi di Pianura

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## Abstract

To market a new network technology effectively, manufacturers need to understand the structure and size of network effects associated with the product. If consumers' surplus from adoption depends positively on the number of interconnections in the network, early adopters may need to be subsidized until a critical mass is reached. Moreover, in a two-sided market where platforms and complementary contents are constrained to non-negative prices, subsidies can be provided both by platform manufacturers and by producers of complementary contents. The article presents a model to analyse adoption dynamics with different subsidies and different stand-alone values for technology. The model shows that if the stand-alone value of technology is limited, subsidies from complementary contents producers may be pivotal to reach the critical mass. Moreover, under given conditions, this type of subsidies can lead to a more efficient adoption, increasing social welfare. In this case, assuming a monopolist platform manufacturer of the technology, complete contracts are needed to reach the Pareto optimal equilibrium.

Keywords: two-sided markets, network effects, technology adoption, copyright, vertical relations, media economics.

## Index

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Abstract	2
<b>Index</b>	<b>3</b>
<b>Introduction</b>	<b>4</b>
<b>A Model for Network Technology Start-up Dynamics</b>	<b>6</b>
<b>Dynamics of Network Technology Adoption with subsidies</b>	<b>17</b>
<b>Conclusions</b>	<b>28</b>
<b>References</b>	<b>30</b>

## Introduction

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A network technology can be defined as a platform (of tools, machines, techniques, crafts, systems, methods of organization or environmental rearrangements) giving access to a number of interconnections embedding externalities (usually positive). Starting with the initial work of Rohlfs (1974), the literature has emphasized the role of externalities and the value of network interaction as determinants of technology adoption. Rohlfs' model of interdependent demand defines consistent equilibrium user sets and finds multiple equilibria at any given price. He concludes that, if the initial disequilibrium is the null user set, early adopters need to be subsidized in order to reach a critical mass compatible with the start-up problem of the technology. Katz and Shapiro (1986) analyse the case of a new technology competing with an incumbent technology, they find that the determinant for adoption is the willingness from the manufacturer to make investments and promote the new technology. In the absence of subsidies, the incumbent technology has a competitive advantage due to his installed base of users.

Many markets deriving from network technologies are two-sided; platform court two or more sides that use the technology to interact with each other. The value of the network technology depends on the two (or more) user sets, in a dynamic of indirect network externalities: it is the case of industries such as Media, software or credit cards. In these cases, as studied by Rochet and Tirole (2003), since demand in the two sides is interdependent, platforms can cross-subsidize between agents which take part in the transactions and producers of complementary contents can provide subsidies to technology adoption.

Moreover, network technologies can slightly differ in their stand-alone value, which is defined here as the utility they bring to a given consumer when the set of interconnections available in the network is the null set. For example, a single telephone cannot provide any utility to any user without an associated set of interconnections. On the other hand, a technology such as PC started providing utility to many users before the associated network (the internet) was deployed. The recent introduction on the market of e-readers, the most known of which being I-Pad from Apple and Kindle from Amazon, is a case of particular interest. These devices are specially conceived to exploit digitized written and visual media, increasing comfort, accessibility and portability of the e-books and other Medias. Many users may thus be interested in e-readers only if they can have access to their favourite Medias through the platform. Nevertheless, other users may allocate a positive stand-alone value to the technology: it is the case of "geeks", which by definition have a high willingness to pay for every new information technology. It can be also the case for specific segments of the population which can be interested in some of the particular characteristics of these technologic devices (light weight, possibility of editing texts, touch screen, design, brand, etc.).

The paper develops a theoretical model to investigate the dynamics of technology adoption with different stand-alone values. While there exists a wealth of literature that examine the role of stand-alone value and

network value in technology adoption<sup>1</sup>, this paper focuses on efficient subsidy schemes and coordination problems arising from different type of network technologies and different installed bases.

The model moves from the start-up problem described by Rohlfs (1974) in which a unit mass of consumers with interdependent demand needs to choose whether to adopt a new technology, marketed by a monopolistic manufacturer. In the next session, we thus formulate a simple model in which the incremental utility of the service to an individual depends only on the number of adopters on the two sides of the market and not on who these adopters are. While the abovementioned models do not consider stand-alone value, following Tucker (2008) we consider that a group of user may adopt the technology because of utilities arising from local usage of the new technology. In her paper, as an example, she estimates the weight of stand-alone value in the adoption decision for a service of video messaging. Nevertheless, different technologies may lead to very different estimations. In our example, we could assume that I-Pad, providing a much broader range of utility, may have a positive stand-alone value for a larger share of the population while Kindle, which is conceived almost exclusively to read books, will have a lower one.

In the paper, we thus consider the general case in which a given share of the population has a positive valuation for stand-alone technology, while the residual part of the population has a null valuation. Given this assumption, there exists a non-negative demand right after the introduction of the technology, before the network is deployed. This demand determines an installed base for a given technology and modifies the start-up problem for a network technology. In some cases, the installed base can be sufficient to solve the start-up problem, leading to a high level of adoption equilibrium without any subsidy. Nevertheless, in many cases the installed base is limited and a subsidy scheme is needed to reach a more efficient equilibrium. In the model, two types of subsidies are considered: a penetration pricing scheme and an investment boosting the awareness or characteristics of the product. Moreover, both the manufacturer and the producers of complementary contents can provide these subsidies. The case of publishers and e-readers is again a good example. A manufacturer such as Apple or Amazon can provide subsidies by reducing the price of the platform or by investing to enhance product characteristics. While the first is a non-discriminatory subsidy, the second one may push more technophiles or brand fans towards adoption but it is not likely to impact the decision process of a consumer which is only interested in exploiting Media contents through his e-reader. On the other hand, a subsidy from a publishing company is likely to impact those consumers that are interested in the network of Medias connected to the platform.

The model shows that when the stand-alone value is small, subsidies from complementary contents can be more efficient to solve the start-up problem. In these cases, a coordination problem emerges in the market. Assuming that platform manufacturer has a market power and other firms don't, the manufacturer can adopt an opportunistic behaviour to free-ride on complementary contents subsidies and internalize all positive externalities. Anticipating this behaviour, companies will not invest to subsidize. Their optimal

<sup>1</sup> See for example Farrel and Saloner (1985) or Tucker (2008)

strategy is to wait until the technology is adopted by a sufficiently large share of the population, eventually free-riding on other firms' investment. If this type of subsidies is pivotal to a successful start-up, the network technology may reach a suboptimal equilibrium due to underinvestment: not only consumers will obtain a lower surplus, since their utility increase with the size of the network, but they will pay a higher price for the technology.

In such cases, vertical agreements leading to a complete contract between manufacturers and complementary contents producer can increase total welfare. This result, which may seem very controversial in the light of recent investigations from U.S. and E.U. Courts against Apple and many important publishers, was the basic principle leading to the promotion of universal service adopted by these same institutions for other network technologies. As an example, subsidies to broadband diffusion (digital divide agenda) have been provided to telecom operators' and internet service providers' (ISP), which were in charge of the deployment of the network, both with financial aids and with a favourable regulation (ex. safe harbour). These distortions, which are now under discussion as well, introduced the problem of piracy and free-riding on media brands, but they did increase the value of broadband network for consumers, accelerating the adoption of the technology. The video game and DVD markets are further examples of successful start-ups of network technologies subsidized by publishers of complementary contents. Economists have shown that the availability of titles on this type of platform is crucial in determining the adopted standard among competitive platforms (Inceoglu, Park, 2009). The key difference in these cases is that the platforms are the only existing distribution channel for the complementary contents. Conversely, in our example books and Medias in general have alternative distribution channels they can exploit. Publishers may thus not accept to sell their products or subsidize technology adoption if they are not able to internalize sufficient externalities.

The paper is structured as follows: in Section 2 we set up a monopolistic network technology adoption framework. We then study the equilibrium users set with different stand-alone values. Section 3 introduces the subsidy schemes outlining the trade-off effects of different types of subsidies and the coordination problem. Section 4 concludes discussing results of the model and eventual policy insights.

## A Model for Network Technology Start-up Dynamics

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### 1. Interdependent Demand for a Network Technology

Consider a population consisting of  $n$  individuals. As in Artle and Averous' and Rohlfs' work, we define a set of binary variables: of demand

$$(1) \begin{cases} q_j = 0 & \text{if individual } j \text{ does not adopt the network technology} \\ q_j = 1 & \text{if the individual } j \text{ does adopt the network technology} \end{cases} \text{ for } j = 1, \dots, N.$$

We assume there are  $M$  potential goods accessible in the network and  $P$  other goods in the economy, where good  $P$  is the platform giving access to the network. Since we are in a two sided market, we establish a linear relation between the fraction  $f = \frac{\sum_j q_j}{N}$  of users adopting the network technology and the share  $m$  of network goods available through adoption:

$$(2) \quad m(f) = af$$

Where:

$$(3) \begin{cases} m_i = 0 & \text{if good } i \text{ is not available through the network} \\ m_i = 1 & \text{if the good } i \text{ is available through the network} \end{cases} \text{ for } i = 1, \dots, M$$

$$(4) \quad m = \frac{\sum_i m_i}{M}$$

To model interdependent demand, we specify a pair of additive utility functions for each individual:

$$(5) \quad U_j^0 = f(r_{j1}, \dots, r_{jP-1})$$

$$(6) \quad U_j^1 = f(r_{j1}, \dots, r_{jP-1}) + r_{jP} + \sum_{h \neq j} v_{jh}(m)q_j$$

Where:

- $U_j^0$  is the utility of individual  $j$  if he does not subscribe to the network technology,
- $U_j^1$  is the Utility of individual  $j$  if he does subscribe to network technology,
- $r_{jp}$  represents the consumption of good  $p$  by individual  $j$ ,
- $v_{jh}$   $h \neq j$  is the incremental utility to individual  $j$  of the additional user  $j$ , which is dependent on the effect of the new user on the number of goods available in the network.

Equations (5) and (6) implicitly assume independent utilities with respect to all goods in the economy other than:

1. The platform,
2. The goods accessible through the network.

In addition, we make the usual monotonicity assumptions:

$$(7) \quad \frac{\partial U_j^k}{\partial r_{jp}} \geq 0 \quad \forall p \text{ and } k > 0$$

$$(8) \quad U_j^0 \leq U_j^1 \quad \forall j, k, q_1, \dots, q_{j-1}, q_{j+1}, \dots, q_n, r_{j1}, \dots, r_{jP-1}, r_{jP}$$

We also make two specialized assumptions, the first applicable to network technologies and the second applicable to two-sided markets:

$$(9) \quad \frac{\partial U_j^1}{\partial m_i} \geq 0 \quad \forall i$$



$$(10) \frac{\partial m_i}{\partial q_j} \geq 0 \quad \forall j, q_1, \dots, q_{j-1}, q_{j+1}, \dots, q_n, r_{j1}, \dots, r_{jp-1}, r_{jp}$$

That is, a subscriber's utility never decreases as additional media goods become available in the network (and none drop out). In the same way, the number of media goods never decreases as additional users adopt technology (and none drop out). This is the logic usually defined as indirect network effect and seems like a sustainable assumption. In fact, it is hard to find an example of a network whose value would decrease if additional goods or services become available through it, or a market in which a higher demand leads to a reduction in the number of firms. It is maybe easier to think of a network technology becoming less valuable for a consumer as more users join it: it is the case for example of premium credit cards or exclusive clubs, in which the quality of service cannot be guaranteed beyond the optimal size of the set of users. However, as a rule, the increase of interconnections (user to goods or good to users) in a network technology is not detrimental to any party involved in the transactions.

Since we have assumed (9) and (10), the adoption of technology from user  $j$  will not be detrimental for any user  $h \neq j$  thus  $v_{jh} \geq 0 \quad \forall j, h$ . The additive model assumes that these incremental utilities do not depend on consumption of other goods outside the network. This is a reasonable assumption for the purposes of this article although the deployment of a new network may certainly have an impact both on social and individual behaviour. To go back to our example, the adoption of e-readers has an effect on the consumption of books or other Medias through other distribution networks. This effect, which is of particular interest for the publishing industry, is not discussed in this article for the sake of simplicity but most of all because it is so complex that it needs a specific article on the subject.

Every user is a rational consumer aiming at the maximization of his utility. The maxima  $U_j^0$  are defined by the *ceteris paribus* conditions and do not depend on the adoption of network technology. Maximizing equation (6) with respect to  $r_{j1}, \dots, r_{jp-1}, r_{jp}$ , subject to individual  $i$ 's budget constraint, we have:

$$(11) \widehat{U}_j^1 = \widehat{U}_j^0 + r_{jp} + \sum_{h \neq j} v_{jh} q_j - c_j(p)$$

Where  $c_j(p)$  is the generic cost function for user  $j$  and  $c_j(0) = 0$ ,  $c_j(p) > 0 \quad \forall j$ . The condition for adoption will thus be:

$$(12) q_j = \begin{cases} 1 & \text{if } r_{jp} + \sum_{h \neq j} v_{jh} q_j \geq c_j(p) \\ 0 & \text{if } r_{jp} + \sum_{h \neq j} v_{jh} q_j < c_j(p) \end{cases}$$

Assuming a linear cost function  $c_j(p) = b_j p$ , we can reformulate (12) as:

$$(13) q_j = \begin{cases} 1 & \text{if } \theta_{jp} + \sum_{h \neq j} \theta_{jhN} q_j \geq p \\ 0 & \text{if } \theta_{jp} + \sum_{h \neq j} \theta_{jhN} q_j < p \end{cases}$$

Where  $\theta_{jp} = \frac{r_{jp}}{b_j}$  and  $\theta_{jhN} = \frac{v_{jh}}{b_j} \quad \forall h \neq j$ . To solve the model we need two more assumptions. The first one is that only a part of the population has a positive evaluation for the platform itself, what we defined in

the introduction as the stand alone-value. The rest of the population derives utility only from the network accessible through the technology. We can write:

$$(14) \theta_{jP} = \begin{cases} \theta_{jP} \sim [0, \widehat{\theta}_{jP}] & \text{if } j \in g \\ 0 & \text{if } j \notin g \end{cases}$$

Where  $g = \beta f$  with  $\beta \in [0,1]$ , and represents the share of "geeks" in the population. This assumption is reasonable in the light of the discussion developed in the introduction and allows us to extend Rohlfs investigations by modelling different network technologies. Following this assumption, we can define different adoption conditions for the two types of consumer.

$$(15) q_j \forall j \in g = \begin{cases} 1 & \text{if } \widehat{\theta}_{jP} \geq p_d \text{ or } \sum_{h \neq j} \theta_{jhN} q_j \geq p \\ 0 & \text{if } \widehat{\theta}_{jP} < p_d \text{ and } \sum_{h \neq j} \theta_{jhN} q_j < p \end{cases}$$

Where  $p_d$  is the price of the platform and  $p_m$  is the price of goods in the network, thus  $p_d$  is given by  $p_d = p - p_m$ . For all the other users, the adoption condition is:

$$(16) q_j \forall j \notin g = \begin{cases} 1 & \text{if } \sum_{h \neq j} \theta_{jhN} q_j \geq p \\ 0 & \text{if } \sum_{h \neq j} \theta_{jhN} q_j < p \end{cases}$$

The second assumption, following Artle and Averous and Rohlfs, is that only the size of the network, in term of users and goods, affects an individual's demand. This is a contestable approximation, since the quality of goods in the network does have an impact on demand, just like the relationships among users does affect the utility of each of them for a communication service. Nevertheless, some interesting results can be derived even considering the simple case in which all goods and all users affect the network in the same way. From now on, we thus assume uniform calling pattern, acknowledging that the relaxation of this hypothesis would be a very interesting field for further research.

Let's start analysing demand for "non-geeks" in the first place. Thank to uniform calling assumption, we can re-write equation (16) for the unit mass representing our total population:

$$(17) q_j = \begin{cases} 1 & \text{if } f \theta_{jN} \geq p \\ 0 & \text{if } f \theta_{jN} < p \end{cases}$$

Where  $\theta_{jN}(m) = \sum_{h \neq j} \theta_{jhN}$  and  $f = \frac{\sum_j q_j}{N}$  is the fraction of users adopting the technology that we have introduced at the beginning of the section. This allows ordering individuals in term of their demand for the service, since if  $\theta_{hN}(m) \geq \theta_{jN}$ , user  $h$  will be an adopter in any equilibrium for which  $j$  is an adopter. Consider a technology where valuation  $\theta_{jN}$  of the  $j^{th}$  consumer associated to the complete network is distributed uniformly over the population  $\theta_{jN} \sim U[0,100]$ . For the marginal consumer we have:

$$(18) \theta_{jN} = 100(1 - m(f))$$

The reserve price a "non-geek" consumer will be willing to pay to join the network when the latter is incomplete is proportional to the fraction of population which has subscribed to the network, since this

determines the quantity of goods available in the network. We have denoted this fraction  $f$ , with  $f \in [0,1]$ . The utility  $U_j$  of the  $j^{th}$  consumer can thus be rewritten as:

$$(19) U_j = \begin{cases} \theta_{jN}m(f) - p & \text{if he adopts technology} \\ 0 & \text{if he does not adopt} \end{cases}$$

The  $j^{th}$  consumer will buy the service if and only if his utility is higher than 0, the condition for adoption becomes:

$$(20) p \leq \theta_{jN}m(f)$$

The fraction of subscribers for a given price  $p$  will be equivalent to a scalar multiplied by the fraction  $f$  of consumers with an utility from adoption equal or higher than  $p$ . To simplify we will start assuming that in (29, coefficient  $a = 1$ , so that we can substitute  $m(f) = f$  as in Rohlfs. If  $U_j$  is the utility of the consumer for which  $p = \theta_{jN}f$  (indifferent consumer), since utility is uniformly distributed we have:

$$(21) U_j \geq 0 \rightarrow \theta_{jN} \geq \frac{p}{f}$$

Substituting we have that demand is the locus of points where:

$$(22) p = 100f(1 - f)$$

The combination of the hypothesis on uniform distribution and the proportionality between utility and the fraction of subscribers allows showing the fraction of the population that may adopt technology for any given price.

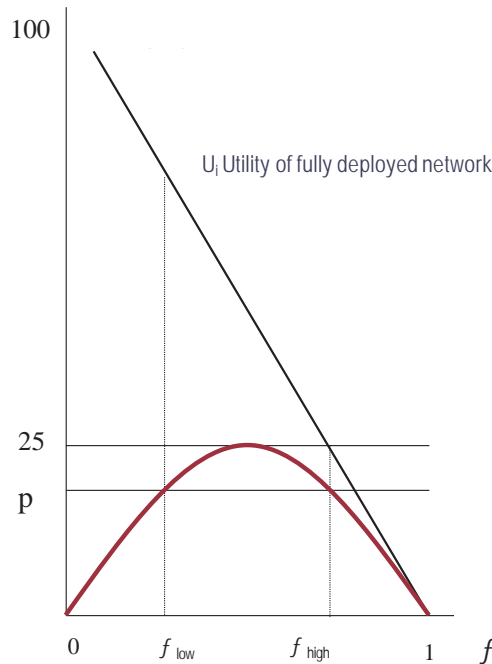


Fig.1 Demand for "non-geeks" users, as in Rohlfs's Model (1974)

The graph above visually shows the demand of “non-geeks” consumers. The black curve represent the valuation of consumers for the complete network, namely a network in which all consumers are connected and all goods are available in the network. The red parabola represents demand for the incomplete network. The intersections (if any) of the red curve with price identifies possible equilibria. Solving for  $f$  we have:

$$(23) f \in [0.5 - \delta, 0.5 + \delta]$$

$$(24) \delta = \frac{1}{2} \sqrt{\left(1 - \frac{4p}{100}\right)}$$

We thus have three possible outputs:

- For  $p > 25$ , we have a single equilibrium in  $f = 0$ , the user set is null,
- For  $p = 0$ , we have multiple equilibria  $f = 0, f = 1$ , depending on the starting disequilibrium, we end up either with a null user set or a user set including the entire population
- For  $0 < p \leq 25$  multiple equilibria,  $f = 0, f = f_{low}, f = f_{high}$ , with the equilibrium on the right-end side of the parabola ( $f_{high}$ ) which is always pareto-superior to the ones on the left-end side.

If  $p$  is higher than the reserve price for the incomplete network, “non-geeks” consumers will not adopt technology in any case. If the price is below this threshold there will always be two possible outputs for non-geeks demand. The left-end equilibrium ( $f_{low}$ ), beside behind suboptimal, is an instable equilibrium: if a single consumer chooses to drop from the network, the utility of others consumers will progressively become lower than  $p$  bringing back the equilibrium to the null user set. On the other hand, if the level of deployment is higher that  $f_{low}$ , the utility for a newcomer will be higher than  $p$  and the roll-out will proceed further and will reach the point of equilibrium defined as  $f_{high}$ .

This model shows the existence of a threshold, a critical mass of consumers which is necessary to solve the start-up problem of a network technology and generate the positive externalities.

**Proposition 1:** If the starting disequilibrium for a network technology is the null user set and all consumers are non-geeks, for any maximizing price  $p^* > 0$ , in order to reach the critical mass and solve the start-up problem, early adopters have to be subsidized.

**Proof:** if  $p^* > 25$ ,  $\forall j \ 0 \geq \theta_{jN}f - p^*$ , thus nobody is interested in adopting the technology, unless subsidies are provided. If  $0 < p \leq 25$ , we have that  $\theta_{jN}f - p^* > 0$  for  $f \in [f_{low}, f_{high}]$  but  $\theta_{jN}f - p^* < 0$  for  $f \in [0, f_{low}] \cup [f_{high}, 1]$ , thus if the starting disequilibrium is  $f = 0$ , nobody will be interested in adopting technology. The share of population that needs subsidies to adopt technology, which we call  $\lambda = f_{low}$ , while the amount of needed subsidies can be calculate as the area under the parabola:

$$(25) \Lambda(p) = \int_0^{f_{low}} p(f) df$$

## 2. Stand-alone Value and Geeks Demand

To learn more about adoption dynamics for network technologies we have to include in our model the demand from “geeks” users. We have assumed that a group of users has a positive valuation for the good defined as platform or device, which is essential to access the network technology. This category of consumers has two options to adopt, as described in (15). When the network user set is null, in the moment in which the technology is launched on the market ( $t = 1$ ), he adopts if his valuation of the device is higher than the price of the device, namely  $\widehat{\theta}_{jp} \geq p_d$ . If this is not the case, he can still adopt at a later stage ( $t = 2$ ) following the dynamics of adoption of “non-geeks” consumers. To simplify the strategic problem for “geeks” consumers, we further assume that a manufacturer cannot change the price of the device discriminating on the different groups of consumers. Moreover, we assume that demand for the device from geeks is less elastic than demand of “non-geeks” consumers. This seems a reasonable assumption since “geeks” users do not suffer any risk by adopting the technology, while for a “non-geeks” it exists the risk of receiving only the local utility from the device, for which he has a null valuation, or finding only a limited number of goods in the network, if a suboptimal equilibrium is reached.

The demand curve of “geeks” (from now on referred to as  $f_g$ ) is defined as function of the share of “geeks” in the population ( $g$ ), the price of device  $d$  ( $p_d$ ) and of a parameter ( $\alpha$ ) which models the investment which can be allocated by a manufacturer to enhance the technologic characteristics or the awareness of the new device.

$$(26) f_g(g, p_d, \alpha) = f_g \in [0, g]$$

Where:

$$\frac{\partial f_g}{\partial g} \geq 0, \frac{\partial^2 f_g}{\partial g^2} = 0, \frac{\partial f_g}{\partial p_d} \leq 0,$$

And

$$(27) \frac{\partial f_g}{\partial \alpha} \geq 0, \frac{\partial^2 f_g}{\partial \alpha^2} \leq 0 \text{ if } j \in g, \quad \frac{\partial u_j}{\partial \alpha} = 0 \text{ if } j \notin g$$

An additional investment has a positive effect on the demand of geeks, but this effect decrease progressively since the share of “geek” in the population is not affected and thus the investment increase the utility of a progressively smaller share of the population. Moreover, investment in technology does not have any effect on “non-geeks” consumers. This property can be observed in most new technologies, a typical example being the PC’s market. Many manufacturers kept investing in technology to increase the

performances of their devices, but only a few consumers, the more technophiles, where actually impacted in their decision to adopt a new model or not. Most people decision to adopt a new model was driven by the appearance on the market of new programs, which required more advanced technology to run. In the same way, when Apple invested to enhance the external aspect of their devices, which can be assimilated to a complementary content, the valuation of a large share of consumers was impacted, but not the one of "geeks".

Consider as an example a demand curve for "geeks" with a linear dependence on parameter  $\alpha$  and a logarithmic dependence on parameter  $p_d$ . The choice of the function derives from the assumed lower elasticity to price of the "geeks":

$$(28) f_g(g, p_d, \alpha) = g - \left(\frac{1}{\alpha+1}\right) \times \log(1 + p_d)$$

With  $\alpha \in R^+$ . This archetypal demand has two advantages: first of all we can visually depict it on the same graph that we used for "non-geeks" demand. Moreover its particular shape its helpful to visually show the effect of additional investment  $\alpha$  on adoption dynamics.

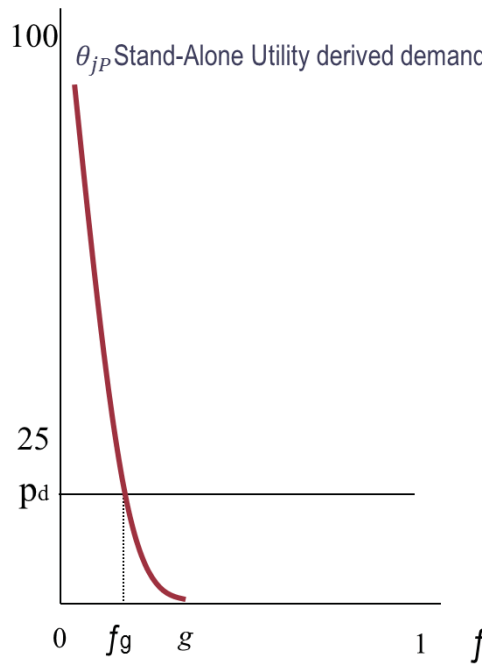


Fig.2 demand curve for "the Geeks"

Fig.2 introduces the demand function of "geeks". If the share of "geeks" in the market increases, the curve will shift to the right, if the quantity of "geeks" decreases, it will shift to the left. An increase of parameter  $\alpha$ , on the other hand, will change the shape of the curve, reducing elasticity to price of geeks and leading to higher demand for the technology. The existence of "geeks", under given conditions, allow for a positive demand even starting with a null user set and with no subsidies available. To complete the definition of the problem, we need to define the dynamics of the technology adoption and to analyse the supply side.

### 3. Maximization Problem for a Monopolistic Manufacturer

#### i. Timeline with no subsidies

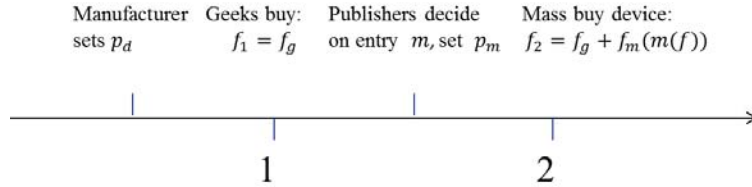


Fig.3 Timeline for network technology adoption with no subsidies

The simplest timeline of the game starts with the manufacturer setting  $p_d$ , which is fixed for the two periods. Then at time  $t = 1$  the geeks for which  $\widehat{\theta}_{JP} \geq p_d$  adopt the technology, creating an installed-base of early adopters of size  $f_1 = f_g$ . Publishers will observe  $f_1$  and decide on entry and set their optimal price  $p_m$ , determining  $m$ . Then at  $t = 2$  "non-geeks" decide on adoption. Fig.3 visually shows the timeline for adoption.

#### ii. Manufacturer Profit function

The manufacturer's problem is to maximize his profits, which are given by the sum of profits in period 1 and discounted profits in period 2 which are a function of the installed base at  $t = 1$ . The profit function can be written as:

$$(29) \max_{p_d} \pi_d = \pi_1 + \delta \pi_2(f_1, p_d)$$

Where  $\delta$  is the discount factor and profits are given by:

$$(30) \pi_1 = p_d f_1 - C(f_1)$$

$$(31) \pi_2 = p_d (f_2 - f_1) - C(f_2)$$

The associated cost functions are simply:

$$(32) C(f_1) = c(f_1) - (1 + \alpha)FC$$

$$(33) C(f_2) = c(f_2 - f_1)$$

$$(34) c = MC_d$$

Where  $c$  is the marginal cost of the device and  $FC$  represents all fixed cost of the technology, which can be increased with further investment ( $\alpha$ ) if subsidies are allowed. To complete the manufacturers market

we have to set two conditions: the first one is a budget constraint, so that a manufacturer cannot keep increasing investment without a limit. We write this as  $\pi_d \geq -K$ , where  $K$  is the initial resources of the firm. The second is a regularity condition:

$$(35) \max \pi_1 \leq \max (\pi_1 + \delta \pi_2(f_1, p_d))$$

This means assuming that a successful adoption of technology by “non-geeks” users is always more profitable for a manufacturer than the simple maximization of profits on the “geeks” market. This assumption is reasonable in most cases, since positive externalities increase with the size of the network, nevertheless there may be some counterfactual examples, in which raising the price to prevent “non-geeks” users from adoption can be the optimal strategy. An example can be a premium credit card: in this case, a limited size of the network is essential to provide exclusive utilities to the adopters and thus a raise in price can lead to higher profits with respect to an increase in the number of adopters. The First Order Condition for the manufacturer is:

$$(36) 0 = \frac{\partial \pi_d}{\partial p_d} = \frac{\partial \pi_1}{\partial p_d} + \delta \frac{\partial \pi_2}{\partial f_1} + \frac{\partial f_1}{\partial p_d}$$

Therefore, if (35) holds, at  $t = 1$  the manufacturer charges a lower price or sets a higher quantity than would maximize short-run profits, in order to raise its customer base and hence its future profits, whenever a successful adoption is feasible.

### iii. Equilibrium User Sets with Geeks in the Market

In the absence of subsidies, the equilibrium user set at  $t = 2$  is determined exclusively by the installed base of geeks obtained at  $t = 1$ . Equilibria for a given price  $p$  is given by:

$$(37) f_2 = \begin{cases} f_g & \text{if } f_1 \leq f_{low} \\ f_{high} & \text{if } f_1 > f_{low} \end{cases}$$

If  $f_1 \leq f_{low}$  the installed base is lower than the critical mass, thus for every consumer  $j \in [f_1, f_{low}]$ , we have that  $0 \geq \theta_{jN}f - p$ , thus no more consumers are interested in adopting the technology and we end up in a stable equilibrium in which only “geeks” adopt the technology. If  $f_1 > f_{low}$  the critical mass is reached and more users adopt technology until the stable equilibrium in  $f_{high}$  is reached, where  $0 \geq \theta_{jN}f = p$  as described at the beginning of this session. Fig 4 illustrates this situation. The disequilibrium point  $f_1$  is located underneath the parabola. This implies that for some non-geek users  $j$  the network valuation is higher than is willingness to pay. User  $j$  thus adopts the technology further increasing the value of the network. Other users successively adopt technology until the stable equilibrium  $f_{high}$  is reached.



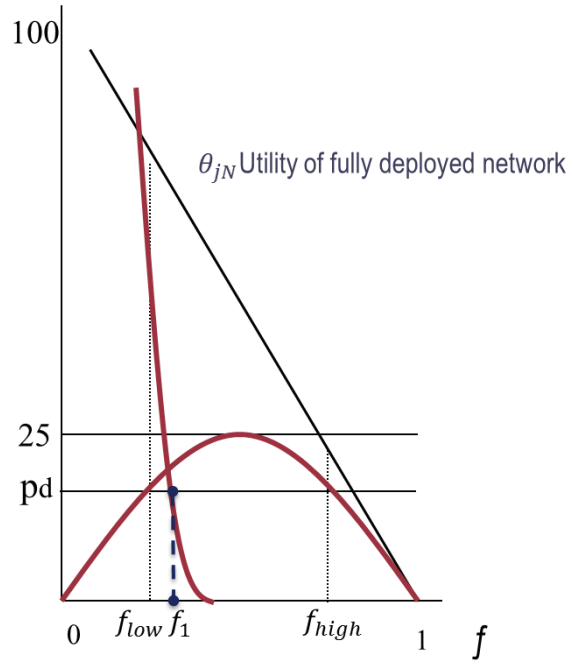


Fig.4 Technology Adoption dynamics with high Stand-Alone Value

**Proposition 2:** if  $f_g(p_d) = f_1 > f_{low}$ , for a given network technology, the start-up problem is solved and there is one and only one stable equilibrium user set at  $t = 2$ . Such equilibrium user set implies that a share  $f_{high}$  of the economy adopts the network technology and a share  $(1 - f_{high})$  does not adopt.

**Proof:** if  $f_1 > f_{low}$ ,  $f_1$  is not a stable equilibrium.  $\forall j \in [f_1, 1 - f_{high}]$  we have that:  $u_j = \theta_j f_1 - p_d \geq 0$ . Thus all users in this set adopt the technology at  $t = 2$ .

This situation captures a scenario in which the network technology has a very high Stand-Alone value and thus the population of “geeks” is predominant in the economy. This output is a first best solution both for the manufacturers, who maximize his profits and for consumers, since “geeks” will pay a lower price and “non-geeks” will obtain a larger surplus than in  $f_{low}$  or  $f_g$ .

The necessary but not sufficient condition to obtain  $f_1 > f_{low}$  at  $t = 2$ , is to have a sufficient share of “geeks” in the economy, namely  $g \geq f_{low}$ . If this condition does not hold, meaning that  $g < f_{low}$  and no subsidies can be provided except lowering the price, optimal strategy for manufacturer may be to choose  $p_d$  in order to maximize  $\pi_1$ , since non-geeks will not adopt the technology unless the price is consistently reduced to  $p_d \leq p_i$ , as depicted in Fig5. The equilibrium user set will then depend on other variables such as the marginal cost of production  $c$ . If the price cannot be reduced below  $p_i$  the final equilibrium user set is in  $f_1 = f_g(p_d)$ . This captures the situation of a technology with low stand-alone value and underinvestment to subsidize early adopters or a technology for which the valuation of the device from “geeks” is very high while the valuation of the access to the network for “non-geeks” is low (Examples can be: Satellite phones or minidisc).

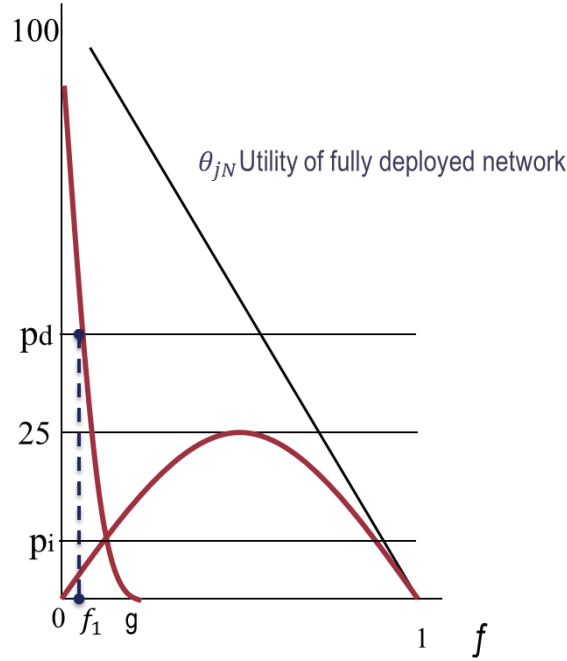


Fig.5 Technology Adoption dynamics with low Stand-Alone Value

**Proposition 3:** for any given  $g$ , in the absence of subsidies, the maximum price compatible with the start-up problem, is  $p_i$ , defined as the price for which  $f_g(p_i) = f_{low}(p_i)$ ,  $p_i = 100f_g(1 - f_g)$ .

**Proof:** for any  $p_d \leq p_i$ ,  $f_1 \geq f_{low}$ , thus  $\forall j \in [f_1, 1 - f_{high}]$  we have that:  $u_j = \theta_j f_1 - p_d \geq 0$ . Thus all users in this set adopt the technology at  $t = 2$ . Conversely, for any  $p_d > p_i$ ,  $f_1 < f_{low}$ , thus  $\forall j \in [f_1, 1 - f_{low}]$ ,  $u_j = \theta_j f_1 - p_d < 0$ , non-geeks users do not adopt at  $t = 2$ .

## Dynamics of Network Technology Adoption with subsidies

In this session we allow for additional types of subsidies from both the manufacturer and the producers of complementary contents and we analyse their effect on the adoption problem. First of all, let's formulate the general scheme of needed subsidies.

**Proposition 5:** Consider  $p = p_d + p_m$ , and assume that for "non-geeks" consumers the two good are perfect complements. For any  $p_d^*$  compatible with adoption, the share of population needing subsidies is at most  $\lambda = f_{low}(p)$ , decreasing with the installed based. Moreover, for any  $f_g > 0$ , the quantity of needed subsidies is lower than:  $\int_0^{f_{low}} f(p) - p df^2$ .

**Proof:** if  $g - \left(\frac{1}{\alpha+1}\right) \times \log(1 + p_d) \leq 0$  then the share of population to subsidize is:  $\lambda = f_{low}(p)$ . If

<sup>2</sup> Quantity of subsidies calculated using Rohlfs (1974) model, starting from the null user set disequilibrium.

$g - \left(\frac{1}{\alpha+1}\right) \times \log(1 + p_d) \geq f_{low}$ ,  $\lambda = 0$  and no subsidies are needed. If  $0 < g - \left(\frac{1}{\alpha+1}\right) \times \log(1 + p_d) < f_{low}$ ,  $0 < \lambda < f_{low}$ . Quantity of subsidies needed is given by:

$$(38) \int_{f_g}^{f_{low}} f(p) - p_i df$$

For any  $p_i$ , we thus have:

$$\int_{f_g}^{f_{low}} f(p) - p_i df \leq \int_{f_g}^{f_{low}} f(p) df \leq \int_0^{f_{low}} f(p) df \quad \forall p_i, f_g$$

## 1. Subsidies from Manufacturer

### i. Timeline with Subsidies from Manufacturer

In this section, we allow the manufacturer to provide subsidies not only by reducing price  $p_d$  but also by increasing investment  $\alpha$ .

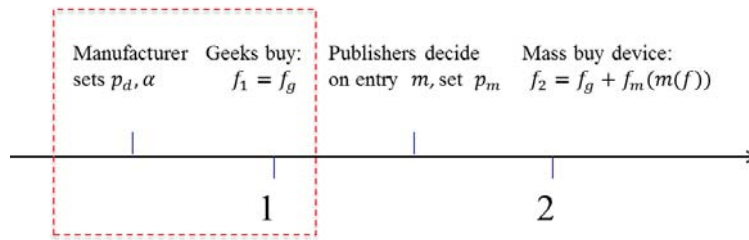


Fig.6 Timeline of Adoption dynamics with manufacturer subsidies

### ii. Adoption Dynamics with Subsidies from Manufacturer

Manufacturer can invest  $\alpha$  at  $t = 1$  in order to enhance technical characteristics or awareness of their technology. We have described this subsidy in the previous session. Recall that we assumed  $\alpha$  is "device related", it affects  $\widehat{\theta}_{jP}$ , thus it does not have significant impact on "non-geeks", since they have  $\widehat{\theta}_{jP} = 0$ . On the other hand, subsidies from complementary contents' producers are "Network related", they will impacts  $\theta_{jN}$ . This working assumption reflects the actuality of the launch of e-readers, characterized by two distinct marketing channels (device, device + Media) from the very beginning. Although scope economies may exist among the two channels, we consider that they have second order effects.

Manufacturers can provide subsidies also by reducing the price of device, as introduced above. A reduction in  $p_d$  will affect the whole market, since price is fixed in the two periods, it is an indiscriminate subsidy. The intuition is that an overinvestment effort in technology, by pushing more geeks towards the adoption of the new technology at  $t = 1$ , can be more profitable than reducing  $p_d$ , since it is a

discriminated subsidy. The condition for this strategy to be effective is that subsidy  $\alpha$  is sufficient to solve the start-up problem. The effect of an increase in investment is shown in Fig 7. Higher investment leads to an increase in the demand from geeks.  $f_1$  grows, nevertheless the share of "geeks"  $g$  in the population is not affected, nor is the utility of "non-geeks". Recall also that the marginal effect of an overinvestment in technology of the hardware is decreasing as  $\alpha$  increases. In our example, the problem for the manufacturer becomes:

$$(39) \max \pi_d(p_d, \alpha)$$

$$(40) \frac{\partial f}{\partial \alpha} = \frac{1}{(\alpha+1)^2} \times \log(1+p_d), \frac{\partial^2 f}{\partial \alpha^2} = -\frac{2 \log(1+p_d)}{(\alpha+1)^3}$$

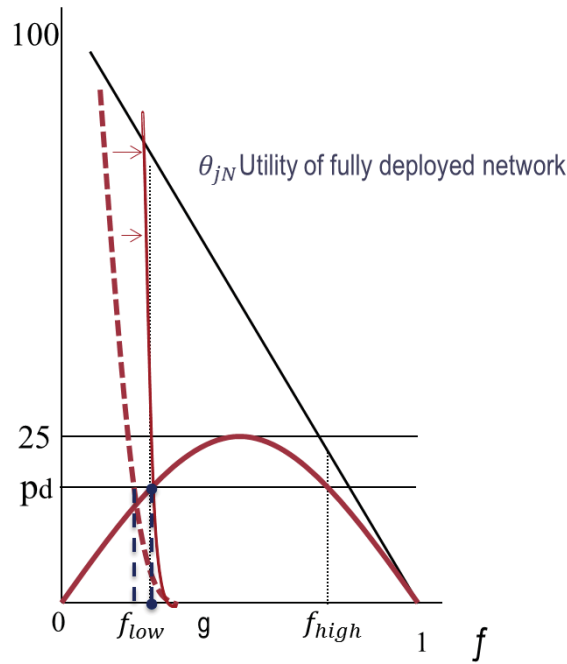


Fig.7 The effect of an increase in the investment effort

The First order condition becomes:

$$(41) \frac{\partial \pi_d}{\partial \alpha} = \frac{\partial \pi_d}{\partial p_d} = 0$$

**Proposition 6:** Consider a technology for which  $g > f_{low}$  for the optimal price  $p_d^*$ . If manufacturer is allowed to provide infinite subsidies ( $K = \infty$ ), then the start-up problem can always be solved without reducing optimal price  $p_d^*$ . The Pareto-superior equilibrium in  $f_{high}$  can be reached thank to subsidy  $\alpha$ . We say that  $\alpha$  can be "pivotal" when  $g > f_{low}$ .

**Proof:** If  $g > f_{low}$ , for every optimal  $p_d^* < 25$ , we can have either  $f_g > f_{low}$  or  $f_g \leq f_{low}$ . If  $f_g > f_{low}$  holds, the start-up problem is solved and no subsidies are needed. If  $f_g \leq f_{low}$  the manufacturer can always set  $\alpha^*$  such that  $f_1(\alpha^*) > f_{low}$ . This solves the start-up problem and it is always feasible if ( $K = \infty$ ). In fact, for  $\alpha \rightarrow \infty$ ,  $f_g \rightarrow g \forall p_d^* < 25$ , thus if  $g > f_{low}$ , the start-up problem can always be

solved.

This choice may also be Pareto-superior for the economy if from the maximization problem we have that  $\pi(f_{high}(p_d^*)) - \alpha^* \geq \pi(f_g(p^*))$ . Otherwise, the manufacturer will have an incentive in non-investing. Technologic investment is progressively more costly and has an impact on a small share of consumers. Nevertheless, over-investing in technology can be justified if “geeks” consumers can be pivotal for adoption. By providing this type of subsidy, the manufacturer can fix a higher price and recover the cost of investment at  $t = 2$ . Manufacturer thus arbitrates between the two types of subsidies, choosing the combination that maximizes his profits.

## 2. Subsidies from Complementary Contents Producers (CCP)

In this section we first describe the CCP market, then we define the subsidies they can provide and we analyse their effect on adoption dynamics.

### i. CCP market

Recall that the utility for a “non-geek” user is given by:

$$(42) U_j = \theta_j m(f_2) - (p_d + p_m)$$

Where  $p_m$  is the price and  $m$  is the fraction of complementary contents in the market as defined in (4). CCP market is composed by a large number ( $N$ ) of identical companies ( $i$ ) facing monopolistic competitions. Each company produces a single good which can be sold in the network associated with the new technology. There is free entry in the network, nevertheless in order to market a product the company suffer a positive cost of entry (which is technology specific and thus sunk), marginal costs are null:

$$(43) FC_i > 0, MC_i = 0 \quad \forall i$$

Each company maximizes profit in his share of the market:

$$(44) \max_{p_{m,i}} \pi_{i,2} = p_{m,i} f_{i,2}(f_1, p_m) - FC_i$$

Since companies are identical and there is free entry in the market for every observed  $p_d$  we can define  $m_i$  as a boolean variable taking value 1 if the company enters the market. We thus have:

$$(45) m = \frac{M}{N} \text{ where } M = \sum_i m_i \forall i$$

And:

$$(46) m: \pi_i = p_m f_2(f_1, p_m) - m NFC_i = 0$$

$$(47) m = \frac{p_m^* f_2(f_1, p_m)}{NFC_i}$$

For every manufacturer's choice, CCP market can end up in two alternative stable equilibria:

$$(48) m_{1,2} = \begin{cases} \frac{p_{m1} * f_1}{NFC_i} & \text{"non-geeks" don't adopt, low } m \\ \frac{p_{m2} * f_2}{NFC_i} & \text{"non-geeks" adopt, high } m \end{cases}$$

### ii. Timeline with Subsidies from CCP – reduction of $p_m$

Let's allow CCP to provide subsidies. For example they can reduce  $p_m$ . Subsidies from manufacturer occur after manufacturer has fixed his price. Non-geek users observe global price  $p$  and then decide on adoption.

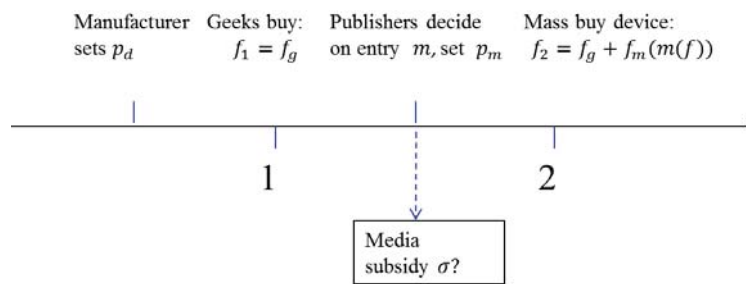


Fig.8 Timeline of Adoption dynamics with CCP subsidies

### iii. Adoption Dynamics with Price Reduction from CCP

In this session we assume  $g < f_{low}$  and  $p_d^* \geq p_i$ . This situation can arise from many different set-ups. For example, assuming  $c > p_i$ , the manufacturer cannot reduce the price of the device to  $p_i$  or he will have negative profits in both periods. Under these conditions, at  $t = 1$  we have:

$$(49) \lambda(p) = f_{low}(p) - f_g(p_d^*) > 0 \text{ and } \Lambda(p) = \int_{f_g}^{f_{low}} f(p) - p_i df > 0$$

Additional subsidies are needed to solve the start-up problem. Fig.9 visually shows this situation through our example. The blue dotted line depicts  $\lambda(p)$  while the red area represents  $\Lambda(p)$ .

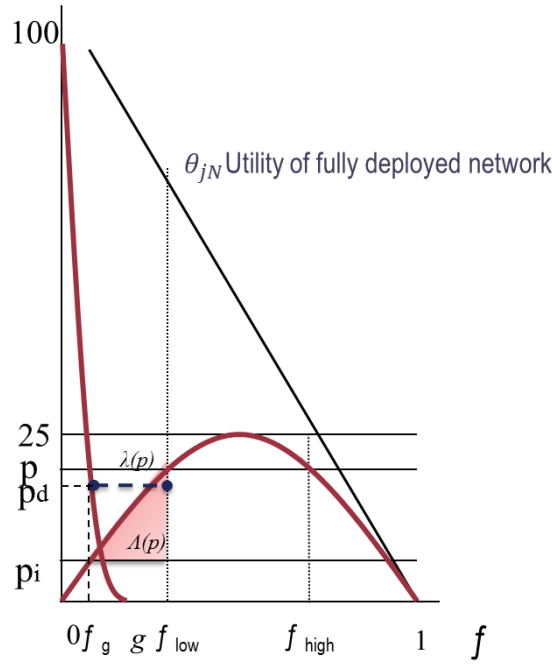


Fig.9 Additional Subsidies needed if  $g < f_{low}$  and  $p_d^* \geq p_i$

Having identified the needed subsidies, let's examine the impact CCP can have on adoption. Suppose that each CCP can make an investment  $\sigma_i$  to subsidize adoption. In our case study of Publishers and e-readers, it can be an investment to create a more comfortable version rather than the pdf standard for written contents or to implement additional features to the existing Media (interactive links, archives, commentaries, etc.). We have assumed that this type of subsidy will only impact the valuation of the network. We can make a further assumption that this investment is not detrimental for any consumer, thus

$$\frac{\partial \theta_{jN}}{\partial \sigma_i} \geq 0.$$

Let's start analyzing CCP subsidies assuming  $\frac{\partial \theta_{jN}}{\partial \sigma_i} = 0$ , thus complementary contents don't increase the value of the network and CCP can provide subsidies only by reducing price of their goods.

**Proposition 8:** if device and complementary contents are perfect complement, meaning "non-geeks" consumers only considering  $p = p_d + p_m$  making their adoption decision, then even assuming  $\frac{\partial \theta_{jN}}{\partial \sigma_i} = 0$  CCP can provide subsidies to adoption. Moreover, these subsidies can be pivotal if

$$f_{low}(p_d) \leq f_g \leq f_{low}(p)$$

**Proof:** for any optimal couple  $(p_d^*, p_m^* > 0)$  we have:

$$(50) \Lambda(p) = \int_{f_g}^{f_{low}} f(p) - p_i df \geq \int_{f_g}^{f_{low}} f(p_d^*) - p_i df$$

Thus CCP can reduce  $p_m' < p_m^*$  and reduce the amount of needed subsidies. In fact:

$$(51) \Lambda(p(p'_m)) = \int_{f_g}^{f_{low}} f(p(p'_m)) - p_i df < \Lambda(p(p^*_m))$$

The maximum subsidy in this case is given by:

$$(52) \int_{f_g}^{f_{low}} f(p) - p_i df - \int_{f_g}^{f_{low}} f(p^*_d) - p_i df = \int_{f_{low}(p^*_d)}^{f_{low}(p)} f(p) df$$

If  $f_{low}(p_d) \leq f_g \leq f_{low}(p)$ , then the quantity of needed subsidies is:

$$(53) 0 \leq \Lambda(p) \leq \int_{f_{low}(p^*_d)}^{f_{low}(p)} f(p) df$$

But then  $\forall f_g \in [f_{low}(p_d), f_{low}(p)]$  CCP can set opportunely  $p'_m$  such that  $\Lambda(p(p'_m)) = \Lambda(p)$ , thus solving the start-up problem.

Now let's assume  $\frac{\partial \theta_{jN}}{\partial \sigma_i} > 0$ . CCP can increase valuation  $\theta_{jN}$  by investing  $\sigma_i$ . Each company can choose to invest or not: if they do, they suffer extra costs. In our example we treat  $\sigma_i$  as a Boolean variable:

$$(54) \begin{cases} \sigma_i = 0, & \text{company does not invest} \\ \sigma_i = 1, & \text{company invests} \end{cases}$$

The extra fixed costs can then be introduced in the profit function as follows:

$$(55) \pi_{i,2} = p_{m,i} * (f_{i,2}(f_1, p_m)) - (1 + \sigma_i)FC_i$$

The effect of the subsidy is modeled as a linear increase in utility, depending on CCP decision. The new utility function can be written as:

$$(56) U_j = 100(1 + \sigma) \times (1 - m(f))$$

$$(57) \sigma = \sum_{i=1}^M \frac{\sigma_i}{N}$$

**Proposition 9:** if  $\frac{\partial \theta_{jN}}{\partial \sigma_i} > 0$ , the range in which CCP subsidies can be "pivotal" to network technology adoption is extended to  $f'_{low}(p_d) \leq f_{low}(p_d) \leq f_g < f_{low}(p)$ , where:

$$(58) f'_{low}(p_d) = 0.5 - \delta' \leq f_{low}(p_d)$$

$$(59) \delta' = \frac{1}{2} \sqrt{\left(1 - \frac{4p}{100(1+\sigma)}\right)} \geq \delta$$

**Proof:** the maximum achievable subsidy is obtained for  $\sigma = m$ , namely all companies that enter in the market invest to provide subsidy. Since all companies are identical, this is also the only positive subsidy reachable at equilibrium, the other possible equilibrium being  $\sigma = 0$ . If a positive subsidy is deployed, since  $\frac{\partial \delta}{\partial \sigma} > 0$ ,  $\frac{\partial f_{low}(p_d)}{\partial \sigma} \leq 0$ ,  $f_{low}(p_d)$  will shift to the left as depicted in Fig.10 to reach  $f'_{low}(p_d)$ . Moreover,  $p_i$  increase to  $p'_i = 100(1 + \sigma)f_g(1 - f_g) > p_i$ . As a result, the needed subsidy is reduced from the blue area to the red area. Analytically:



$$(60) \Lambda'(p) \leq \int_{f_g(p_d^*)}^{f'_{low}(p_d)} f(p) - p'_i df < \int_{f_g(p_d^*)}^{f_{low}(p_d)} f(p) - p_i df$$

For every  $\forall f_g \in [f'_{low}(p_d), f_{low}(p)]$  we can thus find the minimum value of  $\sigma$  that guarantees a successful deployment by setting:

$$(61) f'_{low}(p) = f_g$$

$$(62) g - \left(\frac{1}{\alpha}\right) \times \ln(1 + p_d) = 0,5 - \frac{1}{2} \sqrt{\left(1 - \frac{4p}{100(1+\sigma)}\right)}$$

And solving for  $\sigma$ .

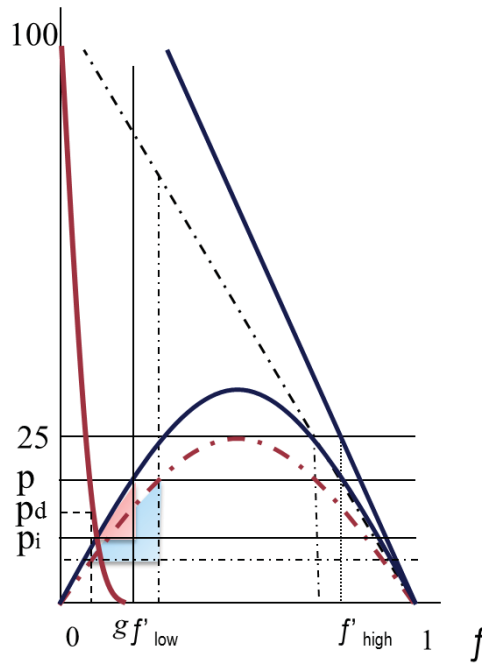


Fig.10 Additional Subsidies needed if  $\frac{\partial \theta_{jN}}{\partial \sigma_i} > 0$

This type of subsidy, besides extending the set-ups in which it is possible to solve the start-up problem, can lead to a Pareto-superior final equilibrium where a larger share of consumers adopt the network technology and receive a higher surplus, while manufacturer obtains higher profits from the solution of the start-up problem (from the regularity condition).

### 3. Hold-up, Free-riding and Coordination Problems

CCP can provide subsidy only if they are compensated so that non negative profits constraint is satisfied. In fact, in the absence of coordination, investing is risky for CCP both because of horizontal and vertical

information asymmetries. Each CCP controls a fraction  $\frac{\sigma_i}{M}$  of the investment, so they do not have *a priori* guarantees that the need optimal investment  $\sigma^*$  would be reached. Moreover, if manufacturer cannot commit on fixing the price for the device, they suffer a hold-up risk (recall that we assumed investment  $FC$  is technology specific). For a CCP the profit function becomes:

$$(63) \max_{p_{m,i}, \sigma_i} \pi'_{i,2} = p_{m,i} f'_{i,2}(f_1, p_m, \sigma_i) - (1 + \sigma_i) FC_i$$

Thus for the company to be able to invest the condition becomes:

$$(64) \Delta\pi(\sigma) = (\pi'_{i,2} - \pi_{i,2}) = p_m * (f'_{i,2} - f_{i,2}) \geq \sigma_i FC_i$$

The intuition is that this condition can be fulfilled only if the manufacturer commits on keeping a fixed price for the device and remunerates CCP willing to invest for their subsidies. We can thus examine two possible scenarios:

- i. Manufacturer can establish complete contracts with CCP
- ii. Incomplete contracts: hold-up and free-riding risk emerge for CCP

#### i. Timeline with complete contracts

The possibility of structuring complete contracts can be modelled similarly to vertical integration. After signing the contract, the monopolist manufacturer can solve the start-up problem efficiently, since he can count on CCP subsidies. At the end of the game, he has to remunerate CCP according with their investment. This situation is shown in Fig.11.

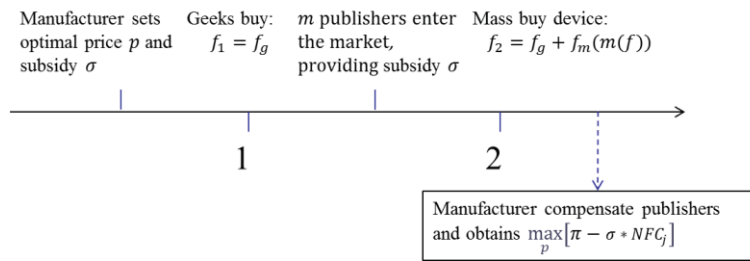


Fig.11 Timeline of Adoption dynamics with CCP subsidies and complete contracts

If  $g \leq f_{low}$  and  $f'_{low} < f_g < f_{low}$ , thus only "network related" subsidies are pivotal the problem for the manufacturer becomes:

$$(65) \max_p \pi_d = \pi_2 - \sigma * NFC_i$$

$$\text{s. t. } f_1 \geq f_{low} \text{ OR } \sigma * NFC_i \geq \int_{f_g}^{f_{low}} f(p) - p_i df$$

If  $g > f_{low}$  and  $f_g < f_{low}$ , thus both "device related" and "network related" subsidies can be pivotal the problem for the manufacturer becomes:

$$\max_p [\pi(f'_{high}, p) - \sigma * NFC_i, \pi(f_{high}, p) - \alpha * FC]$$

$$\text{s. t. } \sigma * NFC_i \geq \int_{f_g}^{f_{low}} f(p) - p_i df \text{ or } \alpha * FC \geq \int_{f_g}^{f_{low}} f(p) - p_i df$$

Where the constraints represent the condition to solve the start-up problem with CCP subsidies or technologic subsidies.

**Proposition 10:** If  $g \leq f_{low}$  and  $f'_{low} < f_g < f_{low}$  or if  $g > f_{low}$  and  $f_g < f_{low}$ , establishing complete contracts can lead to a Pareto-superior equilibrium, with respect to the situation in which both firms act opportunistically

**Proof:** If  $g \leq f_{low}$  and  $f'_{low} < f_g < f_{low}$ , subsidies from CCP are a necessary condition to adoption from “non-geeks”. In this case complete contracts allow to end up in  $f'_{high} > f_g$  thus consumers are better off. Moreover, manufacturer is better off since he does not provide subsidies and obtains  $\max \pi_2 \geq \max \pi_1$  for the regularity assumption. CCP obtains zero profit in both cases but at  $f'_{high}$  more firms enter the market. if  $g > f_{low}$  and  $f_g < f_{low}$ , then we can set two conditions:

$$(66) \alpha * FC \geq \sigma * NFC_i - (f'_{high} - f_{high}) * (p' - p - c) \text{ and}$$

$$(67) f'_{high} - f_{high} \geq 0$$

Where the first term in (66) represents the additional costs if manufacturer provides “device related” subsidies while the second term is composed by the remuneration of CCP for their subsidies and delta profits with respect to the case in which the companies act separately. This condition, if respected, indicates that the manufacturer is better off coordinating with CCPs. Thus if only (66) holds, in the new equilibrium manufacturer and CCPs are better off but not consumers. On the other hand, if only (67) holds but not (66), then consumers are better off in the new equilibrium but manufacturer has an incentive in not stipulating the contracts. Thus if the technology is such that (66) and (67) hold, then establishing complete contracts between manufacturer and CCP leads to a Pareto-superior equilibrium enhancing social welfare.

The next section assume that manufacturer cannot commit on price and show that social welfare enhancing equilibria obtained above cannot be reached in the absence of complete contracts.

## ii. Timeline with incomplete contracts

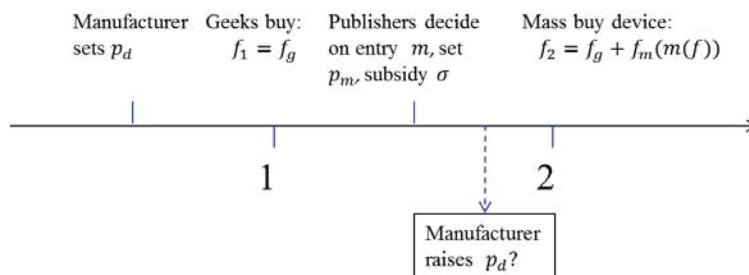


Fig.12 Timeline of Adoption dynamics with CCP subsidies and incomplete contracts

**Proposition 11:** If  $g \leq f_{low}$  and  $f'_{low} < f_g < f_{low}$ , and complete contracts are not available, the Pareto-superior equilibrium depicted in the previous section cannot be attained. The risk of opportunistic behaviour leads to a suboptimal equilibrium.

**Proof:** We assume the same conditions as the previous section but this time we allow the manufacturer to change price of the device before non-geeks decide on adoption on  $t = 2$ . In this case, in the absence of complete contracts, manufacturer has an incentive to initially set price  $p_d$  according to the preceding schema, so it is compatible with CCP subsidies. Then once  $f > f_{low}$  and  $m$  CCP have invested to enter and subsidized, manufacturer can raise the price  $p_d$ , obtaining higher profits. This will bring to the same equilibrium as before, since CCP have already suffered sunk cost and thus will prefer to adjust their price. At equilibrium we will have  $p_m = 0$  and:

$$(68) \pi_d = \pi_2(f'_{high})$$

$$(69) \pi_m = -(1 + \sigma) * NFC_i$$

Anticipating this behavior, CCPs will not invest. Thus we will end up with a suboptimal equilibrium with a lower share of adopters  $f_g$ , and lower profits for the manufacturer as shown in table 1.

CCP \ Manufacturer	Investing	Wait and see
	Investing	Wait and see
Keeping $p_d$	$\pi_2(f'_{high}) - \sigma * NFC_i; 0$	$\pi_1(f_g(p_d)); 0$
Changing $p_d$ before $t = 2$	$\pi_2(f'_{high}); -(1 + \sigma) * NFC_i$	$\pi_1(f_g(p_d)); 0$

Table 1: Coordination problem with incomplete contracts

If we drop the assumption that CCP are identical, we will also have a coordination problem in the CCP market. When the start-up problem is not solved, each company will have an incentive to wait and see, eventually free-riding on the investment of other Media companies, once  $f > f'_{low}$ .

Going back to our case study of Publishing companies and e-readers, we observe the following: investment from Publishers seem to increase consumers' valuation of e-readers and their associated network. Their cooperation may be pivotal for non-geeks to adopt this new technology. In order to invest in the new distribution network, Media companies need to be granted sufficient returns from their investment. Under current market conditions, publishing companies suffer considerable risks by investing in the new distribution networks: first of all, they suffer hold-up risk from manufacturers. In fact, each manufacturer has a dominant position and control distribution through his platform, thus can impact profitability of publishing companies in many ways. Moreover, they suffer a cannibalization risk on their traditional

distribution network; this risk increases if they are forced to reduce prices in one distributive channel. Finally, if they subsidize the new network and there is free-entrance, they suffer a free-riding risk from other Media companies, which can wait and enter the market at a later stage without suffering the costs of subsidies. If complete contracts are available, the positive network externalities generated can be distributed efficiently to bring both sides of the market on-board and increase social welfare.

## Conclusions

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In this paper we show that in a two-sided market with network externalities, cooperation of complementary contents producers can be pivotal to reach the critical mass of adopters needed to solve the start-up problem of a new technology. Moreover, in case of cooperation, under given conditions a Pareto-superior final equilibrium can be reached. Nevertheless, when the technology giving access to the network is proprietary, complete contracts with the producers of complementary contents might be necessary to reach this equilibrium. We also show that for some technologies, overinvesting to enhance technologic characteristics might be profit maximizing, even if only a few consumers are actually valuating positively these technologic innovations. In fact, those few customers can sometimes be essential to constitute an installed customers base large enough to solve the start-up problem.

These results allow for a reflection over recent investigations U.S. Court vs. Apple Inc. and al. or EU Antitrust formal proceedings to investigate sales of e-books. The main claim of these investigations is that recent contracts established by a group of publishers with the leader of tablets' manufacturer constitute a case of vertical restraint (they are basically MRP – minimum retail price – agreements). While MRP can be often considered as negative distortions, in the light of our analysis of the case of Tablets and Media, we could question whether these contracts are the main distortion in this emerging market or a consequence of current regulation and market structure. In fact, profitability of digitized versions sold through e-readers' network is very low for publishers. On the one side, the actual diffusion of e-readers does not guarantee a sufficient market for complementary contents. On the other side, the margins for publisher are lower than in the physical distribution network. This may be counter-intuitive since digitized versions are costless to reproduce. Nevertheless considering the lower willingness to pay of consumers, the unfavourable fiscal regimes (ex. VAT in France is 5% for physical books and 21% for digitized books), and the high distribution fees that publishers have to reverse to manufacturers (since they often act as distributors of digitized contents as well), the algebraic sum can be already negative. Moreover, publishers need to consider the possible negative externalities introduced by the new distribution channel. Overall, the cost of subsidizing early-adopters of the new network is being sustained by Media industry consistently. In order to recover for these costs, publishers would need to control their distribution channels strategically or

at least establishing a complete contract with the digital distributors of their contents. Otherwise, they risk suffering negative profits, due to the dominant position of the manufacturer/distributors in this market and they will stop providing subsidies. If the intention of the regulator is to enhance competition and to favour universal access to new networks, maybe the first distortion to address should be the regulation of digital distributors, which has been acknowledge but not solved with the Block exemption regulation by EU, which allows for instance fashion brands to restraint distribution of their goods in order to prevent their strong investments in the brand from free-riding.

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