Two-way access charges and on-net/off-net differentials[1]

WHAT ARE THE INCENTIVES ON OPERATORS AND CAN LARGE MNOs USE HIGH ACCESS CHARGES TO FORECLOSE THE MARKET?

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This paper presents a discussion of two-way access charging in the context of mobile phone networks. I examine the determinants of access charges and price differentials between on-net and off-net tariffs. I consider the welfare implications of above-cost access charges and on-net/off-net differentials and the potential for larger networks to use high access charges as a means of foreclosing their markets. For the first time, I compare the relative magnitude of the different effects identified in the literature so as to identify which effects are most important in driving MNOs behaviour. To do so I use a simulation model, which I also use to extend the results so far presented in the literature to more complex combinations of factors, including on-net/off-net differentials in the presence of a variable consumer participation rate.

In many, but not all countries, M2M access charges are set at a level in excess of cost[2] and mobile phone customers have to pay higher charges to call subscribers of different mobile networks ("off-net" calls) than to call other subscribers on their own network ("on-net" calls). Such behaviour raises questions regarding the incentives on mobile networks to set efficient M2M access charges and the impact that on-net off-net price differentials have on consumer welfare.

There is a considerable and growing academic literature on the issue of pricing between competing mobile networks. The earliest work in this area was by Armstrong (1998)[3] and Laffont, Rey & Tirole (LRT, 1998)[4]. Both papers show that networks can use their reciprocal access charge as an instrument of collusion: by raising each other's costs they can dampen the effects of competition between them and thus raise their profits. In addition to this basic result, LRT relax some of the initial assumptions, and in doing so call the collusion result into question. Under more realistic assumptions it appears that networks do not have incentives to drive up reciprocal access charges. LRT and other papers published to date typically indicate that mobile operators would prefer to set reciprocal M2M access charges (and thereby off-net retail charges) at

1 I would like to offer my thanks to Patrick Rey, Tomasso Valletti, Richard Feasey and George Houpis for invaluable comments on an earlier draft of this paper.

2 Usually measured as LRIC.

3 Armstrong, M. (1998), "Network Interconnection In Telecommunications", *Economic Journal*, 108 (May), pp. 545-564.

4 Laffont J.J., Rey P. and J Tirole (1998), "Network Competition I: Overview and Nondiscriminatory Pricing", *RAND Journal of Economics 29 (1-37*)

cost[5]. LRT show that Armstrong's result is special to the case where networks are not able to charge any form of fixed rental charge (which would include periodic handset charges for pre-pay customers). Further work (Gans & King (2000)[6]), actually suggests that it may be profit maximising to set call termination charges and retail off-net charges *below* cost when operators can discriminate between the retail price of on-net and off-net calls, while Carter and Wright (2003)[7] suggests that when networks are of unequal size it is the larger network that has the stronger incentive to set termination (and off-net retail charges) at cost.

However, despite the developments in the academic literature, a relatively recent phenomenon in discussions between national telecoms regulators is that it seems to be becoming accepted both that mobile networks have an incentive, if left unregulated, to set high reciprocal M2M access charges and furthermore that differential on-net and off-net pricing can be used as a foreclosure mechanism by large operators against smaller competitors.

The fear of foreclosure is often expressed in one of two ways. The first is summarised by the European Regulators Group of National Regulatory Authorities (the ERG) in its consultation on appropriate remedies under the new EU framework[8]. The ERG puts the case that low on-net and high off-net charges generate "tariff mediated network externalities" for the customers of the larger network and thus put small networks with few participants "at a disadvantage"[9].

The second way the problem is expressed concern is summed up by the Irish regulator, Comreg, in its notification to the EC on call termination[10]. This document suggests that M2M access charges could be raised to "directly influence the retail tariffs of competitors in the mobile market and could cause potential margin squeeze issues"[11].

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5 If charges were set reciprocally and without the risk of arbitrage with F2M call termination charges.

6 Gans, J.S & King, S.P. (2000), "Using 'Bill and Keep' Interconnection Arrangements to Soften Network Competition".

7 Carter M. and W. Wright (2003), "Asymmetric Network Interconnection, *Review of Industrial Organisation 22 (27-46).*

8 "Consultation Document on a Draft joint ERG/EC approach on appropriate remedies in the new regulatory framework", 21st November 2003.

9 A "network externality" occurs when the value that each subscriber to a network gets from being a subscriber increases as the total number of subscribers increases. Assuming equal pricing for all calls, interconnection between two competing networks, allowing subscribers to call other subscribers on *either* network, also creates a network externality effect by increasing the number of people with whom each subscriber can communicate. If the price of on-net and off-net calls differ then "tariff-mediated network externalities" are created, because subscribers care about which network the people they want to call are on.

10 "Response to Consultation and Notification to the European Commission – Wholesale voice call termination on individual networks", Comreg Doc. No. 04/62a, 8th June 2004.

11 See para. 4.35.

The argument runs as follows: setting the M2M access charge above cost means that off-net calls are more expensive than on-net calls. Comparing a large network with a smaller competitor it is to be expected that the customers of the large network will make proportionately more on-net calls than the customers of the smaller network. Hence subscribers to the smaller network experience a higher average call charge. This is the "disadvantage" to which the ERG refers.

The margin squeeze argument is essentially the same: a new subscriber wishes to call existing subscribers on the larger network. If call termination charges are set above cost then the large network will charge the new subscriber less to call their existing subscribers than it would cost the smaller network to connect a call to that customer. Hence the idea of margin squeeze.

I will address both these points specifically later. However, I need first to address the fact that these statements are based on a partial analysis of the determinants of access charges between competing networks, their impact on retail charges and their impact on the intensity of competition between the networks. The fact that the results of more detailed models seem not to have made an impact on the policy debate results, to some extent, from the fact that the theoretical literature in this area is complex, highly mathematical and difficult for a non-technical audience to follow.

To understand fully the relationship between two-way access charges and on-net/off-net differentials it is necessary to think rigorously about the interaction between these factors. In this note I summarise the key findings from the literature on "two-way" access charges so as to build up an overall picture of the determinants of access charges and on-net/off-net price differentials. This summary shows that there are many effects on access charges and that these may drive access charges in different directions.

Drawing practical inferences for access charges requires us to understand the relative magnitude of the different effects and how they combine. Therefore Frontier has designed a flexible simulation model that I use to compare the relative magnitude of the different effects identified in the literature so as to identify which effects are most important in driving MNOs behaviour. In addition I use the model to extend the results so far presented in the literature to more complex combinations of factors, including on-net/off-net differentials in the presence of a variable consumer participation rate.

SUMMARY OF CONCLUSIONS

I show that there are many influences on both the profit maximising and welfare maximising[12] level of access charge. It cannot be relied upon that the profit maximising and welfare maximising levels of access charge will coincide or that cost-based access charges will maximise consumer welfare.

The result showing a collusive outcome for two-way access under linear retail tariffs appears to have dominated the policy debate about two-way interconnection, in spite of (perhaps because of) the fact that this model is very simple and in spite of the fact that subsequent work in the area has shows that this conclusion appears to be special to the very restricted assumptions on which it is based. More realistic models do not produce this collusive result.

The review I present below shows that:

- If networks compete using rentals *and* call charges then the joint interest in driving up reciprocal access charges evaporates.
- While LRT derived the profit neutrality result, it seems that this too is quite a special case. Allowing for either an endogenous market size or asymmetry in the sizes of networks creates an incentive for the networks to set a cost-based reciprocal access charge to maximise profits. However, modelling indicates that this incentive may not, in practice, be very strong.
- By contrast, it seems that differential on-net and off-net tariffs have a dramatic impact on the dynamics of the market. Tariff mediated network externalities (TMNEs) have a dynamic impact, intensifying competition, reducing profits and increasing consumer surplus. Given the chance, therefore, even larger networks would choose low reciprocal access charges, possibly even "bill and keep" to reduce the intensity of competition for these subscribers.
- The dynamic effect of TMNEs on the intensity of competition reveals that the idea of that the "waterbed" effect between access charges and profits is overly simplistic. The key factor for the waterbed effect is not the intensity of retail competition but rather how much that intensity is affected by the access charge. The example of M2M access reveals that the waterbed can be more than 100% effective, even if the retail market is imperfectly competitive.
- Forcing up reciprocal access charges is an expensive way for a large operator to attempt to gain market share. Unless it can completely exclude the competitor from the market the large network will simply doom itself to perpetual and significant damage to its profits in doing so. Moreover, in

12 It is also possible to consider different interpretations of welfare maximisation. Given that we are dealing with models of imperfect competition, the same solution may not maximise profits, consumer surplus and total welfare. From the policy perspective it is a matter of debate whether the appropriate welfare benchmark should be total welfare, or consumer surplus. I try and draw a clear distinction in the discussion that follows.

most circumstances it can be shown that simply cutting retail prices would be a much more "cost effective" predatory strategy.

- In the presence of externalities it does not follow that cost-based access charges are appropriate for maximising total welfare. Furthermore, in many circumstances above-cost access charges have the effect of increasing the welfare of consumers, albeit at the expense of the networks, by intensifying inter-network competition.
- Allowing the participation rate to vary strengthens the effect on competition of above-cost access charges (and hence increases further the consumer benefit they create) but mitigates to some extent the desire for MNOs to reduce access charges to zero.

My conclusion is therefore that, on the basis of the types of models considered here, there is no clear incentive for mobile networks to set high *reciprocal* access charges. Furthermore, it does not appear that larger networks gain any particular advantage as a foreclosure strategy from attempting to force up reciprocal access charges.

By contrast, mobile networks in most circumstances have an incentive to set access charges at or below cost while welfare maximising levels can be expected to be *above* marginal cost either to allow the exploitation of network externalities (in whose presence total welfare may be enhanced by above-cost access charges) or to accentuate competition between networks (in which case total welfare may not be increased, but consumer surplus certainly is).

The policy implications that arise from these results would appear to be as follows. First, before any other measures for regulating M2M access charges are considered, a requirement of reciprocity should be placed on *all* operators.

Secondly, neither prohibiting on-net/off-net differentials (to the extent that these reflect underlying access charges) nor mandating cost-based access charges is necessarily in the interests of consumers. If access charges are currently above cost then prohibiting on-net/off-net differentials has the effect of softening competition, increasing profits and reducing consumer surplus. This follows because prohibiting on-net/off-net differentials saves the networks from the intense competition to which they are subjected by network price differentials.

Conversely, setting access charges above cost (combined with on-net/off-net differentials) actually increases consumer surplus even in the absence of network externalities, because of the impact that higher access charges have on the intensity of competition.

WHAT DETERMINES M2M ACCESS CHARGES?

There are a number of articles investigating the two-way access problem. These have generally been written to examine the impact of particular factors on the profit or welfare maximising access charge and therefore do not attempt to model the "real" situation in mobile markets. In the following discussion I review the results of the major articles in the literature. However, in most cases these articles present purely algebraic analysis, which identifies equilibrium conditions but gives little or no insight into the relative magnitude of the effects identified or how they might combine in a more comprehensive model. To address this, Frontier has designed a flexible simulation model that can be used to quantify the effects identified in a framework that applies common empirical values. By using this model I am able both to appraise the relative magnitude of different effects but also to extend the academic analysis by modelling more complex combinations of factors than can be feasibly handled algebraically.

Competition through linear tariffs

The earliest and in many ways best known contribution to this literature came from Armstrong (1998). This paper sets the standard framework for modelling imperfectly competition between networks. In this paper consumers are assumed to choose between two mobile networks within a "Hotelling" framework[13]. The networks compete to provide the highest possible level of consumer surplus.

Armstrong assumes that the networks can only charge a uniform linear call price for all calls, regardless of whether they are on-net or off-net calls. Importantly, Armstrong assumes that the networks cannot charge subscribers a fixed rental; hence all competition takes place through the linear call prices.

Under these circumstances, Armstrong finds that the networks can increase their equilibrium profits by agreeing a reciprocal access charge in excess of cost. This is Armstrong's key result, that *networks can use their reciprocal access charge as an instrument of collusion: by raising each other's costs they can dampen the effects of competition between them and thus raise their profits*.[14]

This result is illustrated in Figure 1 from my model, which graphs total profits as a function of the access charge under Armstrong's assumptions.

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13 Consumers are assumed to be located along a line. Two competing firms locate one at each end of the line. Consumers are assumed to choose one of the firms based on a trade off between the utility they would get from each firm and the "cost" of buying from each firm. The utility they get depends on the prices each firm offers. The cost of buying from a firm is assumed to be a linear function of the distance from the consumer to each firm. The lower is this cost the more competitive will be the market.

14 The proof of this and other results discussed here is presented in Annexe 1.

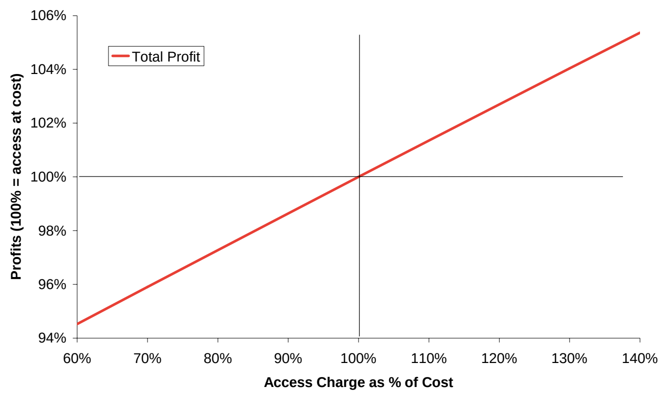

Figure 1: Collusive outcome with linear pricing

Source: Frontier model

However, before we assume that this result might have general applicability to real situations it is worth outlining the simplifying assumptions Armstrong makes:

- networks cannot charge subscribers a fixed rental charge, this would include any charge not variable with usage, neither a monthly rental charge nor a periodic charge to replace the user's handset;
- networks cannot charge subscribers a different on-net and off-net call charge;
- the networks are symmetric: in equilibrium they will be the same size, and they know this fact when they choose their tariffs;
- the level of subscription is fixed: all possible subscribers are assumed to join one of the two networks so the level of charges has no effect on market penetration;
- there are no network externalities: the level of calls made by each subscriber is independent of the total number of subscribers. If the volume of calls made by each subscriber depends on the total number of subscribers in the market then there are externalities that may affect the profit and welfare maximising outcome.
- All subscribers are the same: the marginal subscriber is the same as the average subscriber, hence there is no reason for networks to offer different packages to different customers (i.e. to engage in second degree price discrimination).

Subsequent papers have attempted to relax several of these assumptions.

Rentals

Laffont, Rey and Tirole (LRT 1998) introduce rental charges (but keep the other simplifying assumptions, including, importantly, equal on-net and off-net prices). They find two important results. *First, under these circumstances calls are priced at (perceived) marginal cost. Secondly, they find that network profits are independent of the level of the access charge.* The first result (calls priced at marginal cost) is common to virtually all models with two-part tariffs. The second result shows that the "raise each others costs" result is special to the case where rental charges are not possible. However, LRT's profit neutrality result leaves ambiguous where the networks would choose to agree a reciprocal access charge. The output of the model under LRT's assumptions is shown in Figure 2.

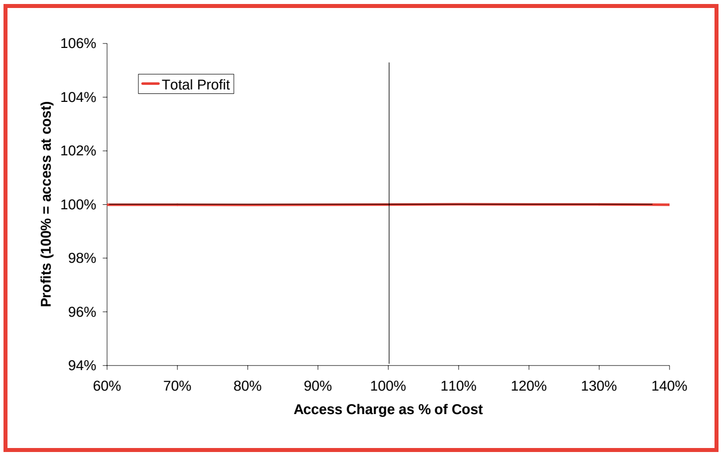

Figure 2: Profit neutrality result with two-part tariffs

Source: Frontier model

On-net/off-net differentials

LRT's model was further generalised by Gans & King (2000) by the introduction of differential on-net and off-net call charges. This paper also finds that it is profit maximising for networks to price calls at marginal cost. Hence if the access charge exceeds cost then off-net call charges will be higher than on-net charges, but if access is priced below cost then on-net charges are set *higher* than off-net charges. Gans & King find a result that at first sight seems surprising: *the level of access charge that maximises network profits unambiguously lies below cost.* Indeed Gans & King show that under almost all likely circumstances joint profits will be maximised by networks agreeing a "bill and keep" arrangement[15]. Joint profits under the Gans & King assumptions are illustrated in Figure 3.

15 Including linear demand or constant elasticity demand within normal bounds for the elasticity.

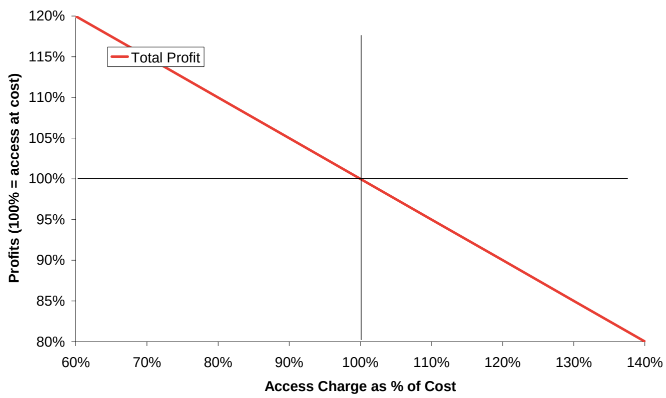

Figure 3: The effect of access charge on profits with network price discrimination

Source: Frontier model

The first thing to note is that the effect of varying the reciprocal access charge on profits is not only the reverse of that shown by Armstrong but the impact on profits is much greater.

Gans & King refer to this effect as networks using bill and keep to "soften competition". This result casts light on *several* key drivers of network competition.

- The first is the effect of tariff mediated network externalities (TMNE). The ERG paper referred to previously talks about TMNE in terms of favouring large networks over small ones. While this is true in a static sense, it ignores the *dynamic* effect of TMNE. For any *given* relative size of networks (in the Gans & King case they are assumed to be symmetric) setting access charges above cost drives up off-net call charges, which creates positive TMNE. The existence of these TMNE means that *both* networks have a strong incentive to increase their market share to benefit from these externalities. Thus setting access charges above cost results in networks competing more ferociously to gain market share. This intensifying of competition *reduces* joint profits. However the reverse also applies if access is priced below cost: in this case off-net calls are priced below on-net ones *and* the networks make a loss on every incoming off-net call, thus creating negative TMNE. In these circumstances both networks actually have an incentive to *reduce* market share in order to gain from TMNE. Thus they compete less aggressively. In conclusion, therefore, setting access charges above cost may favour larger networks to some extent, but misses the point that access charges above cost make networks compete harder with each other, while access charges below cost make them want to compete less hard. Thus, given the choice, competing networks would want to avoid high two-way access charges *regardless* of their effect on equilibrium market shares.
- The second point picks up from this conclusion: the key phrase is "given the choice". It has to be recognised that it is difficult to treat a model like Gans & King's seriously from a policy-making perspective when its conclusions

appear to differ so strikingly from what is observed in practice. Clearly it is the case that in markets pricing by CPP[16] two-way access charges are typically above cost; bill and keep is the exception, not the rule. However it is critical to understand that competition between networks can be expected to arrive at some form of "Nash Equilibrium" at which neither network can increase its profits by *independently* changing its prices. Gans & King show that if networks have no choice but to set a reciprocal access charge then they would prefer bill and keep. However, if either network is free to set its termination charge independently it is easy to show that the Nash equilibrium is for both networks to set access charges above cost, because at a low access charge either network can gain temporarily by cheating and raising their access charge to the other network.

- The final point to be highlighted by Gans & King relates to the interaction between access charges and competition in the market (in truth this is also highlighted by the original linear pricing models). In models of imperfect competition the relationship between prices and costs depends on the strength of competition between the parties. In a Cournot oligopoly model (in which competition occurs in quantities) the number of players in the market determines the strength of competition. However in models of the type being discussed here, which are forms of "differentiated Bertrand" models, competition occurs in prices and the relationship between prices and cost is a function of the degree of differentiation between the competing firms. In a simple differentiated Bertrand model differentiation is an exogenous factor in the model. However, what these models show is that when competing networks charge each other for two-way access the level of the access charge affects the terms of competition between them. Competition can be stronger or weaker depending on the level of access charges. In a "first best", perfectly competitive world consumer surplus is typically maximised when prices equal marginal cost[17]. In the case of competition between networks it is reasonable to assume some degree of imperfect competition as being necessary to recover fixed and common costs. In this case the consumer surplus generated will depend on the intensity of competition in the market: the more intense the competition the nearer the higher will be overall welfare.

  The significance of these observations for two-way access pricing is that in an imperfectly competitive market consumer surplus will depend on the strength of competition, while the strength of competition itself depends on the access charge. Hence it cannot be taken for granted that consumer surplus is maximised by setting access charges equal to marginal cost (or by having equal on-net and off-net call charges).

Gans & King conclude that regulators might be happy to allow networks to choose bill and keep, because at least it avoids the problem of high access

16 Calling Party Pays.

17 In the absence of externalities.

charges. However, they do not discuss the welfare implications of this proposal. Because of the effect of access charges on the intensity of competition, Gans & King's model predicts that consumer surplus *increases* with the access charge. The implication is therefore that setting an access charge above cost can actually benefit consumers, because the effect of more intense competition outweighs the inefficiency resulting from pricing calls above their true marginal cost[18].

The effect of the access charge on consumer surplus in the Gans & King model is illustrated in Figure 4 below. It should be noted that the impact on consumer surplus of varying the access charge is much weaker than the effect on profits.

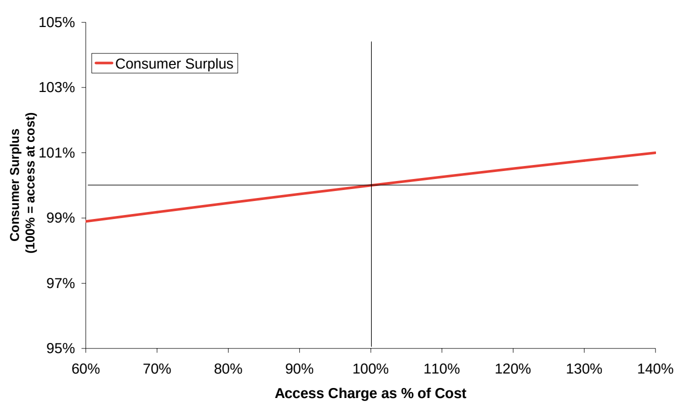

Figure 4: The effect of access charges on consumer surplus with network price discrimination

Source: Frontier model

The importance of these results cannot be under-estimated because they call into question many of the concerns that regulators have about two-way access charges being above cost.

It is also worth noting in passing that these results show that simple regulatory arguments about the "waterbed effect" have little basis in a proper theory of imperfect competition. The term was coined by the UK Competition Commission when considering how much of any movement in F2M access charges would be passed on to retail customers in the mobile market. [19] However the concept is equally applicable to the case of M2M access charges.

The Competition Commission argued that if the outbound market is imperfectly competitive then the mobile operator will retain a proportion of any increase in F2M access charges above cost, indeed an entire chapter of welfare analysis was based on this presumption. This argument is profoundly flawed. As I have shown, if the level of access charge (F2M or M2M) does not affect the intensity

18 It should be noted that while consumer surplus is maximised by raising access charges above cost, total welfare is maximised in this model by cost-based access charges. The implications of this for policy depend on the extent to which the authorities value producer surplus as opposed to consumer surplus.

19 Competition Commission (2003), *Vodafone, O2, Orange and T-Mobile*. See also Comreg Doc. No. 04/62a.

of competition then equilibrium profits will be invariant to the level of the access charge irrespective of the extent to which outbound competition is imperfect. Thus in the Competition Commission's terms the waterbed will be 100% effective. However, if the access charge does affect the intensity of competition then equilibrium profits will change. But as the intensity of competition could (in theory) increase or decrease as access charges increase it is clear that the waterbed effect is not limited by 100%. Gans & King show that with tariff differentials and Hotelling competition the waterbed effect from M2M access charges could exceed 100%. That is, an increase in access charges is more than fully passed on to subscribers because of the intensifying of competition.

Network asymmetry

The examples discussed so far all assume that the two competing networks are symmetric. Hence, in equilibrium, they will both have 50% market shares and will charge equal prices. Carter & Wright (2003) extend LRT's model into the case of asymmetric networks.

In this model it is assumed that, due to brand reputation or some other property, one of the two networks provides subscribers with an additional benefit of membership. As a consequence, if the two networks charge equal prices, the network that offers this additional benefit will have a larger market share.

This model is interesting both because it starts to examine how the interests of small and large networks may differ in setting access charges but also because it is the first model I have discussed in which it is possible for there to be an imbalance in interconnection traffic in equilibrium. Under these assumptions it is easy to show that it is still efficient to price calls at perceived marginal cost[20].

If the access charge is set above cost then both networks will charge more than cost for calls. However, the larger network charges will charge a lower average call charge because a smaller proportion of the calls its customers originate will be terminated than the other network. Because the larger network charges a lower call price, its subscribers will make more calls than the subscribers of the smaller network. As a result the larger network will also incur an interconnection deficit[21]. So setting access charges above cost appears to benefit the larger network because it can charge lower call charges than its rival, but the interconnection deficit this creates works *against* larger networks wanting above cost access charges as they create an interconnection deficit, because it loses money on this deficit. The equilibrium outcome will be the trade off these two effects.

Carter & Wright find that *in these circumstances the profit neutrality result of LRT breaks down and the larger network will always strictly prefer to set a reciprocal access charge at*

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20 In the absence of on-net/off-net differentials marginal cost perceived marginal cost will be the average marginal cost of on-net and off-net calls, taking into account the access charge on off-net calls.

21 The large network's subscribers will make more calls to the small network than will be made from the small to the large network.

marginal cost. By contrast setting access at cost minimises the smaller network's profits provided the asymmetry is not too great. For more extreme asymmetry between the two networks, the smaller network also maximises profits with a reciprocal access charge at cost. Consumer (and total) surplus is maximised by cost-based access charges. In this model, if access is priced above cost, the larger firm experiences a traffic deficit, which gives it an incentive to reduce access charges, whereas if access is priced below cost it experiences a surplus on which it loses money, so it has an incentive to raise access charges. The converse is true for the smaller firm. If access is priced above cost it experiences a profitable surplus. However, as access charges rise it loses market share. Provided the smaller network is not too small the first effect outweighs the second, but for a very small network the loss of market share outweighs the profit from termination, leading it to prefer cost-based access charges.

These effects are shown from the results of Frontier's model below. I note that there are two effects, one on market share and one on traffic surpluses and deficits. However the effect on market share is not simply that the larger network takes an increasing market share if access is priced above cost. In fact, it is possible to show that in equilibrium the smaller network maximises its market share with cost-based access charges and loses market share to the larger network for *high or low access* charges. This is illustrated in Figure 5 below. This figure shows that the greater the initial asymmetry between the two networks the greater is the impact on the smaller network's market share of a divergence of access charges from cost. When the networks are close in size the effect on the smaller network's market share is negligible. However, for larger asymmetries the smaller network loses proportionately more market share when access diverges from cost.

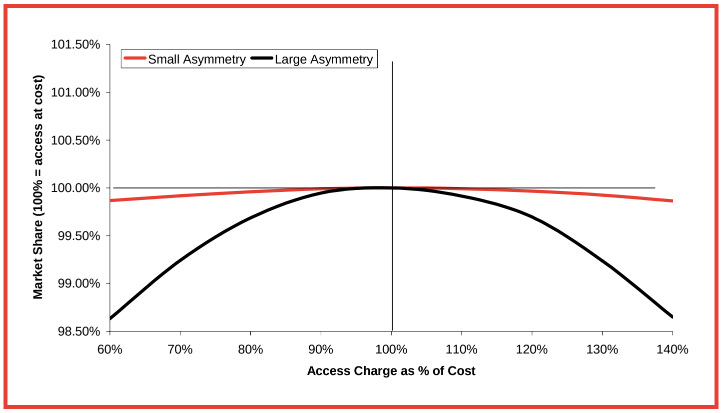

Figure 5: Effect of access charge on smaller operator's market share

Source: Frontier model

It is the impact on the smaller network's market share for different degrees of asymmetry that drives Carter & Wright's results. Figure 6 shows that the variation in profits - resulting from the size differences between networks - is small (as in the red line in Figure 5).

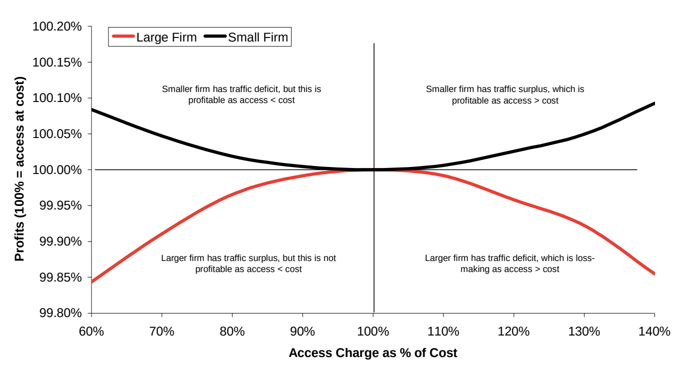

Figure 6: The effect of access on profits with small asymmetry

Source: Frontier model

Figure 6 shows that when the asymmetry is small, the interests of the two networks diverge. This is because the market-share effects of varying access charges are small, so the results are dominated by the effect of traffic imbalances.

This result is tested in Figure 7, where I model the impact of different access charges with an extreme asymmetry (that leads to 83/17 market shares when access is priced at cost – the black line in Figure 5 above). This shows that with greater asymmetry the sensitivity of profits is greater but still extremely small compared to the effects identified by Gans & King[22]. Furthermore, Figure 7 shows Carter & Wright's result that with asymmetry greater than 67/33 the smaller network *also* prefers cost-based reciprocal access. In this case the loss of market share for the smaller firm from varying access charges from cost outweighs the benefit the smaller network gets from profits on interconnection.

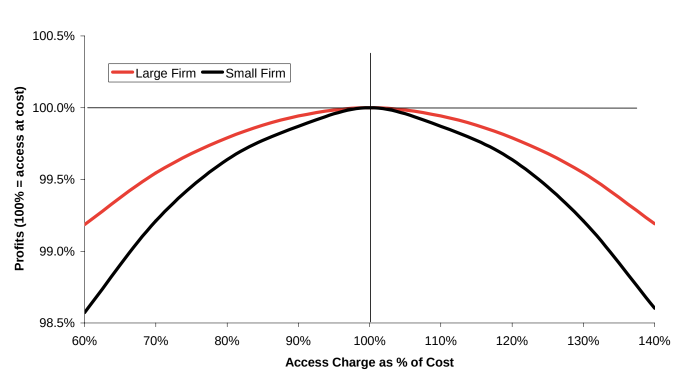

Figure 7: The effect of access on profits with significant asymmetry

Source: Frontier model

22 These results are, of course, sensitive to the intensity of competition between the networks. However, for an equilibrium to exist across the range of access charges shown here competition cannot be too intense. My sensitivity analysis indicates that, for any values for the intensity of competition parameter t that allow stable equilibria in this range, the impact of access charges on profits is very small indeed.

Two-way access charges and on-net/off-net differentials

These results strongly suggest that the effect of asymmetry between networks on equilibrium access charges is extremely small compared to the impact of on-net/off-net differentials.

The possibility of foreclosure in the Carter & Wright model

In the context of suspicions of the use of high access charges for predation whether, under Carter & Wright's model, a large operator could increase its market share by driving up (or down) the reciprocal access charges (which it might arguably be able to do as a result of greater bargaining power). In Figure 5 I have already shown that setting the reciprocal access charge either above or below cost can reduce the smaller network's market share. Figure 8 below shows the equivalent market share figures for the larger network under the more extreme assumption of asymmetry.

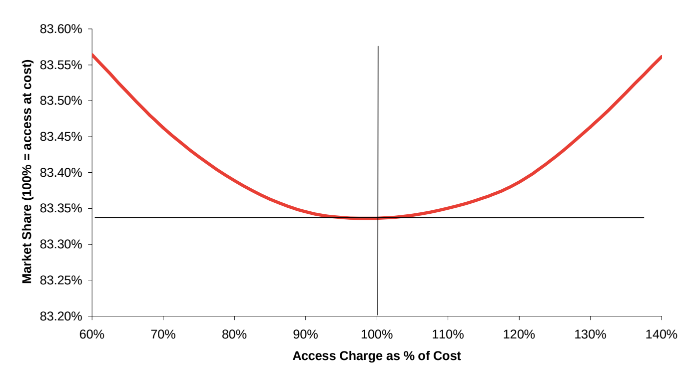

Figure 8: Effect of different levels of access charge on larger operator's market share

Source: Frontier model

This demonstrates clearly that varying the access charge has a very small impact on the larger network's market share, even when the initial asymmetry is great. Furthermore, its market share is not strictly increasing with the access charge, rather it is minimised at the profit maximising point.

Further sensitivity tests with the model indicate that given an initial asymmetry of 95/5, setting an access charge of twice cost would only increase the larger network's market share from 95% to 96%. To put this in context as a credible strategy for foreclosure, the larger network could achieve the equivalent increase in equilibrium market share by reducing rental charges by 1% relative to their profit maximising level.

I have also tested this result for different values of the parameter that determines the intensity of inter-network competition and conclude that for values that allow an equilibrium to exist[23] the impact of the access charge on market share under this model is very small indeed.

[23] For very small values of this parameter it can be shown that there are no stable internal equilibria.

I conclude therefore that exploration of Carter & Wright's model, adding network asymmetry, provides no support for the suggestion that forcing up reciprocal access charges could be advantageous to a larger network as part of a foreclosure strategy.

Network asymmetry in the presence of on-net/off-net differentials

In my earlier analysis I showed that on-net/off-net differentials mean that symmetric networks can jointly profit maximise by setting a low reciprocal access charge, possibly adopting a bill and keep arrangement.

I am interested in analysing how the network asymmetry modelled by Carter & Wright might affect the findings in the presence of network-based price discrimination. I am not aware of any published paper covering this topic, and the outcomes are mathematically complex. As a consequence, Frontier's model is an ideal tool for examining this scenario.

We have seen that Carter & Wright's work suggests that asymmetry should strengthen the preference of a larger network for cost-based access charges. I would expect this effect to carry over into a world with price differentials, but would expect it to be swamped by the greater effect of TMNEs. I would expect the large network to retain its interest in bill and keep, because of the impact of TMNEs on competition at the margin described above. However, because positive TMNEs will tend to favour larger networks I would expect the profits of the larger network to be less sensitive to the access charge than in the symmetric case, while I would also expect the smaller network's profits to be more sensitive than in the symmetric case.

The impact of different levels of reciprocal access charges on profits is shown in Figure 9. In this figure and those following I have assumed the more extreme example of asymmetry used earlier, that is an 83/17 split at cost-based access charges[24]. Figure 9 confirms expectations.

[24] In practice it is my view that such an asymmetry is extreme and unlikely to be relevant to a real world example. Actual market shares may be split in this way in the short-run, especially shortly after a the launch of a new network. There is no reason, however, to believe that a single network should permanently hold such a huge intrinsic advantage that cannot be competed away over time. Nevertheless, I use this extreme asymmetry to illustrate clearly the qualitative results generated by these models.

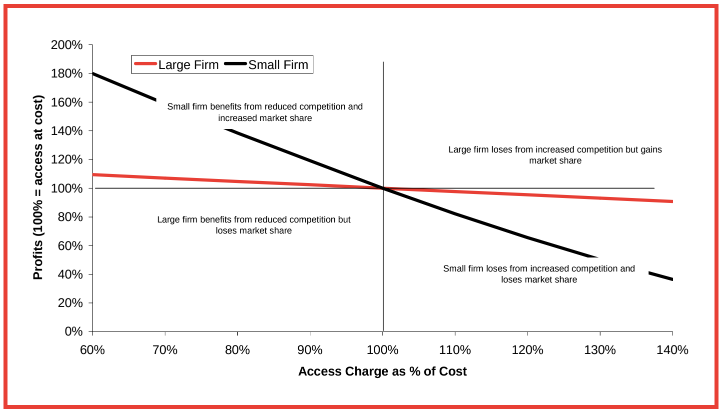

Figure 9: Sensitivity of profits to access charge with significant network asymmetry (83/17)

Source: Frontier model

It is clear that the presence of TMNEs in this model significantly change the implications of asymmetry. The marginal effect of TMNEs outweighs the effect identified by Carter & Wright for both networks. However , the advantage for the larger network of lower access charges is significantly less than in the symmetric case.

On the other hand Figure 10 shows that consumer surplus still increases with the access charge in the presence of network asymmetries[25]. Hence the result I found earlier holds even in the presence of significant network asymmetries: consumers benefit from above cost access charges in the presence of network price discrimination because of way price discrimination intensifies competition.

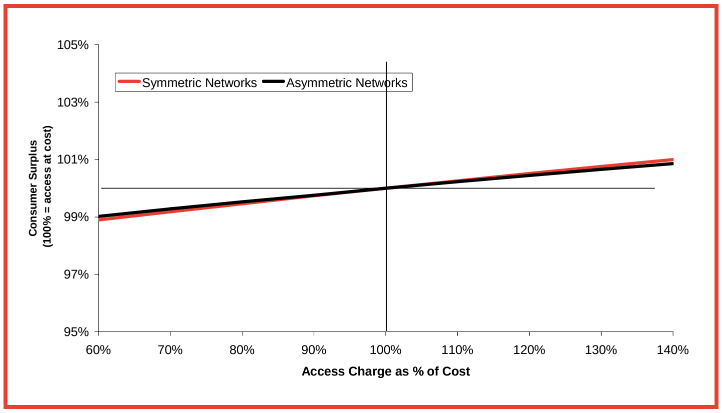

Figure 10: Network asymmetry does not affect the relationship between consumer surplus and the access charge

Source: Frontier model

25 This measure of consumer surplus excludes network specific benefits, which I take to be a modelling device to create asymmetries.

Implications for the possibility of foreclosure

When considering the use of an inefficiently high access charge to maintain a high market share, the impact of TMNEs means that there is a much more pronounced effect, as shown in Figure 11.

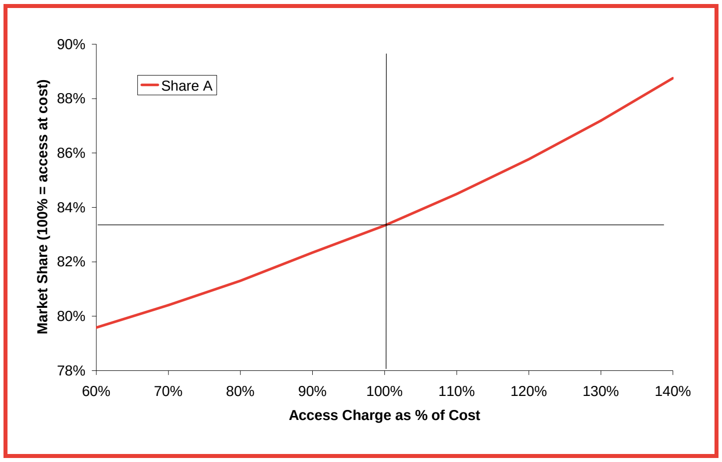

Figure 11: Effect of access charge on larger operator's market share with differential pricing

Source: Frontier model

In contrast to Figure 8, this shows that the TMNEs created by differential charging allow the larger network to increase market share if it can raise the reciprocal termination charge above cost. Furthermore, sensitivities on the value of the intensity of competition show that for low values of t (i.e. more intense competition) the impact on the market share of the larger operator can be even greater[26].

In order to examine the likelihood of larger networks using high reciprocal access charges as a foreclosure strategy, I have used my model to compare the relative cost to a larger network of building market share by one of two strategies: either by cutting consumer rental charges or by raising reciprocal access charges[27]. Both strategies reduce profits in the short-run, but might (in theory) be adopted in an attempt to drive a smaller rival out of the market so as subsequently to reap the benefit of monopoly profits. It seems logical to ask which one of the two strategies is most cost effective in achieving this end.

The answer I have found inevitably depends on the degree of (intrinsic) asymmetry between the networks and on the intensity of competition between them. When the market is highly competitive, the gain in market share per unit of profit foregone can be shown always to be higher by cutting rentals than by

26 However, I would question how realistic a scenario is which posits a huge intrinsic asymmetry in networks co-existing with a highly competitive retail market.

27 It should be emphasised that these two strategies are not equally easy. In the latter case it is not clear how a larger incumbent could force a smaller network to accept high reciprocal access charges, especially if the smaller network had recourse either to a competition or regulatory authority.

forcing up the reciprocal access charge in the range for which an equilibrium exists (see Figure 12)[28].

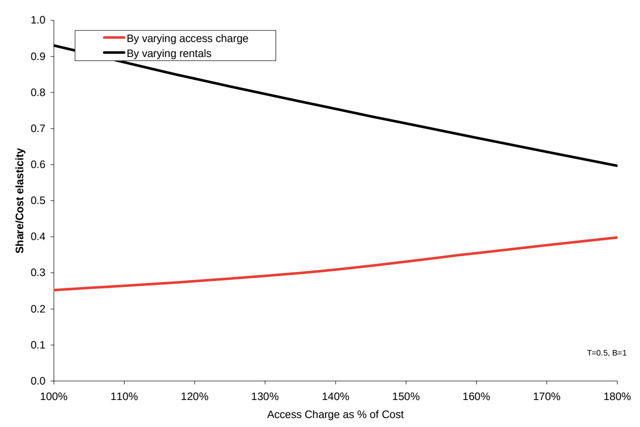

Figure 12: Relative effectiveness of cutting rentals or raising reciprocal access charge to gain market share, with strong competition

Source: Frontier model

If competition between the networks is weaker then the range over which an equilibrium in access charges exists is wider. In these circumstances I can show that it may become more effective for the larger network to win market share by pushing up reciprocal access charges, but only once access charges are already several times cost (see Figure 13). Provided access charges are in the vicinity of cost this indicates that cutting rentals is likely to be a much more cost effective way for a larger network to artificially increase its market share.

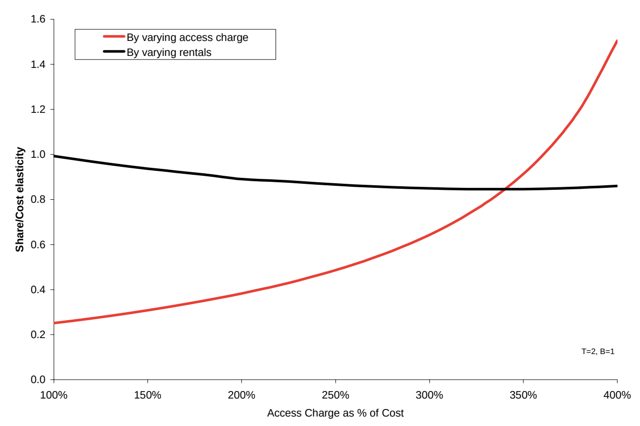

Figure 13: Relative effectiveness of cutting rentals or raising reciprocal access charge to gain market share, with weak competition

Source: Frontier model

28 In this modelling I have assumed an intrinsic asymmetry of 67/33, which I believe represents a reasonable upper bound.

These results do not prove that a larger network would not under any circumstances attempt to use high reciprocal access charges to increase its market share (assuming it was able to force these through negotiation). What they do strongly indicate, however, is that there is a substantial cost of profits foregone to the large network if it were to do so. Moreover, there are more obvious routes (e.g. the conventional approach of cutting retail prices) which appear to be a much more effective means of increasing market share.

Endogenous market size

The analysis presented so far assumes that the number of network subscribers is a given. Clearly this has not been true historically and it could be argued that it remains the case that the number of subscribers is sensitive to the price of rentals and calls.

Schiff[29] presents a variant of the LRT model (i.e. without on-net/off-net price discrimination) but with an endogenous subscriber numbers and with or without network externalities[30]. In all these models, Schiff finds that it is still efficient to price calls at marginal cost and compete over the level of the rental charge. Schiff finds that *an endogenous market size without externalities[31] intensifies competition relative to the LRT model (because networks compete for new subscribers as well as for market share) but profits, consumer surplus and hence total welfare are maximised by cost-based access charges*.

Figure 14 illustrates Schiff's model, applying the same parameterisation as in the previous analysis, but allowing for an endogenous participation rate (but no externalities). For illustration, I have used a linear distribution of subscriber values that determines participation. This distribution is independent of consumption once they have decided to subscribe. The parameters I have chosen deliberately imply a very high elasticity of subscription with respect to the rental (of around –2.5) in order to demonstrate clearly both the impact of endogenous participation and its relatively small effect for what is a very high elasticity from a real-world point of view. Figure 14 demonstrates Schiff's result that endogenous market size leads to profits and welfare being maximised by cost-based access charges, but shows that this effect is very weak in comparison to the TMNE effect identified above.

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29 Schiff, A. (2001), "Two-way interconnection with partial consumer participation", University of Auckland Working Paper # 223.

30 The former is modelled by assuming that potential subscribers have an option value associated with joining the market, which is randomly distributed. Once the decision to subscribe is made, based on expected benefits from joining, the subscriber chooses network in the same way as in the other models discussed here. All subscribers still make the same volume of calls. Schiff by models network externalities assuming that the calls made by each subscriber are a linear function of the number of subscribers.

31 This is modelled by assuming the number of calls made by each subscriber is a function of the price of calls but is not affected by the number of subscribers.

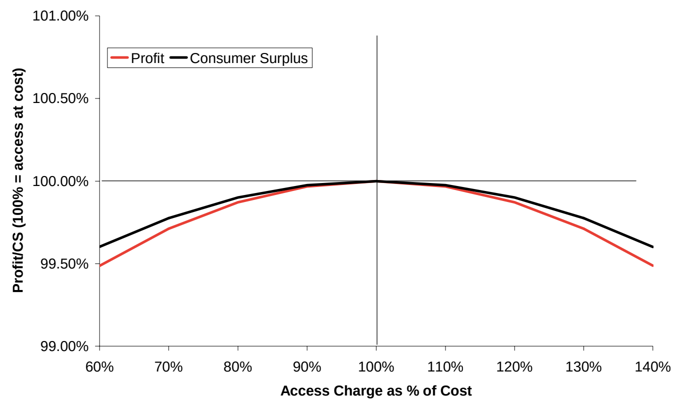

Figure 14: Schiff model of endogenous market share

Source: Frontier model

Endogenous participation with network price discrimination

Schiff shows that an endogenous market size increases the incentive for networks to price reciprocal access at cost. I have extended his analysis therefore to the case of endogenous subscription in the presence of on-net/off-net differentials and in the presence of network asymmetry. In each of these cases it is extremely difficult to solve these problems algebraically, but relatively straightforward to obtain answers using Frontier's modelling framework.

Intuitively I would expect an endogenous market size to reduce the incentive for symmetric networks to adopt bill and keep. Depending on the elasticity of subscription it is possible that profits may be maximised at a positive access charge, although this charge will always be less than cost[32]. This result is demonstrated in Figure 15, which shows that for a subscription elasticity of –2.5 there exists a profit maximising access charge, less than cost but greater than zero, whereas for an elasticity of –0.25 profits are increasing as the access charge falls to zero.

32 See Annexe 1 for proof.

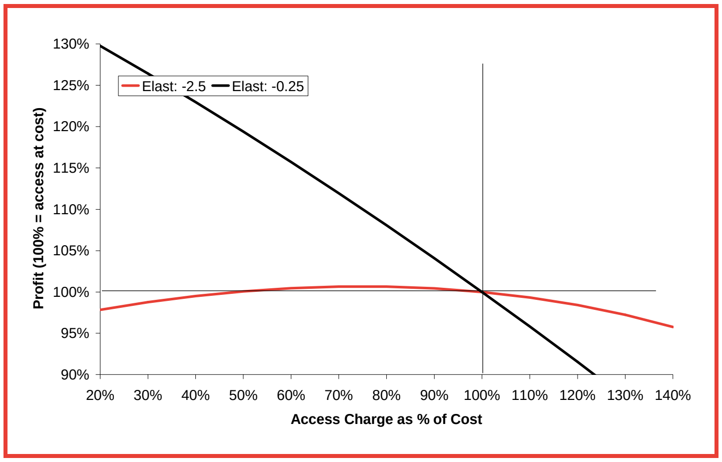

Figure 15: Effect of subscription elasticity on profit maximising access charge with endogenous market share

Source: Frontier model

Introducing network asymmetry, I find that unsurprisingly it is the smaller, rather than the larger network that is affected more by the endogenous penetration rate. Figure 16 shows, with the same exaggerated subscription elasticity of –2.5, that the larger network would still prefer bill and keep, while the smaller network would strictly prefer a positive (although below-cost) reciprocal access charge.

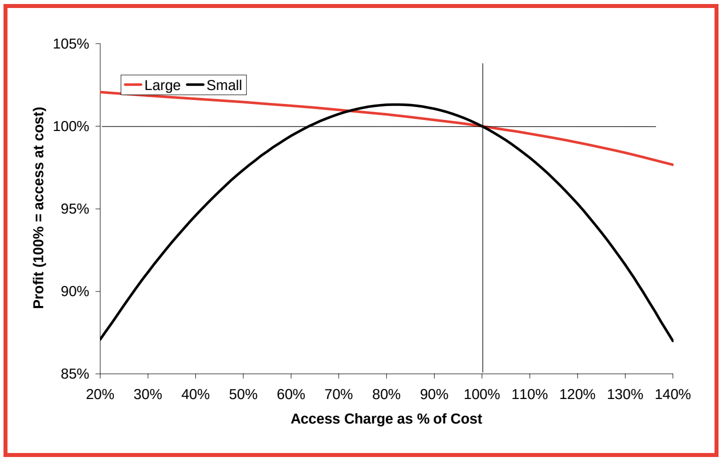

Figure 16: The effect of endogenous participation and asymmetry on profit-maximising reciprocal access charge

Source: Frontier model

I stated previously that because TMNEs intensify competition: setting above-cost access charges can increase consumer surplus. My modelling shows that the introduction of an endogenous penetration rate intensifies competition even further. As a consequence, the result that consumer surplus can be increased by setting access charges above cost is even stronger in the presence of an endogenous penetration rate. This is illustrated in Figure 17 below.

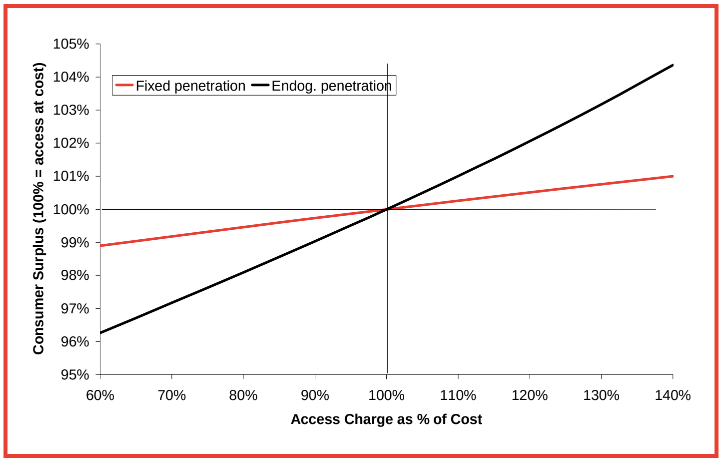

Figure 17: Impact of access charge with endogenous penetration on consumer surplus

Source: Frontier model

Comments on network externalities

In the presence of network externalities Schiff shows that the networks will *profit maximise by pricing access below marginal cost (even though they are charging uniform on-net and off-net prices), while consumer surplus is maximised by pricing access above marginal cost.* The intuition of this result is that externalities make competition even fiercer in a non-linear way. Adding a customer when access is priced above cost creates profits directly *and* increases the volume of calls by existing customers, which multiplies the profit. The networks would choose to mitigate competition by setting the price of access (and calls) below cost to offset the effect of the network externality. Total welfare on the other hand is maximised with access priced above marginal cost, because this leads to a lower rental charge, which in turn drives up the penetration rate[33].

I have not replicated this modelling in the current analysis, because the modelling of externalities is extremely sensitive to the parameters used. However my intuition is that Schiff's results are consistent with the preceding analysis. The introduction of externalities may somewhat strengthen the tendency of profit maximising operators to set access charges below cost, but also strengthens the welfare argument for above cost access charges.

Comments on customer heterogeneity

In each of the models presented here it can be shown that it is efficient for networks to price calls at (perceived) marginal cost and for them to compete over the level of the rental charge. However, this results from the fact that in each model subscribers are assumed all to have the same demand to make calls once they have joined a network.

33 Dessein, W. (2001), "Network Competition In Non-Linear Pricing". Shows that the welfare result is not completely general, but is true provided that two duopolists offer a larger net surplus to customers than a monopolist

If the models are generalised further so that consumers vary in their characteristics, either in terms of the volume of calls they would make at a given call price, or in terms of the volume of calls they receive, then it no longer is the case that it will be efficient for networks to price calls at marginal cost.

This is an aspect of pricing dealt with by Dessein and by Houpis & Valletti[34]. The specific insight that these papers bring is that they show that when the marginal subscriber makes fewer calls than the average caller then it will be efficient to price calls above marginal cost and reduce rentals.

Both LRT (1998) and Armstrong (1998) argue (without formal proof) that once customers are heterogeneous in their consumption and access prices differ from marginal cost then the market outcome may resemble the collusive outcome created by linear pricing, even if two-part tariffs are used in practice. Dessein demonstrates that this is *not* the case. He shows that LRT's profit neutrality result holds even in the presence of customer heterogeneity. Moreover, he extends Schiff's result by showing that in the presence of customer heterogeneity *and* externalities networks would choose to price access below marginal cost while welfare is maximised by pricing access above marginal cost. Houpis & Valletti note specifically that results are sensitive to the way in which heterogeneity is modelled. If the differences between subscribers are additive then marginal cost pricing will remain efficient, while other formulations tend to result in pricing calls above marginal cost.

Schiff's paper is a good example of this. An endogenous participation rate is explained by customers having an "option value" from subscription which is randomly distributed, but unrelated to the calls they make if they become subscribers because of the additive structure that Schiff has chosen. Hence in Schiff's model, even in the presence of externalities, the marginal customer makes the same number of calls as the average customer, so the conditions for marginal cost pricing still hold. By contrast, in Dessein's model, customers are split into low and high calling (and receiving) behaviour. Inevitably marginal customers are drawn from the low-use group. In these circumstances it becomes efficient to raise call charges above marginal cost and lower rental charges.

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34 Houpis, G. & Valletti, T., (2004), "Mobile termination: what is the right charge?". This article concerns optimal F2M access charges and so is not directly relevant to the present case, but contains important insights about how customer heterogeneity affects efficient pricing.

CONCLUSIONS

The result showing a collusive outcome for two-way access under linear retail tariffs appears to have dominated the policy debate about two-way interconnection, in spite of (perhaps because of) the fact that this model is very simple and in spite of the fact that subsequent work in the area has shows that this conclusion appears to be special to the very restricted assumptions on which it is based. More realistic models do not produce this collusive result.

This review has shown that:

- If networks compete using rentals *and* call charges then the joint interest in driving up reciprocal access charges evaporates.
- While LRT derived the profit neutrality result, it seems that this too is quite a special case. Allowing for either an endogenous market size or asymmetry in the sizes of networks creates an incentive for the networks to set a cost-based reciprocal access charge to maximise profits. However, my modelling indicates that this incentive may not, in practice, be very strong.
- By contrast, it seems that differential on-net and off-net tariffs have a dramatic impact on the dynamics of the market. Commentators have noted that setting access charges above cost creates (positive) tariff mediated network externalities (TMNEs), which should favour larger networks. This view is static, however, and fails to account for the interaction of TMNEs and inter-network competition. Positive TMNEs make customers more profitable, and therefore more attractive for each network, giving all networks a strong incentive to increase their market share. This intensifies competition, ultimately reduces profits and increases consumer surplus. Given the chance, therefore, networks would choose low reciprocal access charges, possibly even "bill and keep" to reduce the intensity of competition for these subscribers, which would be to the detriment of the consumer surplus of subscribers.
- The dynamic effect of TMNEs on the intensity of competition reveals that the idea of that the "waterbed" effect between access charges and profits is overly simplistic. This concept has usually been applied to the case of F2M access charges, but can equally be considered in the case of two-way access. What is critical to the effectiveness of the waterbed is not the intensity of competition in the retail market *per se*, but rather the extent to which changes in termination charges alter the intensity of retail competition. If access charges (one-way or two way) do not affect the intensity of competition then changes in termination charges would not be expected to alter the equilibrium level of profits. Hence the waterbed will be 100% effective regardless of the absolute level of competition in the outbound market. In the case of two-way access this is likely to be the case when on-net and off-net prices are uniform. In the presence of differentials however, higher access charges *increase* the intensity of competition, which means that networks pass on more than 100% of any movement in access charges. Although the consideration of waterbed effects in one-way access is outside the scope of this paper, these

observations highlight how important it also is for regulators not to make simplistic assumptions about the relationship between F2M access charges and competition in the retail market.

- Forcing up reciprocal access charges is an expensive way for a large operator to attempt to gain market share. In the absence of on-net/off-net differentials it seems to have a negligible effect on market share. With network price discrimination, on the other hand, it is possible for the larger network to increase its market share if it can force up the reciprocal access charges. However, unless it can completely exclude the competitor from the market it will simply doom itself to perpetual and significant damage to its profits in doing so. Moreover, it is not at all clear why a large incumbent attempting to adopt a predatory strategy would behave in this way. Modelling shows that, unless the access charge is substantially in excess of cost, it is almost certainly more cost effective for the dominant firm to cut retail prices than to force up reciprocal access charges (even if it has the power to do so) in order to build market share.
- It is usually assumed that welfare will be maximised by cost-based access charges. However, the evidence I have reviewed shows that this need not be the case. First, in the presence of network externalities (for which an endogenous market size is a necessary but not sufficient condition) total welfare will be maximised by setting access charges above cost. Secondly, even without externalities setting access charges above cost can be an effective method of intensifying competition provided networks charge differential on-net and off-net tariffs. This does not increase total welfare, but does increase consumer surplus. Thus in many circumstances above-cost access charges have the effect of increasing the welfare of consumers, albeit at the expense of the networks.
- I also find that allowing for the level of consumer participation in the market to be variable (i.e. a participation rate of less than 100% that varies depending on the prices offered) strengthens the effect on competition of above-cost access charges (and hence increases further the consumer benefit they create) but mitigates to some extent the desire for MNOs to reduce access charges to zero. It remains the case however, that MNOs would choose to set two-way access charges below cost so as to maximise profits.

My conclusion is therefore that, on the basis of the types of models considered here, there is no incentive for mobile networks to set high *reciprocal* access charges. Furthermore, it does not appear that larger networks gain any particular advantage as a foreclosure strategy from attempting to force up reciprocal access charges.

By contrast, mobile networks in most circumstances have an incentive to set access charges at or below cost while welfare maximising levels can be expected to be *above* marginal cost either to allow the exploitation of network externalities (in whose presence total welfare may be enhanced by above-cost access charges) or to accentuate competition between networks (in which case total welfare may not be increased, but consumer surplus certainly is).

All this, of course, begs the question as to why mobile networks do not choose reciprocally to reduce M2M access charges when they are free to do so? There are two answers to this, the first practical the second economic. The practical argument is that it may not be possible for mobile networks to set different F2M and M2M access charges because of the risk of arbitrage. Given that it is accepted that mobile networks have incentives to maintain high F2M access charges (the classic one-way interconnection problem) it is to be expected that mobile networks will not reduce their M2M access charge.

The economic argument returns to the concept of Nash equilibrium that underpins this analysis. While I have shown that a low reciprocal access charge will maximise joint profits, it is straightforward to show that this level of access charge is not a Nash equilibrium if reciprocity is not mandated. For a given, low, access charge either network can raise profits by increasing its own access charge. Unless reciprocity is mandated, the only outcomes that will be stable will involve high access charges. This is in the nature of competition and what prevents collusive outcomes in competitive markets. The policy implications are therefore: before any other measures for regulating M2M access charges are considered, a requirement of reciprocity should be placed on *all* operators.

The second policy implication of this analysis is that neither prohibiting on-net/off-net differentials (to the extent that these reflect underlying access charges) nor mandating cost-based access charges is necessarily in the interests of consumers. If access charges are currently above cost then prohibiting on-net/off-net differentials has the effect of softening competition, increasing profits and reducing consumer surplus. This follows because prohibiting on-net/off-net differentials saves the networks from the intense competition to which they are subjected by network price differentials.

Conversely, setting access charges above cost (combined with on-net/off-net differentials) actually increases consumer surplus even in the absence of network externalities, because of the impact that higher access charges have on the intensity of competition.

ANNEXE 1: MATHEMATICAL DERIVATION OF MODELS

Linear pricing

Firm i charges a uniform outbound price p_i. and no fixed rental. The marginal cost of origination and termination is c (therefore the marginal cost of an on-net call is 2c). A common call termination charge of a is set for off-net calls, hence the perceived marginal cost of an off-net call is c + a.

There are two firms competing are competing for market share $s_i \in [0,1]$ by attempting to offer the greatest consumer surplus to customers. Market share is determined by the difference between the consumer surplus offered by the two firms and a search cost parameter t. The bigger is t the weaker is competition between the two operators.

Each firm maximises:

$$\Pi_i = s_i(p_i - 2c)q(p_i) + s_i s_j(a-c)(q(p_j) - q(p_i)) - s_i f \qquad (1.)$$

subject to share s_i:

$$s_i = \frac{1}{2} + \gamma(w(p_i) - w(p_j)) \qquad (2.)$$

where consumer surplus $w(p_i)$ is defined relative to the indirect utility function $v(p_i)$:

$$w(p_i) = v(p_i) - r_i \qquad (3.)$$

and $\gamma = 1/2t$.

First order conditions on (1.) assuming symmetry give:

$$p^* = 2c + \left(\frac{\frac{1}{4}(a-c)q'(p^*) - \gamma f q(p^*) - \frac{q(p^*)}{2}}{\frac{1}{2}q'(p^*) - \gamma q(p^*)^2} \right) \qquad (4.)$$

It can be shown that p* is above perceived marginal cost and increases with the access charge at a=c, hence the suggestion that networks could collude to raise profits by setting above - cost access charges.

The profit neutrality result

Firm i charges subscription price r_i as well as a uniform outbound price p_i.

Each firm maximises profit:

$$\Pi_i = s_i(p_i - 2c)q(p_i) + s_i s_j(a-c)(q(p_j) - q(p_i)) + s_i(r_i - f) \qquad (5.)$$

with the same derivation of share s_i as in the Armstrong case above.

First order conditions on (5.), assuming symmetry give:

$$p_i = 2c + s_j(a-c) \quad (6.)$$

given symmetry $s_i = s_j = 0.5$, $p_i = p_j = p^*$

$$p^* = 2c + \frac{1}{2}(a-c) \quad (7.)$$

which shows that network i prices calls at perceived marginal cost.

Also first order conditions on (5.) show:

$$r_i = f + \frac{s_i}{\gamma} - (p_i - 2c)q(p_i) - (s_j - s_i)(a-c)(q(p_j) - q(p_i)) \quad (8.)$$

As in equilibrium, the outcome will be symmetric ($s_i = s_j = 0.5$),

$$r^* = f + \frac{1}{2\gamma} - \frac{1}{2}(a-c)q(p^*) \quad (9.)$$

which implies that equilibrium profits are:

$$\Pi = \frac{1}{2}[(p^* - 2c)q(p^*) + (r^* - f)] = \frac{1}{4\gamma} \quad (10.)$$

Equation (10.) shows that profits are independent of the access charge a. This is the standard profit neutrality result, implying that the competing firms *cannot* collude to raise profits by manipulating the level of the access charge.

Introducing on-net/off-net differentials

The previous model can be generalised by allowing the networks to charge different on-net and off-net call charges. This is Gans & King's model.

Each firm maximises profit:

$$\Pi_i = s_i^2(\bar{p}_i - 2c)q(\bar{p}_i) + s_i(1-s_i)(\hat{p}_i - c - a)q(\hat{p}_i) + s_i(1-s_i)(a-c)q(\hat{p}_j) + s_i(r_i - f) \quad (11.)$$

where $\bar{p}_i$ is network i's on-net call charge and $\hat{p}_i$ is its off-net call charge.

subject to share s_i:

$$s_i = \frac{1}{2} + \gamma(w(\bar{p}_i, \hat{p}_i) - w(\bar{p}_j, \hat{p}_j)) \quad (12.)$$

and consumer surplus $w(p_i)$ is defined relative to the indirect utility function $v(p_i)$:

$$w(\bar{p}_i, \hat{p}_i) = s_i v(\bar{p}_i) + s_j v(\hat{p}_i) - r_i \quad (13.)$$

First order conditions on (11.) show that give:

$$\bar{p}^* = 2c, \ \hat{p}^* = a + c \quad (14.)$$

hence it is profit maximising for firms to price call at marginal cost, which is 2c for on-net calls and a + c for off-net calls.

Also first order conditions on (11.) show that:

$$r_i = f - s_i\left(v(\bar{p}_i) - v(\hat{p}_i) + v(\bar{p}_j) - v(\hat{p}_j) - \frac{1}{\gamma}\right)$$
$$- 2s_i(\bar{p}_i - 2c)q(\bar{p}_i) + (s_j - s_i)(\hat{p}_i - c - a)q(\hat{p}_i) - (s_j - s_i)(a - c)q(\hat{p}_j) \quad (15.)$$

However, because the solution will be symmetric, with $s_i=s_j=0.5$, $\bar{p}_i = \bar{p}_j = \bar{p}^*$, $\hat{p}_i = \hat{p}_j = \hat{p}^*$, (15.) simplifies to:

$$r^* = f + \frac{1}{2\gamma} - (v(\bar{p}^*) - v(\hat{p}^*)) \quad (16.)$$

which implies equilibrium profits of:

$$\Pi_i = \frac{1}{4\gamma} + \frac{1}{4}(a - c)q(\hat{p}^*) - \frac{1}{2}(v(\bar{p}^*) - v(\hat{p}^*)) \quad (17.)$$

Clearly at a=c, $\bar{p}^* = \hat{p}^*$, profit equals the Hotelling profit of $1/4\gamma$, as in the case with no differentials.

However, differentiating (17.) with respect to the access charge a we see that:

$$\frac{d\Pi_i}{da} = \frac{1}{4}q(\hat{p}) + \frac{1}{4}(a - c)\frac{dq(\hat{p})}{da} + \frac{1}{2}\frac{dv(\hat{p})}{da} = -\frac{1}{4}q(\hat{p}) + \frac{1}{4}(a - c)\frac{dq(\hat{p})}{da} \quad (18.)$$

given Shepherd's lemma v'=-q.

Equation (18.) shows that when access charges are at cost, a=c, profits are strictly declining as the access charge increases. Hence the networks can increase profits by reducing access charges below cost.

As a falls below c, the first term remains negative, but the second is positive. Whether there a profit maximising access charge exists will depend on the second order conditions.

$$\frac{d^2\Pi_i}{da^2} = \frac{1}{4}(a - c)\frac{d^2q(\hat{p})}{da^2} \quad (19.)$$

In a linear demand system (19.) is zero, hence profits will *always* be increasing as the access charge falls. Assuming the lowest feasible access charge to be zero. In a constant elasticity model a profit maximising value of a may exist, but it is very likely to be negative. This is how Gans & King come to the conclusion that networks may well prefer bill and keep arrangements to maximise profits.

However, it is also possible to show that in Gans & King's model consumer surplus is *increasing* with the level of the access charge when a=c:

Differentiating (13.) at the profit maximising level with respect to the access charge gives:

$$\frac{dw(\bar{p}^*, \hat{p}^*)}{da} = \frac{1}{2}\frac{dv(\hat{p}^*)}{da} - \frac{dr^*}{da} \quad (20.)$$

but from Shepherd's lemma and (16.) it is clear that:

$$\frac{dw(\bar{p}^*, \hat{p}^*)}{da} = \frac{q(\hat{p}^*)}{2} \qquad (21.)$$

which is greater than zero, hence consumer surplus is increasing with the access charge for any value of that charge.

Network asymmetry

Carter & Wright's model maximises the same profit function as LRT, (5.), but does not assume symmetry between the two networks. This is achieved by assuming that network i provides additional network specific benefits to subscribers, equal to B*t, where t is the search cost defined above.

Thus:

$$w(p_i) = v(p_i) - r_i + Bt \qquad (22.)$$

$$w(p_j) = v(p_j) - r_j \qquad (23.)$$

It is easy to show that equation (6.) still holds, so the two networks both price at perceived marginal cost. However, because $s_i^* > s_j^*$, if access is priced above cost the larger network will charge a lower average price than the smaller one, and will experience an interconnection deficit in equilibrium.

Solving this model reveals that:

$$s_i^* = \frac{1}{2} + \frac{B}{6} + \frac{\gamma}{3}\left(v(p_i^*) - v(p_j^*) + (a-c)\left(s_j^* q(p_i^*) - s_i^* q(p_j^*)\right)\right) \qquad (24.)$$

$$s_j^* = \frac{1}{2} - \frac{B}{6} + \frac{\gamma}{3}\left(v(p_j^*) - v(p_i^*) + (a-c)\left(s_i^* q(p_j^*) - s_j^* q(p_i^*)\right)\right) \qquad (25.)$$

$$\Pi_i = \frac{s_i^{*2}}{\gamma} + s_i^{*2}(a-c)\left(q(p_i^*) - q(p_j^*)\right) \qquad (26.)$$

Carter and Wright show that:

$$\left(\frac{ds_i}{da}\right)_{a=c} = 0\text{, and} \qquad (27.)$$

$$\left(\frac{d^2 s_i}{da^2}\right)_{a=c} = \frac{\gamma}{3}\left(s_j^2 \frac{dq(p_i)}{da} - s_i^2 \frac{dq(p_j)}{da}\right) \qquad (28.)$$

At a=c the first derivative of market share is zero and the second derivative is negative for the smaller firm (because $q''(p_j)=q''(p_i) < 0$ and $s_j^2 > s_i^2$). Hence a=c represents a local *maximum* for the market share of the smaller firm.

Also

$$\left(\frac{d\Pi_i}{da}\right)_{a=c} = 0\text{, and} \qquad (29.)$$

$$\left(\frac{d^2\Pi_i}{da^2}\right)_{a=c} = si\frac{dq(p_i)}{da}\left(4s_i^{\ 2} - \frac{10}{3}s_i + \frac{2}{3}\right) \qquad (30.)$$

where the term in brackets is negative if and only if $\frac{1}{3} < s_i < \frac{1}{2}$, so that:

$$\left(\frac{d^2\Pi_i}{da^2}\right)_{a=c} \begin{cases} > 0 & if\ \frac{1}{3} < s_i < \frac{1}{2} \\ = 0 & if\ s_i = \frac{1}{2} \\ < 0 & otherwise \end{cases} \qquad (31.)$$

hence the result that the larger network (s_i > ½) strictly prefers cost-based access charges, while for the smaller network cost based access *minimises* profits for a market share less than a half but more than a third, but *maximises* profits if the market share is less than one-third.

ANNEXE 2: DESCRIPTION OF THE FRONTIER MODEL

Frontier's model is an Excel spreadsheet encompassing a Hotelling model of price competition between two operators that charge each other an access charge for traffic interconnection. The model uses circular calculations to calculate demand, market shares, profits and consumer surplus for a given set of retail prices and access charges.

Demand is assumed to be linear and traffic proportional to the number of subscribers on each network.

The model allows each network independently to choose whether to differentiate on-net and off-net retail prices. However, call prices are always set at perceived marginal cost.

Figure 18 shows a screenshot of the Frontier model.

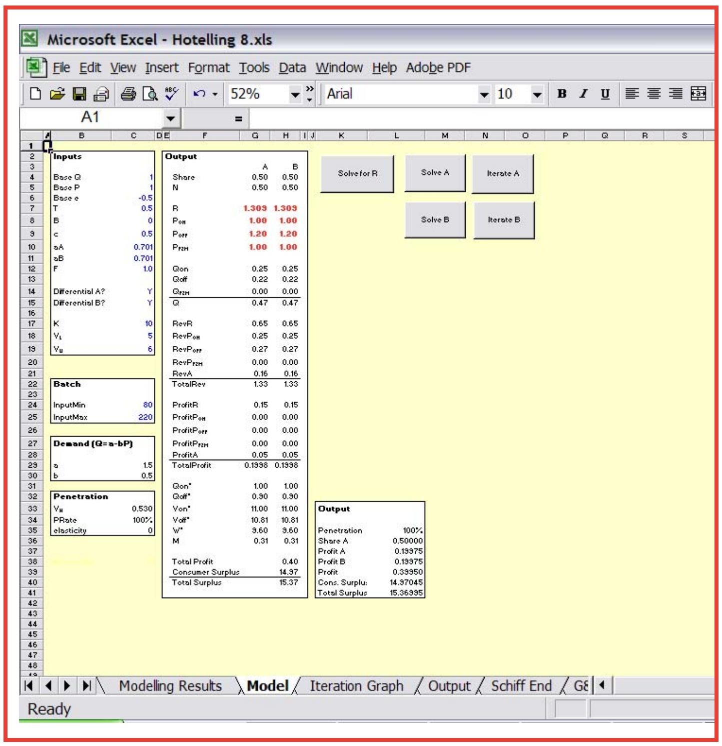

Figure 18: Screenshot of Frontier model

A Nash equilibrium for a given access charge is identified as follows.

1. Access charges are set.
2. Call prices and rentals for network A and B are set at cost.
3. Call prices and rentals for network B are held fixed.
4. Call prices for network A are set equal to marginal cost (by formula, hence in the case of uniform on-net/off-net charging, call prices will vary as the rental is altered, because of the effect on market share).

5. The rental charge for network A is varied across a range to identify the profit maximising rental charge, give network B's charges. The output of one pass of this process is shown in Figure 19 below.

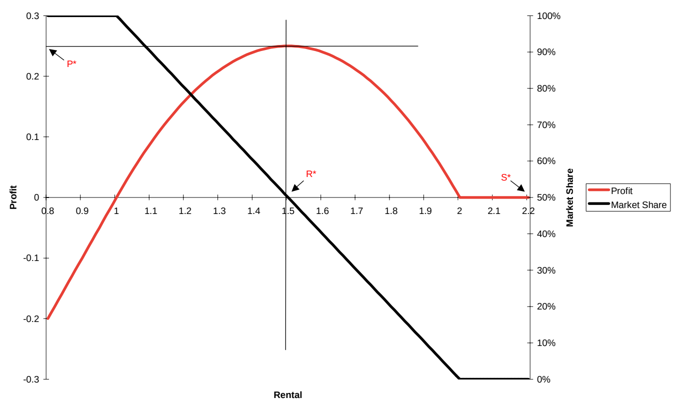

Figure 19: Illustration of solving routine

Source: Frontier model

6. The rental charge for network A is fixed at the maximum found in step 5.
7. Retail call charges for both networks are recalculated for the current rental charges and market shares.
8. Steps 3 to 7 are repeated for network B, holding network A's prices constant.
9. The process is repeated until the model converges to a Nash Equilibrium.