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Enhancing Broadband Penetration in a Competitive Market

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***Abstract*—In spite of the exponential growth of IP traffic, broadband market is suffering from a stagnation which limits Internet penetration and discourages investors/operators from deploying access infrastructures in sparsely populated areas because of low (or negative) rate of return and unsustainable operation costs. Although perfect competition is not a suitable model to describe Internet access market, the economic equilibrium between supply and demand curves in a competitive market can be used to discuss the issues of Internet penetration and infrastructure sustainability and to envisage new business models that could be applied to enhance them. This is the purpose of this paper.**

***Keywords*-Economic equilibrium; Internet penetration; Network sustainability; Business model; Competitive market;**

I. Introduction

This is a position paper which starts from general concepts of neoclassical economics to analyze the mechanisms which might change the price-quantity equilibrium in a competitive market in such a way that both market penetration and collective welfare are increased. The results are then applied to the case of broadband Internet access [7] under the simplifying assumption of perfect competition to motivate the introduction of new business models triggering positive changes in the economic equilibrium and granting long term sustainability to access network infrastructures.

The applicability of the business models envisioned in this paper is not discussed from a technological point of view for two main reasons. First, because economic arguments come first and possibly prompt for the development of new technical solutions. Second, because some of the existing network models [1], [4] already provide a suitable support for the application of the business models proposed in this paper.

Section II provides some background on economic equilibrium in competitive markets, introduces the concepts of *complementary* and *base* goods, and analyzes the determinants of the price-quantity equilibrium in order to outline the actions that can be taken to change it. Section III applies the theoretical framework of economic equilibrium to the case of Internet bandwidth by discussing the possibility of exploiting emergent network models (with particular emphasis on neutral access networks) to enhance market penetration. Conclusions are drawn in Section IV.

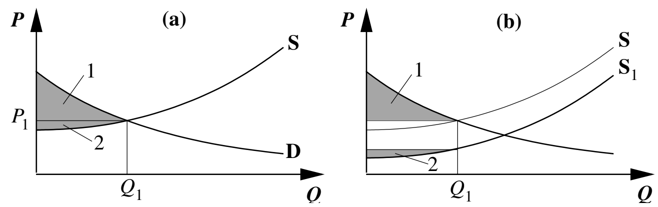

Figure 1. (a) Economic equilibrium in a competitive market. (b) Effect of the marginal cost of a complementary base good.

II. Economic equilibrium in a competitive market

According to neoclassical economics, the price quantity equilibrium of a good exchanged in a competitive market is reached at the point of intersection between demand and supply curves [11].

The *demand curve* represents the relation between the *price* of a good and the *quantity* of that good that the market is willing to buy at that price. In the following we use the term "*good*" to represent a generic product or service. The willingness to pay a given price is related to the perceived *utility* of the good. An individual is willing to pay a price P for the Q-th unit of a good if and only if P is less or equal to the *marginal utility* of this additional unit, according to his/her own evaluation. The overall demand curve is obtained by summing up, for any given price, all the quantities determined by the individual marginal utilities.

The *supply curve* represents, for any given price, the quantity of a good that the producers are willing to supply at that price. From a producer's perspective, the minimum acceptable price for the Q-th unit of a good corresponds to the *marginal cost* of producing and supplying such a unit. In a competitive market, the supply curve can be obtained by summing up, for any given price, all the quantities determined according with the marginal costs of all the suppliers.

Neither the existence nor the uniqueness of a point of intersection between demand and supply are always guaranteed. For our purposes, however, we restrict the discussion to the typical case of an increasing supply curve (S) which crosses a decreasing demand curve (D).

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Figure 1.a plots the two curves for a generic good (say, α), together with the corresponding economic equilibrium $(Q1, P1)$ that would be achieved in an ideal competitive market characterized by: a large number of rational buyers, a large number of suppliers who sell homogeneous products and want to maximize their profits, low entry/exit barriers, and perfect information about quality and prices [8]. Although perfect competition is an abstract model based on unrealistic assumptions, it leads to interesting results that can be extended to more realistic scenarios.

Exchanging the $Q1$-th unit at price $P1$ produces no benefits either for the supplier (who covers only its marginal costs) or for the buyer (who pays exactly for the marginal utility he/she perceives). However, all other units exchanged at the same price produce a benefit both for the suppliers (who incur marginal costs lower than the price) and for the buyers (who perceive a marginal utility higher than the price). The area of grey regions 1 and 2 in Figure 1.a represents the *collective welfare* obtained thanks to competition.

A. Complementary goods

Figure 1.b shows the same curves of Figure 1.a with an additional supply curve S1, which represents the actual aggregate marginal cost of good α as a function of the quantity supplied. The distance between S and $S1$ (assumed to be a constant for the sake of simplicity) is due to the marginal cost of a different good (say, β) which needs to be sold together with α since it is required to enable the exploitation of α, but it is not attractive as a good by itself. Technically speaking, α and β are called *complementary goods* and β represents a *base good* (i.e., an enabling condition) for α.

Examples of base goods are videogame consoles for videogames, antennas and set-top boxes for DTV channels, or PCs for computer programs.

As long as the cost of β is hidden behind the price of α, it affects the economic equilibrium of α by reducing both its market penetration ($Q1$ is much lower than the point of intersection between S1 and D) and the collective welfare (the area of the white rectangle between regions 1 and 2 in Figure 1.b represents the loss of collective welfare in the market of α).

This is what would happen if any videogame needed to be sold together with a new console, if any new DTV channel required a new antenna and set-top box, or if any new software required a dedicated hardware.

B. Changing the economic equilibrium

Often, base goods are not only sold together with a given complement good, but they have their own market. This happens either because they have a marginal utility which is communicated to customers, or because they are required to exploit many different complementary goods.

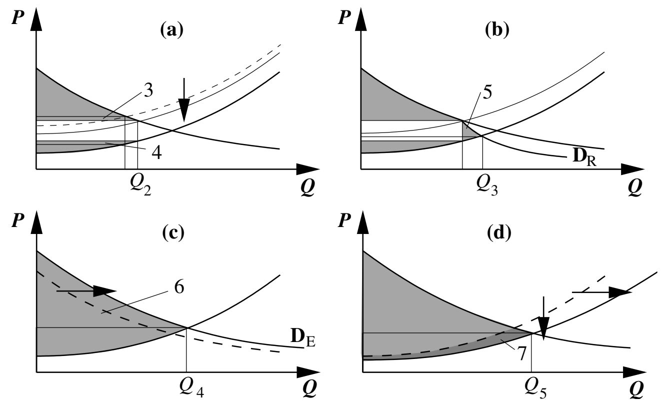

Figure 2. Changes in the economic equilibrium of a good exchanged in a competitive market, as induced by: (a) the reduction of the marginal cost of a complementary base good, (b) the independent acquisition of the base good by part of the buyers, (c) the presence of a new demand from people who do not need to buy the base good, and (d) the lowering and extension of the supply curve.

For the sake of simplicity let's assume that β is a base good not only for α, but also for some other complementary good denoted by γ. The market of γ produces beneficial effects on the market of α which may end up changing its economic equilibrium, as depicted in Figure 2.

First, the presence of multiple complementary goods creates a (possibly competitive) market for β which is expected to be sold at a lower price because of scale economies, specialization of suppliers, and competition. Since the price of β is a cost for the suppliers of α which does not add to the perceived utility, the lower the price the better for the market of α. Figure 2.a shows that a reduction in the marginal cost of β increases the market penetration of α ($Q2 > Q1$) and the collective welfare (augmented by the area of regions 3 and 4).

Second, a fraction of the individuals who decided not to buy α because its equilibrium price was above the utility they perceived, could decide to buy γ (together with the base good β). Once they have bought γ, they could buy α at a lower price, discounted by the marginal cost of β they do not need to buy any more. This situation is shown in Figure 2.b, where a residual demand curve (D_R) crosses the discounted supply curve of α finding a new economic equilibrium with increased penetration ($Q3 > Q2$) and collective welfare (the added value being the area of region 5).

Third, the population of customers of γ (who already own the base good β) are not only allowed to buy α at its net price (without incurring additional costs for the enabling good) but they may be also enabled to test and try it, which is an essential condition for perceiving the actual utility of any *experience good*. Hence, the independent diffusion of the base good creates a new demand curve for α, denoted by D_E in Figure 2.c. If γ has a large market penetration, the induced demand curve can even exceed the original one.

Moreover, this curve has to be directly compared with the net cost of α, increasing its penetration ($Q4 > Q3$) and creating the additional collective welfare represented by the area of region 6 in Figure 2.c.

Fourth, the positive externality of γ also affects the supply curve of α. In fact, the augmented demand might induce additional suppliers to enter the market. Since the supply curve is obtained by summing up the quantities produced by all the suppliers at any given marginal cost, new-entrant suppliers cause the supply curve to be stretched to the right. In addition, if the suppliers of α can avoid taking care of β (once it has gained its own market) they can specialize their production in order to reduce the net marginal costs of α, thus lowering the supply curve. Both effects are represented in Figure 2.d, which shows the corresponding benefits in terms of penetration ($Q5 > Q4$) and collective welfare (area of region 7).

III. The case of Internet bandwidth

Gaining access to the Internet from a subscriber's terminal is a multi-faceted problem the solution of which requires the availability of a local access infrastructure and entails: creating a physical connection (*local loop*) between the *customer's premises equipment* (CPE) and the local access infrastructure, assigning an IP address to the CPE, and routing IP packets across the access network through some Internet gateway. According to the vertical integration model, typical for telecommunication networks, Internet service providers (ISPs) are usually responsible for the entire process, in that they supply CPEs to create local loops, they manage and maintain the access infrastructure, and they manage and maintain the Internet gateway. In addition, they are responsible for authenticating their customers and for maintaining traffic logs in compliance with anti-terrorism and privacy regulations.

In spite of the complexity of the access infrastructure, Internet access is usually sold as a service the quality of which is expressed in terms of bandwidth, exactly if the user was directly connected to the Internet gateway. The costs of CPEs, local loops, and access infrastructures are hidden behind a monthly rate which seems to depend only on the allocated bandwidth and, possibly, on its actual usage.

To follow the discussion of Section II, Internet bandwidth is a good, α, which is sold together with a cumbersome base good, β, representing whatever is needed to create a connection between the user and the Internet gateway (i.e., the CPE, the local loop, and the routing of IP packets across the access infrastructure).

The same pattern could be applied at a higher level by considering Internet bandwidth as a base good in its turn, in that it enables the exploitation of the online services made available worldwide. This complementarity relation is apparent (and properly exploited) in the Internet market: end-users buy Internet connectivity from local operators separately from the services they want to access once they are online.

On the contrary, complementarity is not evident at the access infrastructure level, which is the focus of this paper. In fact, in most cases local access networks are used only to connect to the Internet, so that end-users do not perceive any utility in being connected to the access infrastructure unless they can gain access to the Internet. Hence, β (i.e., local connectivity) cannot be sold without α (i.e., Internet bandwidth). This is exactly what happened in telephone networks, where the last-mile copper cables and (most) terminals were sold as base goods together with the telephone service. There are, however, two main differences between Internet access and telephone services. First, telephone services were developed on top of dedicated circuit-switching networks, motivating the adoption of vertical integration as a business model for telephone companies, while IP networks are conceived to carry countless services (including voice communication) suggesting a separation between network management and service provisioning [10]. Second, telephony is a basic service the utility of which can be easily communicated and perceived, while the Internet is a comprehensive high-technology data network the utility of which is hard to be communicated to people who have no experience of it [7], thus suffering from the so called *information asymmetry*.

As a matter of fact, broadband connectivity has to be regarded as an experience good the market penetration of which is heavily impaired by information asymmetry and by the marginal cost of its base good (i.e., the connection to the local access infrastructure) which is hidden to end-users.

A. Emergent network models

The capability of IP networks to transport digital information and services over a sole infrastructure is prompting for the development of an all-IP infrastructure integrating data, voice, and real-time multimedia services [6]. Although the phrase *next generation network* is usually adopted to denote such an infrastructure, existing IP networks (if suitably sized and managed) already provide sufficient support for service integration. In fact, many ISPs provide voice over IP (VoIP) services with geographic numbers and video streaming services which reach (and sometimes overcome) the quality of broadband satellite TV.

On the other hand, new business models are required to overcome the limitations of vertically-integrated access networks [5]. The concepts of *open access networks* (OANs) [3], [2] and *neutral access networks* (NANs) [4] have been recently introduced in an attempt of separating network management from service provisioning, thus enabling specialization, promoting innovation, and creating a competitive market of IP services on top of a shared infrastructure.

An OAN is an operator-neutral [9] shared infrastructure which acts as an intermediator between users and service providers (SPs) [2]. ISPs are nothing but a special category of SPs, offering Internet bandwidth through their own edge routers. From end-users' perspective, OANs should allow them to choose among multiple SPs while having the perception of connecting directly to the network of the provider they subscribed to. From SPs' perspective, the ideal OAN should combine the economic advantage of sharing investments and maintenance costs, with the distinguishing features of a proprietary network. Hence, existing implementations of OANs are mainly aimed at hiding the shared nature of the access infrastructure [1]. In this way, they induce a beneficial separation between network access and services, but they do not change too much the business model of SPs, nor the motivation of users for entering the network.

NANs retain the benefits of OANs, while making the shared access network visible (rather than invisibile) to end-users in order to trigger positive externalities and to create a market for local connectivity [4]. This is done by delivering a sizeable set of services directly within the access network, in order to make them available to all users (who are no longer viewed as subscribers) before they register with a service provider and go through a specific edge router.

For instance, in a NAN could coexist: many ISPs offering different Internet navigation options, VoIP operators offering voice services through their own dedicated edge routers, IPTV broadcasters having their streaming servers within the NAN, and SPs delivering local services and applications for active citizenship, proximity marketing, tourism, ...

B. Enhancing broadband penetration

The migration of traditional communication services to IP networks, together with the paradigm shift from a vertical integration to a separation between network and services, creates the conditions for changing the economic equilibrium of the broadband market by triggering all the positive externalities analyzed in Section II-B.

Consider, for instance, the NAN described at the end of previous subsection, which grants access to many different services, including Internet bandwidth, VoIP, IPTV, and local services.

Going back to the discussion of Section III, Internet bandwidth is the good under study (α), while local connectivity to the NAN is its base good (β). Thanks to the nature of the NAN, β is a base good not only for α, but also for all the other services made available through the same NAN. In fact, once a user is connected to the local infrastructure (i.e., once he/she has paid for β) he/she is enabled to buy any service at its net price, without incurring additional costs.

For the sake of explanation, let's use γ to denote one of such services, namely, VoIP. Thanks to the sharing of the same base good, the market of γ induces all the beneficial effects on the market of α described in Section II-B.

In particular, consider the case of User1, who perceives a marginal utility of Internet bandwidth which is lower than the sum of the equilibrium prices of α and β. In a vertical model, such a user would not subscribe to any ISP. However, User1 could be also interested in VoIP (i.e., γ), possibly perceiving a marginal utility which is greater than the sum of the equilibrium prices of γ and β. Hence, he/she decides to bear the cost of connecting to the NAN in order to use γ. Once he/she is connected, he/she can reconsider to buy α at its net price (which is not augmented by the price of β any more). Referring to Figure 2.b, User1 contributes to the residual demand curve denoted by D_R.

Now consider the case of User2, who is not attracted at all by Internet navigation, but he/she is so attracted by VoIP, that he/she decides to connect to the NAN (β) just to use voice services (γ). Once he/she is in the NAN, he/she has the opportunity of experiencing some other online services for free, so that he/she can start perceiving the added value of Internet bandwidth, until the perceived utility reaches the market price and he/she decides to register with one of the ISPs operating in the NAN. Referring to Figure 2.c, User2 contributes to the creation of the new demand curve denoted by D_E.

Finally, there is the case of User3, who connected to the NAN because of VoIP, experienced some online services, but he/she remained in the tail of the demand curve D_E corresponding to a perceived utility lower than market price. At some time new entrant ISPs could come into the picture, causing a stretching of the supply curve which produces a reduction of the equilibrium price which motivates User3 to enter the Internet, as shown in Figure 2.d.

Similar externalities are triggered by any additional service delivered within the same NAN. The net effect is the enhancement of broadband penetration and the increase of collective welfare.

IV. Conclusion

Neoclassical economics provides the instruments for studying the price-quantity equilibrium in a competitive market and to understand the mechanisms that could affect it.

Price-quantity equilibrium models have been applied to the broadband market in order to explain its apparent stagnation and to discuss the potential of emergent network models and architectures. Qualitative results achieved under perfect competition assumptions suggest that broadband penetration could be significantly improved thanks to the convergence of voice and video services over all-IP networks and to the adoption of neutral access network models.

Since perfect competition is an abstract model, the hints it provides need to be validated by means of more realistic economic experiments to be conducted either on the field or on a simulation environment. Agent-based simulation models are being developed to this purpose.

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