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Regulatory legacy, VoIP adoption and investment incentives[1]

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Abstract

The introduction of VoIP telephony raises concerns about current regulatory practice. Access regulation has been designed for PSTN and the liberalization of the PSTN market. This paper explores the effects of access regulation of PSTN networks on consumers' adoption of a new technology in the form of VoIP. It also discusses the link between access regulation and the incentives to invest in VoIP.

JEL-Classiffcation: L96, L51, L13.

Keywords: telecommunications, voice over broadband (VoB), voice over Internet protocol (VoIP), entry, access, regulation.

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1. Introduction

The emergence of voice telephony based on the Internet protocol (VoIP) has had, and will continue to have, a profound impact on the telecommunications landscape. Without even mentioning the threat posed by Internet companies, incumbent operators were forced to think beyond milking the PSTN (public switched telephony network). A possible response is to introduce VoIP quickly and at low prices, while incurring the cost of cannibalizing PSTN revenues. For instance, in order to compete with cable operators, Dutch incumbent KPN had hastened to introduce VoIP telephony. The telecoms operator wasn't prepared for the large uptake during the first year, which resulted in serious installation problems and quality/service issues.[4] In this new landscape faced by incumbent operators in liberalized markets, the nature of competition between incumbents and entrants is substantially changing, compared to what has been observed in the early years after liberalization of the telecoms sector.

This paper explores competition between an incumbent offering both PSTN and VoIP telephony (or voice over broadband, VoB), and an entrant present only in the latter segment. It investigates the effects of regulation in one segment on competition in the other, unregulated segment, and explores possibly undesirable side effects of access price regulation. Based on the obtained insights, it discusses various policy implications.

A situation is considered in which an incumbent with a history in PSTN telephony, competes with a newcomer in the VoIP segment. The incumbent has a local access network with complete coverage. The entrant may be a cable operator with a full-coverage broadband network, or a newcomer without a local network, making use of mandatory unbundling of the incumbent's local loop to reach end-users. The incumbent offers PSTN (public switched telephone network) voice telephony to one segment of customers, as well as VoIP services to another segment, while the entrant only offers VoIP services in the latter segment. Consumers can choose between staying with the

[4] KPN made VoIP telephony available in February 2006. See "KPN Suffers VOIP Hiccup", Light Reading, 8 May 2007, http://www.lightreading.com/document.asp?doc_id=123468.

PSTN network versus migrating to VoIP services. In this setting, this paper explores to what extent regulatory intervention in the PSTN segment may distort the adoption of VoIP by consumers, and operators' investment incentives.

In particular, the focus is on the effects of regulation of PSTN terminating access prices and the effects of regulation of the PSTN retail price. Accordingly, regulation of the VoIP market itself is outside the scope of this paper, which looks instead at the broader picture in which PSTN and VoIP are connected market segments. In particular, it is discussed how the level of the PSTN access charge and the level of the PSTN retail price affect the intensity of competition in the VoIP segment and the speed of consumer migration to VoIP. By adopting a welfare perspective, policy implications are derived.

While short-run effects of regulation on retail competition appear to be important, the impact on investment levels should not be ignored. The analysis is therefore extended to study the effect of access regulation on investment incentives in the VoIP segment. One can then observe that, in general, an access price different from cost levels generates asymmetric incentives for incumbent and entrant. Often the incumbent has weaker investment incentives, because it cannabalizes revenues in the PSTN-segment. However, no unambiguous results with respect to investment incentives can be derived. Because of the effect of investment on wholesale PSTN revenues, the incumbent's rather than the entrant's investment may turn out to be more profitable at the margin.

The policy relevance of this paper is evident. It looks at the broader regulatory picture, in which PSTN and VoIP market segments cannot be viewed separately. The point is this may be at odds with the idea behind the European regulatory framework for communications markets, which has tended to view market segments in relatively isolated contexts, and offers regulatory instruments to be applied within "markets" in which a problem occurs.[5] This paper demonstrates that "compartmentalizing" communications market may conflict with maximizing overall consumer or total welfare,

[5] This tendency has diminished with the reduction of the number of predefined markets over time, but nevertheless, the underlying philosophy places little weight on the interconnectedness of market segments (De Bijl & Peitz, 2008).

especially if the regulatory process cannot keep up with the speed at which operators adapt their business strategies, and the speed at which consumers change their communications behaviors. The message is that, if only because of network interconnection, regulators should be aware of the explicit effects that PSTN regulation may have on the emerging VoIP market. It is surprising that regulatory practice has not put more explicit attention to this type of interdependence. This may partly be due to considerations of a universal service obligation regarding PSTN or by market power with regard to PSTN call termination, that create a bias towards existing regulations. Nevertheless, within the European regulatory framework, such considerations can easily introduce distortions when the technological environment changes over time (for a policy document on such considerations, see OECD, 2006). This paper articulates how regulation in one segment can have undesirable side effects in another segment, both through strategic pricing interaction and through investment incentives.

This paper builds on the literature on "one-way" and "two-way" access (for overviews, see e.g. Armstrong, 2002, and Vogelsang, 2003; for references to recent contributions on two-way access see Peitz et al., 2004) by analyzing the emergence of VoIP networks in a PSTN environment, and in which the PSTN and VoIP networks are interconnected.[6] Part of this paper draws on De Bijl and Peitz (2009), which provides a formal (game-theoretic) analysis of imperfect competition between an incumbent active in both PSTN and VoIP, and a VoIP entrant. This paper is also related to the literature on investment incentives in infrastructure markets (see Valletti, 2003; and Gans, 2006). Foros (2004) models a situation of a vertically integrated firm controlling both local access and providing broadband access, and a downstream Internet retailer. The focus of that paper is mainly on regulation as a way to induce the integrated firm to invest efficiently and to deter it from foreclosing the market – in this paper the regulator cannot commit to a particular policy before investment decisions are made. Also related is Hansen (2006), addressing regulatory concerns with respect to the migration from fixed to mobile.

[6] Relevant contributions to the access price issue in environments in which firms enjoy market power include Ebrill and Slutsky (1990), Laffont and Tirole (1994), Armstrong and Vickers (1998), Lewis and Sappington (1999), and De Bijl and Peitz (2006b).

This paper is organized as follows. Section 2 contains some illustrative data and discusses some elements of the analysis. Section 3 presents the stylized model. Section 4 explores how access regulation in the PSTN segment affects competition in the VoIP segment. Section 5 discusses how the incentives to invest in VoIP can be affected by PSTN access regulation. Section 6 concludes the paper.

2. Developments in broadband and VoIP

The emergence of VoIP is closely linked to developments in broadband Internet access. Initially, broadband connections were primarily meant for Internet access. Worldwide, (narrowband) dial-up access to the Internet has been in decline due to migration to broadband access. In January 2009, the penetration rate of broadband was 23.9% of the EU population.[7] One years earlier, it was 20,2%, coming from about 7% in 2004. Penetration is different among EU member states. At the beginning of 2009, it ranged from 11% in Slovakia to almost 37% in Denmark and the Netherlands. Outside of the EU, Korea was traditionally leading (25% in 2005, and 32% in the fourth quarter of 2008), but was recently overtaken by Denmark, the Netherlands, and Norway (34.5% in fourth quarter of 2008). Growth rates of broadband penetration remain high: in June 2009, the Netherlands was frontrunner (38.1%), followed by Denmark (37.0%), while Korea was at position five (32.8%).

DSL, the prevalent broadband technology in Europe, Australia and New Zealand, has been the main force driving the migration to VoIP, also in countries in which cable modems have traditionally played important roles. In Europe, the share of DSL relative to other broadband technologies has gradually been declining since a couple of years. In

[7] The data reported in this section is taken from the 14th Report on the Implementation of the Telecommunications Regulatory Package, published by the European Commission, http://ec.europa.eu/information_society/policy/ecomm/library/communications_reports/annualreports/14th/index_en.htm and OECD, http://www.oecd.org/sti/ict/broadband. See also De Bijl and Peitz (2006a).

January 2009, the shares in the EU were as follows: DSL 79.4%, cable 15.3%, fiber 1.4%, WLL 1.1%, and other platforms (e.g. satellite) 2.8%.

The number and variety of IP-based telephony service propositions are large and increasing, and terms like VoIP, IP telephony and Internet telephony are often used interchangeably. This paper looks at "managed" VoIP and voice over broadband (VoB).[8] In December 2007, (managed) VoIP originated calls represented 8.3% of fixed telephony traffic in the EU, led by the Netherlands (32% IP originated calls) and France (27%).

Consider the emergence of managed VoIP by focusing on competition between an incumbent and an entrant, in a stylized set-up that will be used throughout this paper to derive regulatory implications. The incumbent offers both PSTN and IP-based telephony through DSL technology. That is, the incumbent is still in the process of upgrading its network from a PSTN to an all-IP network, and therefore still able to offer both services. The entrant may be an operator with or without a local access network. If the entrant does not have a local network itself, it can reach end-users through local-loop unbundling (LLU), that is, by leasing the incumbent's unbundled local connections, or through bitstream access.[9] If a customer switches to a LLU-based entrant, he or she completely substitutes the PSTN service with the entrant's IP-based service. Alternatively, the entrant may have its own local network, for instance cable, fibre or WLL. In many local markets, this competitor is a cable company that has upgraded its network to offer broadband internet access and IP-based telephony. As this set-up captures essential elements of the market structure in countries like, for instance, the Netherlands, Belgium and Germany, conclusions can be derived that have wider relevance in the light of current regulatory issues. Also in countries in which the incumbent in the PSTN-segment has so far refrained from offering VoIP-telephony, the analysis is relevant since it can shed light

[8] This paper abstracts from "unmanaged", that is, peer-to-peer software-based, VoIP services, such as Skype. The most recent "Progress Report on the Single European Electronic Communications Market" by the European Commission hasn't yet included peer-to-peer/unmanaged VoIP in its descriptive statistics of the development of VoIP. This can easily change once the handset becomes more like a computer, as is already happening in mobile telephony, raising a range of new issues (e.g. whether mobile operators should allow their customers to use Skype). As discussed in the conclusion, including such players in the analysis would require a different set-up, which is left for future work.

[9] This paper abstracts from regulatory problems associated with the setting of the wholesale lease price of local loops. For this issue, see e.g. De Bijl and Peitz (2002).

on the strategic incentives of the PSTN-operator to postpone entry into the VoIP-segment.

As a starting point, suppose that the incumbent charges for call termination on its PSTN, and that no termination charges are used for calls terminated on IP networks. This is in line with the observation that the incremental cost of call termination on IP-based networks tends towards zero, in contrast to PSTN networks. Actually, such a structure of access prices may in some market environments be seen as a good approximation of the outcome of negotiations between VoIP and PSTN operators. As stated in OECD (2006, p. 26), "[...] it seems likely in reality that VoIP operators might not charge PSTN operators for IP termination while PSTN operators would still charge VoIP operators for the same call in the opposite direction, due to the VoIP providers' weaker negotiation power." Note, however, the importance of analyzing different interconnection agreements between VoIP networks.[10] Indeed, one can observe in a number of countries that VoIP providers set termination charges for off-net calls at comparable levels as those charged by PSTN operators.[11]

[10] See Yoon (2006) for such an analysis.

[11] See section 4.2.

3. Fixed Telephony with a PSTN and a VoIP-Segment

Consider a stylized market for voice services in which a consumer can maintain its PSTN connection or upgrade to VoIP, in the form of a VoB connection.[12] Based on these decisions, a PSTN segment of relative size λ_0 and a VoIP segment of λ result (adding up to 1).[13] PSTN is offered by the incumbent, called operator 1, only, whereas VoIP is offered by the incumbent and an entrant, operator 2 (see the previous section). Since the focus is on competition in the VoIP-segment, one can take the retail price in the PSTN-segment, p_0, as a parameter throughout most of the discussion. This is appropriate if, for instance, the retail price is regulated, or if competition in the PSTN segment comes from pure resale competitors, whose conditions for access are regulated.[14] Although the discussion is simplified by having only two firms competing in the VoIP segment, the main insights are robust to analyzing a small number of VoIP providers with some degree of market power (a situation of oligopoly or imperfect competition). The operators compete in the VoIP segment by choosing fixed fees p_1 resp. p_2. Indeed, in many countries one can observe a move towards flat rates, and therefore, abstracting from per-call or per-minute prices seems to become a good description of actual fixed telecoms markets.[15] Thus, consumers have an inelastic demand for one unit of the good (they will not purchase more than one subscription, no matter how cheap). Market shares in the VoIP segment are denoted by $s_i(p_1, p_2)$, $i = 1, 2$.

The timing of events is as follows. At the outset, the charge for terminating access to PSTN-customers, called a, is given (e.g. because of regulation). Similarly for the PSTN retail price p_0.

[12] See De Bijl and Peitz (2009) for a complete and detailed model and analysis.

[13] Note that as long as the firm offering PSTN-services can distinguish between the different types of incoming calls, namely if they come from a PSTN-connection or a VoIP-connection, it is immaterial for the modeling whether firms run an IP-based network in their backbone or whether they still operate a circuit-switched network.

[14] Pure resale competitors can easily included in the analysis without affecting the results.

[15] This paper abstracts from software-based IP-solutions in which consumers substitute single calls. Clearly, in an ideal world of flat rates such incentives for substitution are present only if there are important quality differences. Such individual call substitution takes place in practice. Full migration is considered here. Individual call substitution would not affect the main insights. Note that this is not the case for international calls, where the cost savings of using a PC rather than a telephone may be substantial. Such calls are typically outside of the basket of services covered by the flat subscription fee.

- At $t = 1$, consumers form beliefs about prices in the VoIP segment.
- At $t = 2$, based on their individual preferences (which are heterogenous among consumers) and beliefs, consumers choose between PSTN and VoIP, while simultaneously, firms 1 and 2 set VoIP retail prices.
- At $t = 3$, consumers observe retail prices and make purchase decisions, that is, consumers who stayed with PSTN purchase from the incumbent, while consumers upgrading to VoIP choose between the incumbent and the entrant. Consequently, market shares and profit levels are realized.

Concerning the timing, before consumers learn the prices of VoIP services, they already hold (equilibrium) beliefs about the prices that they can expect after their technology adoption decision. Think of a situation in which consumers have already heard or read about the new technology, for instance through friends, magazine articles, and trade announcements. Hence, they know that the new technology exists. Based on the prices they expect, they make their "costly" technology adoption decision (think of this as consumers making a choice before they "go shopping"). Thus, consumers' technology adoption is a lumpy decision that is not reversed if actual prices change (however, it is easy to change the provider for a given technology). An alternative motivation of the proposed timing is to postulate that consumers do mental accounting in decision making (Thaler, 1999). It is important to remark that in the problem explored here, it is formally equivalent to analyze a game in which consumers first decide simultaneously between PSTN and VoIP, and next, operators set VoIP prices.[16]

Given the segment size of PSTN customers λ_0, it is assumed that each customer makes exactly this share of calls to PSTN-customers. This occurs if calling patterns are balanced.[17] Thus, a VoIP operator has to make, on average, a payment of $\lambda_0 a$ for each customer subscribed to its network. While this assumption is not essential for the argument, it allows one to express objective functions in an unambiguous way. Further, while operators have to pay for terminating access on the PSTN network it is assumed (at

[16] See the companion paper De Bijl and Peitz (2009) for a more elaborate exposition.

[17] This situation provides a natural starting point for the analysis. For more on this, see De Bijl and Peitz (2002, 2009).

this point) that there are no termination charges for calls that terminate with a VoIP customer. In section 4 it will be discussed what happens if there are terminating access charges for calls from the PSTN to VoIP customers.

De Bijl and Peitz (2009) choose a particular parametrization in this model, which the interested reader may want to consult. However, the main results are robust to variations and the purpose of the following discussion is to elaborate on these main results and the underlying mechanisms. Concerning the methodology, the analysis will be restricted to situations which are strategically stable, in the sense that no player would have an incentive to deviate from its action, given the actions of the other players (a "Nash equilibrium"). Also, it is postulated that actors foresee the effect of their actions on future outcomes and that beliefs that lead to such actions are confirmed.

The regulatory environment and in particular prices a and p_0 are known by the firms before other decisions are made. While this is a heroic assumption in the dynamic landscape of telecoms, the underlying notion is that operators have expectations about the type of regulatory policy, and that individual deviations by firms (e.g. in their pricing decisions) will not make regulators reconsider their regulatory principles. This means that the regulator has built up quite some reputation for "sticking to its guns".[18]

Based on the announced or inferred access regime, operators make their investment decisions (in infrastrucure and services). Section 5 will focus on investment incentives; for the moment, those investments are assumed to be given. At $t = 2$, based on the resulting product characteristics customers make their migration decisions; each customer individually decides whether to remain with PSTN-telephony or migrate to VoIP. At this point, consumers have to form expectations about p_1 resp. p_2. These expectations are consistent with the expected degree of competition in the VoIP-segment, since this will determine the price level for VoIP compared to PSTN-telephony. For instance, customers

[18] Relatedly, Deutsche Telekom communicated in 2005 that some of its investment plans were conditional on the regulatory policy that will be applied in the future. In line with the modelling assumption, this corresponds to seeking the kind of regulatory commitment on which it then bases its investment decision. Commitment by the regulator is always a demanding requirement; however, the vast majority of the formal analyses of the effects of regulatory intervention require commitment.

foresee that regulation favoring the PSTN-segment through increasing access price a, increases costs for VoIP suppliers, and hence leads to higher VoIP prices. At $t = 3$, based on the expected segment sizes of PSTN and VoIP (reflecting customers' migration decisions), operators set VoIP prices p_1 resp. p_2. The price difference in the VoIP segment determines market shares $s_1(p_1, p_2)$ and $s_2(p_1, p_2)$.

Suppose that the operators have market power in the retail market, so that each operator can sustain a strictly positive price-cost margin. Due to fixed costs and initial investments, these margins do not necessarily make operators profitable, but they are a precondition for an operator to be active. There are a number of justifications for the existence of market power. In line with most of the theoretical literature on telecommunications markets (see e.g. the references in de Bijl & Peitz, 2002; and Peitz, Valletti, & Wright, 2004) one can argue that operators offer differentiated services. For technological reasons this is clearly the case for PSTN versus VoIP. But also within the VoIP segment, providers have ample opportunity to differentiate themselves, for instance through marketing and image building.

The incumbent's profits derive from revenues in the PSTN and in the VoIP-segment. Denote the marginal cost of call termination on the PSTN by c. Since a share λ_0 of calls terminates on the PSTN-segment the associated costs are $\lambda_0 c$ (this is independent of the segment and operator a consumer belongs to). Hence the profit margin per PSTN consumer is $p_0 - \lambda_0 c$. Similarly the profit margin per VoIP consumer subscribing to the incumbent is $p_1 - \lambda_0 c$. All remaining VoIP consumers contribute $\lambda_0 (a - c)$ to the incumbent's (wholesale) profits. Hence, the incumbent's profit can be expressed as:

$$\pi_1(p_0, p_1, p_2) = \lambda_0 (p_0 - \lambda_0 c) + \lambda [s_1(p_1, p_2)(p_1 - \lambda_0 c) + s_2(p_1, p_2)\lambda_0 (a - c)], \quad (1)$$

and rewritten as:

$$\pi_1(p_0, p_1, p_2) = [\lambda_0(p_0 - \lambda_0 c)] + [\lambda s_1(p_1, p_2)(p_1 - \lambda_0 a)] + [\lambda\lambda_0(a - c)] \quad . \tag{2}$$

This can be understood as follows: the VoIP part pays an internal transfer price for access to the PSTN part of the incumbent. However, since the incumbent operates as an integrated firm, strategic incentives are not affected by the level of the transfer price.

It is now straighforward that the entrant's profits take the form

$$\pi_2(p_0, p_1, p_2) = \lambda s_2(p_1, p_2)(p_2 - \lambda_0 a). \tag{3}$$

Before going deeper, consider the benchmark case in which λ and λ_0 are assumed to be fixed (not affected by pricing decisions). Note that a change of the access price has two effects for the incumbent: it affects retail revenues in the VoIP segment, which is the expression in the second square bracket in equation (2), and it affects wholesale or access revenues, which is the expression in the third square bracket. An increase of the access price unambiguously increases wholesale revenues. In addition, the level of these revenues is independent of the retail prices which are eventually chosen. Thus, the effect of the access price on wholesale revenues is neutral on incentives in the retail market. Hence, what drives the incumbent's price setting in the VoIP market is the second term in square brackets in equation (2). In a symmetric setting, the access price therefore affects both firms symmetrically. The increase of the access price, weighted by the market share of the PSTN segment reflects perceived marginal costs. In an equilibrium, higher access prices feed one-to-one into higher retail prices. Consequently, since the entrant only makes retail profits in the VoIP segment, its profits are not affected. Thus, when the migration decision is determined in the first place by beliefs about VoIP prices (and not *directly* by observed price levels), then as long as PSTN and VoIP segment are separated, access price regulation does not affect the entrant's profits, nor its entry and investment decisions (for a formal analysis see De Bijl & Peitz, 2009). Clearly, the incumbent benefits from the higher access price due to its larger wholesale revenues, whereas

consumers in the VoIP-segment suffer from higher prices (as the higher access price translates into higher retail prices).

4. PSTN Access Regulation and VoIP Competition

4.1 The PSTN terminating access price

This section analyzes the effects of access regulation on market outcomes, taking investment decisions as given.[19] Throughout the migration decision of customers are explicitly taken into account. The focus is first on the effect of the access price. Next, possible additional interventions in the PSTN retail segment are discussed. An elaboration of the possibility that VoIP-operators charge for terminating access if the call originates from a PSTN-customer, concludes.

Result 1a: *A higher access charge for terminating calls on the PSTN-segment, a, leads to less intense competition in the VoIP retail segment. Effectively,* p_1 *and* p_2 *increase and they do so at an increasing rate.*

It is interesting to go through the mechanism. Firstly, a higher *a* inflates the entrant's (perceived) marginal cost. Since a higher access price increases access revenues, the incumbent's opportunity cost of losing customers to the VoIP segment decreases as well. Together with the property of "strategic complementarity" this implies that both operators will increase VoIP retail prices. Secondly, since consumers anticipate higher VoIP prices, more consumers stay with PSTN. As the entrant's customers will effectively make more off-net calls (because of balanced calling patterns), this feeds back into higher expected access costs for operator 2 and marks a new "round" in which firms increase their prices. Hence, in equilibrium, prices increase and the market penetration of VoIP, λ, decreases. The latter is formulated in the following result.

[19] This Subsection largely summarizes and comments on the results derived in the formal analysis of De Bijl and Peitz (2009).

Result 1b: *A higher access charge for terminating calls on the PSTN-segment, a, leads to less migration to VoIP, that is, a smaller λ.*

Furthermore, it can be shown that the entrant's profits are reduced when *a* increases. This is an intuitive result. Less intuitive is the result that the incumbent's profits may be first increasing and then decreasing in *a*, depending on the level of the access price. For small values of *a*, a PSTN consumer is in expectations more valuable for firm 1 than a VoIP consumer. Thus, an increase in *a* which shifts consumers to the PSTN segment increases profits. However, for larger values of *a*, competition in the VoIP segment becomes more relaxed so that, for retail prices in the VoIP segment above a certain level, a VoIP customer is in expectations more valuable than a PSTN customer. A lower access price may therefore imply higher profits for firm 1, due to the increase in size of the VoIP segment.

Result 1c: *A higher access charge for terminating calls on the PSTN-segment, a, reduces profits of the entrant in the VoIP segment, whereas the integrated incumbent typically benefits. (The former holds always, the latter is necessarily true when the firm is not restricted in market power in the PSTN segment.)*

Total welfare (the sum of producer and consumer surplus) is decreasing in access price *a*. Hence, from a welfare viewpoint, regulating the PSTN access price as low as feasible is desirable. Note that it was assumed that the demand for calls is perfectly inelastic. This implies that the levels of retail prices do not affect whether consumers purchase a subscription or not. Therefore, the welfare level is determined by the division of the market among PSTN and VoIP, and within the VoIP segment, by the division between the two operators.

4.2 Terminating access to VoIP customers

So far, it was assumed that VoIP telephone operates under a bill-and-keep environment and that terminating call to VoIP customers is free for calls coming from the PSTN. However, some VoIP operators charge for terminating access and this forms an important source of revenues for them. Consider therefore an access price *b*, the access price for calls originating from the PSTN-segment and terminating in the VoIP-segment. Note that all the comparative statics result with respect to *a*, derived in the previous subsection, still hold when keeping *b* constant.

Suppose that *a* constant. A VoIP provider's profits are increasing in *b*, since a higher *b* leads to higher profit margins on terminating access.[20] If the PSTN retail price is flexible, the PSTN operator can adjust its retail price in response to a different level of *b*. Here, if *b* increases, the PSTN operator, at least partially, passes the higher access price on to customers through a higher retail price p_0. This results in a larger VoIP segment.

In this argument the possibility was ignored that the terminating access price not only applies to calls originating from PSTN but to all off-net calls terminating on VoIP. If one assumes that access is charged between the VoIP networks, then the additional revenues for VoIP operator *i* are equal to the access price times the number of VoIP users subscribed to the competing network times the share of calls terminating on operator *i*'s VoIP network, or $b\lambda s_j(p_1,p_2)\lambda s_i(p_1,p_2)=\lambda^2 s_i(p_1,p_2)s_j(p_1,p_2)b$. In addition, operator *i* also has to make payments to the other VoIP provider, equal to *b* times the number of its own VoIP customers times the share of calls terminating on the competing operator's VoIP network, or $b\lambda s_i(p_1,p_2)\lambda s_j(p_1,p_2)=\lambda^2 s_i(p_1,p_2)s_j(p_1,p_2)b$. Two terms are the same and thus cancel out. Therefore, the conclusions about the incentive to increase *b* are unaffected by the level of the (reciprocal) terminating access price between the two VoIP providers.

[20] However, if the incumbent can charge its PSTN-customers for terminating off-net there is an upper limit of b above which profits from terminating access decline because the reduction of the number of calls overcompensates the price effect.

4.3 The PSTN retail price

Consider the level of the PSTN retail price p_0, which is mostly considered to be exogenous in this paper.[21] Although it may no longer be fully regulated, various forms of wholesale regulation still affect retail prices in the PSTN segment (e.g. resale competition limiting the incumbent's market power in the retail market). Thus a fixed price for PSTN can be seen as a simplification of situations in which the PSTN price is less flexible than VoIP prices, for instance due to regulatory measures that stimulate unbundling and resale-based competition in the PSTN segment. Alternatively, universal service obligations in the PSTN segment may involve a (binding) price cap.

The results that are obtained more or less mirror the results with regard to access price a, but the underlying mechanism is different, as will be seen. Basically, an increase in p_0 has the same effect on prices in the VoIP segment as an increase in the fixed utility of PSTN telephony: it increases the customer base for PSTN services, and hence inflates the entrant's perceived marginal cost.

Result 2: *Provided that the PSTN access price a is positive, a higher PSTN retail price p_0 leads to more intense competition in the VoIP retail segment. (This effect does not occur if a is zero.). Further, a higher price for PSTN telephony p_0 leads to more migration to VoIP (a larger λ) and increases profits of the entrant in the VoIP segment.*

The mechanism is as follows. As long as the PSTN price p_0 is sufficiently small, the incumbent's profits are increasing, since this retail price directly feeds into profits. A possibly countervailing effect is the loss of market share in the retail market. However, as long as a VoIP customer is in expectations more valuable than a PSTN subscriber, migration to VoIP is good news. This effect is reversed for larger values of the PSTN price, so that for a given access price a, there is a finite value of p_0 that maximizes profits. Accordingly, although firm 1 wants to milk its PSTN customer base, if it sets its

[21] De Bijl and Peitz (2009) analyze two cases in which it is endogenously determined. The results that are obtained in those cases are in line with the results discussed here.

price too high it will lose consumers to VoIP. This result lays bare an interesting link between the market segments, and illustrates that competition within the VoIP segment disciplines the incumbent in the PSTN segment. Note that these results and the underlying mechanisms describe the "dilemma" that former PSTN incumbents encountered when IP-based telephony came knocking on their doors.

4.4 Competition in the PSTN-segment

So far, it was assumed that there is a monopoly in the PSTN segment. However, one often observes intense price competition made possible by mandated access of call origination at the incumbent's local access network, at a regulated originating access price a_o ("Carrier Select"-based entry). Calls generated by a competitive fringe of PSTN entrants without local networks, terminate either on the incumbent's PSTN network, or on one of the VoIP networks. Accordingly, Carrier Select-based entrants face a perceived marginal cost composed of the originating acces price plus the terminating access price discounted by the relative size of the PSTN segment, or $a_o + \lambda_0 a$.

If there is perfect competition in the PSTN retail segment, and if the incumbent is free to set PSTN price p_0, then this price is driven down to the level of entrants' perceived marginal cost $a_o + \lambda_0 a$. Note that now, access price a does not affect the size of the VoIP segment λ, nor does it affect market shares within that segment. An increase in a does increase p_0, and also the perceived marginal cost of the entrant. Therefore, a higher level of a increases retail prices in both segments. In terms of profits, though, only the incumbent benefits from a higher access price, as the entrant is just passing on its marginal cost increase to VoIP customers. Finally, note that consumers surplus in both segments is reduced.

5. Investment Incentives

This section focuses on entry incentives and (marginal) investment incentives of both firms in the VoIP segment under different levels of PSTN access price a. By doing so one is able to discuss the effects of access regulation on entry and investments. First consider entry. As was observed in the previous section, an operator active onloy in the VoIP segment finds it more difficult to operate under a regulatory regime that involves a high PSTN access charge. Therefore, a higher access price reduces the incentive to become active in the market, and hence makes entry in the VoIP-segment less likely.

From an ex ante point of view, this can be formalized as follows. Suppose that the cost that is required to enter is unknown to the regulator. Suppose that this entry cost K is distributed according to some distribution function F. Depending on the access price a, denote the critical entry cost such that the entrant breaks even by $K^*(a)$. If the access price a is under the control of the regulator, by setting a the regulator implicitly chooses the probability of entry $F(K^*(a))$. Since K^* is decreasing in a, a higher access charge makes entry less likely.

Result 3a: *A higher access charge for terminating calls on the PSTN-segment, a, makes entry into the VoIP segment less likely.*

Less obvious is the effect of access regulation on marginal incentives which determine the investment level for a given entry decision. Suppose that a higher investment level results (at least in expected terms) in a more attractive (or higher quality) service being offered. Such an investment may occur at the network level (and focus on bandwidth) or at the service/product level (and then contains investments in software and bundled services such as hotlines). To focus the discussion, suppose that firms 1 and 2 in the VoIP segment choose investment levels I_1 and I_2, which are incurred after the regulatory policy is known but before firms compete in the retail market. Note that in reality, investment decisions are often made under a high degree of uncertainty. Nevertheless,

also with respect to the regulatory policy that will apply, it is useful to assume that regulatory policy is consistent over time, and thus can be communicated to firms before they take the relevant investment decisions.[22]

Using the setting presented in Section 3, each firm's profits depend on investment levels. Suppose that the higher I_1 for given I_2, the larger firm 1's market share in the VoIP segment. Correspondingly, the larger I_2 for given I_1, the larger firm 2's market share in the VoIP segment. The firm that has invested more can set a higher price and will gain a larger market share. Also, insufficient investments may even drive an operator out of the market. For instance, if both firm invest too little, then consumers may not be interested in switching to VoIP at all. Thus the higher are investment levels, the larger is the penetration rate of VoIP, λ.

Since the focus has been on a symmetric environment of VoIP on the demand and the supply side (apart from the fact that firm 1 is vertically integrated whereas firm 2 is not), one may wonder whether investment incentives are symmetric in the sense that both firms choose the same investment levels in equilibrium. As will be seen, for an access price different from the underlying marginal cost of access, investment incentives are typically not symmetric, so that firms will choose different investment levels.

Reconsider the profit functions of firms 1 and 2, as reported in section 4: $\pi_1(p_0,p_1,p_2)=[\lambda_0(p_0-\lambda_0 c)]+[\lambda s_1(p_1,p_2)(p_1-\lambda_0 a)]+[\lambda\lambda_0(a-c)]$ for the incumbent, and $\pi_2(p_0,p_1,p_2)=\lambda s_2(p_1,p_2)(p_2-\lambda_0 a)$ for the entrant. One can show by contradiction that investment incentives for firms 1 and 2 are not the same. Note that the second term in square brackets for firm 1 is symmetric and hence has the same structure as the profit function of firm 2. Thus, if a change in investment levels leaves the sum of the first and the third term unchanged, both firms would choose identical investment levels in a strategically stable situation. Observe that typically consumers benefit from higher

[22] The regulator's commitment problem and the effects on investments, a topic that merits a whole research avenue, are outside the scope of this paper. As has been established in the microeconomics literature, if the regulator is a long-run player he may gain commitment because of reputation concerns: deviating from announced policies endangers the credibility of future policy announcements.

investments by one firm, if one takes the other firm's investment level as given. Therefore, as firm 1 increases its investment level for VoIP, customers consider the VoIP-option as more attractive and more of them will migrate. This means that λ_0 decreases and retail profits in the PSTN segment suffer from higher investment in the VoIP segment. Hence, there is an unambiguously negative effect of investment in the VoIP segment for the incumbent that does not apply to the entrant, since the latter has nothing to lose in other market segments. For the incumbent this constitutes a *cannibalization effect*: Since higher VoIP investment levels make more customers substitute VoIP for PSTN, PSTN retail profits are cannibalized.

There is, however, a second effect which has to be taken into account. Investment levels also affect the flow of calls between segments and thus firm 1's profits from granting access. Given that calling patterns are balanced, the largest number of calls crossing from VoIP to PSTN occurs when both segments are of equal size. The number of calls between firm 2 and the PSTN-segment of firm 1 is maximal if the share of the PSTN segment is 1/3 in the special case that firm 1 and firm 2 share the VoIP-segment equally. Investment levels determine the size of the two segments. Surprisingly, firm 1 may actually have stronger incentives to invest than firm 2 if it can increase the volume of calls terminating on the PSTN-segment because this will increase profits at the wholesale level (i.e., profits from granting access). This effect can be called *access revenue effect*. It is of ambiguous sign because a change in *a* may increase or decrease access revenues. Hence, it depends on specific market conditions whether this effect is positive or negative. If the access revenue effect is negative, both effects go in the same direction. If it is positive but not too large, the cannibalization effect will dominate. In both instances the finding then is that firm 2 invests more than firm 1 in an equilibrium. Summarizing:

Result 3b: *If the cannibalization effect is strong, the integrated firm (firm 1) tends to invest less in its VoIP-infrastructure and services than the VoIP-provider (firm 2).*

Accordingly, it may happen that the incumbent strategically underinvests in VoIP. The rationale is as follows. Consumers observe the relatively lower quality of the incumbent's

VoIP-service. They thus anticipate weakened competition in the VoIP-segment, which makes migration to VoIP less attractive, because of high expected, quality-adjusted prices.

If the cannibalization effect is strong, there may be a concern of entry deterrence through underinvestment. To see this, suppose that the incumbent underinvests. A potential entrant will anticipate this, and hence knows that the incumbent firm will be a "weakened" competitor. At the same time, the entrant has no possibilities (and hence cannot commit) to offer a low-price alternative to the incumbent's PSTN-services. The reason is that since the retail price can be easily changed in the short term, the entrant cannot commit to a certain price. Thus, the entrant rationally expects that few consumers will migrate to VoIP. This makes entry less attractive, since there are less profits to be made to recover investment consts.. In the extreme, the refusal of the incumbent to offer VoIP services may deter entry from other VoIP providers. The incumbent's unwillingness to offer VoIP services leads to monopoly pricing in the VoIP segment. Consumers foresee this and, therefore, the new technology will be embraced by only few of them. While the entrant's profit margin per consumer goes up, the entrant will be unable to attract many consumers. It may therefore be unable to recover its entry costs. Thus, the entrant anticipates that it is not profitable to enter.

Result 3c: *The vertically integrated firm may want to strategically underinvest in VoIP in order to deter entry.*

In other words, the underinvestment by the incumbent leads to more rent extraction by the entrant. This discourages consumers from adopting the new technology and, thus, makes entry unprofitable.

It is interesting to take a closer look at the role of the access price in this context. Note that due to consumers' lumpy migration decision, the incumbent's and the entrant's investments are complementary, in the sense that the profitability of entrant's investment relies on the incumbent investing and vice versa, given entry. However, in the a dynamic

setting with entry, the incumbent can strategically exploit the entrant's reliance on the incumbent's investment. A higher access price in an environment in which only firm 2 offers VoIP will reduce the entrant's profits. Thus, it becomes more likely that strategic underinvestment by the incumbent in the VoIP segment makes this segment sufficiently unattractive to consumers and, therefore, to the entrant. Possibly, the latter cannot recover its fixed cost. This implies that a higher access price increases the risk of strategic underinvestment by the incumbent. In the extreme, a high PSTN access price may lead to the VoIP sector not taking off at all.

To summarize the argument, note that entry deterrence by underinvestment in VoIP may occur in a market in which the incumbent would develop the VoIP sector on its own if the entry decision was exogenous. Given the incumbent's investment, the entrant would also invest. However, for strategic reasons the incumbent may refrain from investing in VoIP. The welfare implication is that society could be better off under a protected monopoly for the incumbent in the VoIP-segment than under competition. This of course a rather stylized result, and should be explored in more detail in case studies and richer models. While strategic underinvestment may be impossible to sustain over a prolonged period, the risk of delayed investment is a real possibility. Indeed, this argument provides an alternative light to the example of the Netherlands given in the Introduction. Instead of having hastened to introduce VoIP, and being unprepared for the large initial uptake, it may have been the case that incumbent KPN has underinvested with the aim of putting a brake on the growth of the VoIP segment. Indeed, the resulting negative press may easily have made consumers more skeptical about VoIP in general, and wary to switch to any VoIP provider. In the terms of the analysis here, this corresponds to the effect that less consumers migrate to VoIP, making entry into the VoIP segment less attractive.

To make entry deterrence happen, though, some assumption is necessary along the line that the entrant cannot commit itselves to make the VoIP market attractive on its own. Furthermore, the entry deterrence argument critically hinges on the fact that there are limited alternatives to the incumbent's offers. Such a situation is a good description for markets in which cable provides the only feasible alternative infrastructure to the

incumbent's upgraded (IP-enabled) network. If however more than one entrant becomes active, there is likely to be competition among entrants which consumers rationally foresee. Thus, even if the incumbent did not enter the new segment, consumers may expect low prices in the VoIP segment which makes switching attractive. Put differently, the strategic role of the incumbent's investment decision is less pronounced if there is more than one potential entrant. Entry by multiple firms will lead to intense competition even in the absence of the incumbent firm, making the VoIP segment more attractive.

One possibility is that operators without a physical network can also offer VoIP-services. Also in this case the effect of the incumbent's actions on the intensity of competition in the VoIP-segment is less pronounced and the possibility of entry deterrence is of less concern. Note the implied rationale for mandating access to the incumbent's network, which is different from the motivations that were put forward after liberalization of the telecoms market (e.g. facilitating entry, stimulating entrants to advance on the "ladder of investment"). Here, if underinvestment is an effective mechanism to slow down the development of the VoIP segment, mandating access to the incumbent's VoIP network may prevent the "abuse" of this mechanism as a means of entry deterrence.

While the entry deterrence result suggests underinvestment by the incumbent, under alternative conditions the incumbent's investment incentives may be rather strong. To see this, expand a bit more on the earlier result 3a. Suppose that the cannibalization effect is relatively weak, that is, customers in the PSTN-segment contribute little to retail revenues. The PSTN terminating access price is above the marginal cost of call termination. Furthermore, suppose that only a small fraction of consumers migrates to the VoIP segment. Then, because of the access revenue effect, the incumbent actually has *stronger* investment incentives than the entrant to invest. Note that an increase in the access price increases the asymmetry in the investment decision of firms 1 and 2. In other words, a higher access price makes the access revenue effect more pronounced. Thus the following result is obtained:

Result 3d: *If the cannibalization effect is relatively small, the vertically integrated firm may invest more in its VoIP-infrastructure and services than the entrant.*

6. Conclusion

The emergence of VoIP, which is, in turn, driven by broadband, creates various challenges for policy makers and regulators. Of course, NRAs have to address how they should regulate VoIP (see De Bijl & Peitz, 2005, 2006a). Various countries, including Austria, Belgium, Czech Republic, France, Germany, Hungary, Ireland, Italy, Slovak Republic, Turkey, and the US, have, at least initially, imposed minimum or no regulations specific to VoIP services. Other countries, including Australia, Canada, Denmark, Finland, Greece, Iceland, Japan, Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Spain, Sweden, Switzerland, and the UK, view VoIP services offered to the public as a telecommunications service, which is then subject to regulations as those for PSTN services.

A central point in this paper has been that, in addition to the issue of regulation of VoIP, NRAs have to be aware of negative side-effects that may be caused by PSTN regulation on the emergence of VoIP. For instance, higher prices for terminating access to the PSTN network slow down the adoption of VoIP and reduce the profits of entrants that exclusively offer VoIP telephony. Of particular interest have been possible implications for the incentives to invest in VoIP. Among others, the link between access regulation in PSTN and distortions of VoIP investment decisions has been pointed out. Thus policy makers and regulators have to think beyond the framework of "traditionally" defined markets, and take interactions between (converging) markets into account, in order to avoid well-intended but socially costly interventions. This paper points out the relevance and importance of this problem. A more detailed and specific analysis is left to future research. For instance, for practical cases, a regulator may want to expand the model in

De Bijl and Peitz (2009) by introducing additional market features and run numerical simulations.[23]

As also discussed in De Bijl and Peitz (2009), the results seem to be quite robust as long as one makes adaptations that do not stray too far from the structure of the model. However, a change that certainly goes beyond the model is the incorporation of internet-based (unmanaged) VoIP providers like Skype, who play according to different rules, based on different business models. Such an entrant can bypass the PSTN altogether as various peer-to-peer VoIP services have demonstrated. This type of bypass reduces the incumbent's incentive to set high terminating access charges. Moreover, for this type of entrant, building a customer base—making maximum use of network effects—is the first step. At a later stage, complementary functionality, for instance through integration with an e-market environment, may be added, while revenues are generated through advertising. To analyze the disruptive effects of such business models on more traditional telecoms operators, other types of models are needed. This is left to future work.

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[23] See De Bijl and Peitz (2002) for a similar approach in other regulatory settings.

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