

Some Economics of Carrier Of Last Resort Auctions

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Abstract

This paper discusses the possible use of Carrier Of Last Resort (COLR) auctions to allocate Universal Service subsidies to carriers in high-cost areas. I discuss the factors involved in the choice of service areas, contract length, form of payment, number of supported firms, and auction format. I also show that COLR auctions can sometimes (but not always) lead to allocations that have a higher social welfare value than those generated by uniform subsidy schemes, even if the latter were based on extremely accurate cost-proxy models.

1. Introduction

The Telecommunications Act of 1996¹ has fundamentally changed the United States' Universal Service policy. In the Act, the goal of Universal Service has received its strongest and most explicit endorsement ever:

"UNIVERSAL SERVICE PRINCIPLES.--The Joint Board and the Commission shall base policies for the preservation and advancement of universal service on the following principles:

(1) QUALITY AND RATES.--Quality services should be available at just, reasonable, and affordable rates.

(2) ACCESS TO ADVANCED SERVICES.--Access to advanced telecommunications and information services should be provided in all regions of the Nation.

(3) ACCESS IN RURAL AND HIGH COST AREAS.--Consumers in all regions of the Nation, including low-income consumers and those in rural, insular, and high cost areas, should have access to telecommunications and information services, including interexchange services and advanced telecommunications and information services, that are reasonably comparable to those services provided in urban areas and that are available at rates that are reasonably comparable to rates charged for similar services in urban areas." ²

At the same time, the Act has gives the final blow to the traditional way of pursuing the Universal Service goal. The old web of implicit cross-subsidies and, in particular, the practice of mandated geographic price averaging of large regulated monopolies have not merely been undermined by the lifting of legal entry barriers in the local telephony market; they have been expressly repudiated in favor of the (Universal Service) principle of explicit subsidies:

"SPECIFIC AND PREDICTABLE SUPPORT MECHANISMS.--There should be specific, predictable and sufficient Federal and State mechanisms to preserve and advance universal service." ³

The Federal Communications Commission (FCC) soon began to consider "distributing high-cost assistance on the basis of competitive bids" based on the belief that

¹ Hereinafter referred to as simply "the Act".

² Section 254(b). The Act has also introduced a new Universal Service goal. The sixth Universal Service Principle states that "Elementary and secondary schools and classrooms, health care providers, and libraries should have access to advanced telecommunications services."

³ Section 254(b)(5). Some form of explicit subsidies was also in place before the passage of the Act (see Weinhaus et al., 1995). Incidentally, the 'S-word' is not very popular in political circles and the Act uses euphemisms such as "support payments" or "high-cost assistance". I will use all these terms interchangeably.

"competitive local exchange markets may develop even in high-cost areas."⁴ The "Recommended Decisions" of the Federal-State Joint Board on Universal Service expressed considerable interest in this possibility, but left the matter open, deeming it in need of further study. The FCC's May 8, 1997 Report and Order on Universal Service took the same position. The FCC chose to focus initially on the use of engineering cost-proxy models to determine the amount of support available in each area, but the interest in auction mechanisms remained alive.⁵

This paper provides a brief informal introduction to some of the main issues in the design and implementation of auctions for the allocation of Universal Service subsidies for high-cost areas.⁶

The idea of using auctions as substitutes for regulation is not a new one, of course, as it can be traced back at least as far as Demsetz's seminal 1968 paper.⁷ Demsetz's problem was to achieve the second-best average-cost pricing solution when the regulator cannot subsidize the regulated firm. The problem discussed in this paper is, in a sense, the polar opposite: the regulator knows the price it wants, but not the subsidy it must pay for it.

The earliest paper advocating the use of auctions for Universal Service subsidies is Salant (1996), where Carrier of Last Resort (COLR) auctions are introduced. Salant was also one of the consultants who helped GTE Corp. design its auction proposals submitted to the FCC and the California Public Utility Commission in 1996 and 1997.

⁴ Paragraphs 35-37 of the Notice of Proposed Rule Making and Order Establishing Joint Board, CC Docket No. 96-45, March 8, 1996.

⁵ A Further Notice of Proposed Rule Making on auctions for universal service support was in the making at the FCC several months ago. The California Public Utility Commission has also been actively studying the possibility of using such auctions.

⁶ Note that I will *not* discuss the economic or political rationale for a Universal Service policy. Consequently, I will not try to interpret what "reasonably comparable" prices and services should mean. Moreover, I will focus on high-cost assistance only.

⁷ Laffont and Tirole (1993) provide a modern treatment and extensive references to the later literature. Spulber (1989, Ch. 9) provides an interesting alternative approach to franchise competition in which the regulator controls the bargaining between consumers and producers.

GTE has been one of the most vocal supporters of auctions for Universal Service subsidies and its proposals have often set the tone of the debate on the issue.⁸

Milgrom (1996) offers the first formal model of COLR auctions. He focuses on the endogenous determination of the number of COLRs and derives some technical conditions for the optimal auction design.⁹ Kelly and Steinberg (1997) discuss a possible implementation of a simultaneous ascending COLR auction that allows combinatorial bids for sets of service areas.

Anton, Vander Weide, and Vettas (1997) also discuss auctions for universal service subsidies, but they use a different specification of the Universal Service Obligation (USO) than the one used in this paper. They assume that the winner of the auction has the obligation to provide service at the same price prevailing in another ("urban") market where, after the auction, the firm may compete Cournot-style with some of the other bidders. Although this specification appears quite unrealistic,¹⁰ it has an interesting interpretation. It can be seen as an attempt to capture in a static framework the regulators' dynamic adjustments of the "affordable price" to prices in low-cost areas and the corresponding reactions of those firms who may be active in both areas. Their results, however, appear to be quite sensitive with respect to alternative (possibly more realistic) specifications of the model.¹¹

⁸ The GTE proposal was, in the Federal-State Joint Board opinion, the only reasonably complete auction scheme put forward at the time - and the situation has not changed much in this regard. This is one reason why I will keep referring to GTE's scheme in the following discussion. The other reason is that the team of consultants that worked on it also included Paul Milgrom, Padmanabhan Srinagesh, Debra Aron, and, in the summer of 1997, myself.

⁹ Milgrom's model is very similar to Dana and Spier's (1994), although they were developed independently and the latter was not aimed at Universal Service issues in particular. Both models are part of a growing recent literature on regulation with endogenous market structure. See Auriol-Laffont (1992), McGuire-Riordan (1995), Riordan (1996), and Wolinsky (1997).

¹⁰ Firms are unlikely to be asked to submit bids for an obligation that will be fully specified only later as an equilibrium outcome in another market. Moreover, there is no guarantee that the final price will be "just, reasonable, and affordable". In COLR auctions, instead, the price constraint for the winner of the auction is specified before bidding occurs.

¹¹ For example, "a central result of the paper" is that there may be "a perverse incentive for each firm to lose the auction for the rural market in order to gain the more profitable position of serving only the urban market. Equilibrium bidding then leads to a subsidy that compensates for the strategic disadvantage associated with winning. As a result, both firms ultimately benefit and earn the higher profit ... Further, the urban market has higher prices and lower quantities relative to those of unconstrained oligopoly competition (Cournot) in the urban market." (p. 13). If the Cournot game in the urban (low-cost) market is played *before* the auction and the resulting price is used to define the USO in the rural (high-cost) market, however, there would be no "perverse" incentives in the auction.

The plan of the paper is as follows. Section 2 describes the problem faced by regulators¹² and introduces COLR auctions of the form proposed by GTE. Sections 3 and 4 discuss the definition of the object of COLR auctions and the bidding format, respectively. Section 5 compares COLR auctions and uniform subsidy schemes based on cost-proxy models. Section 6 provides a summary of the argument and indicates some avenues for further research.

2. Universal Service and Carrier of Last Resort Auctions

The design of the Universal Service policy can be divided in three parts: the definition of the Universal Service obligation (i.e., the set of subsidized “core services” and the “affordable price” at which they must be available), the design of the tax scheme used to finance the Universal Service Fund, and the design of the subsidy scheme that will use those funds to guarantee the satisfaction of the USO.

In the following, I will assume that the regulators have already solved the first two problems and I will focus on the design of the subsidy scheme. This assumption places an implicit restriction on the class of mechanisms to be considered. For example, it rules out mechanisms that determine endogenously the trade-off between inclusiveness of the core services, their price, and the level of subsidies. It is, however, a realistic restriction - and one that applies equally to both auction schemes and schemes based on cost-proxy models. The FCC has already defined the set of “core services”¹³ and, though State regulators may add other services to the definition, there has been no proposal to endogenize such additions; endogenizing the “affordable price” would certainly be easier,

¹² The division of competencies between federal and State regulators is another contentious matter I will not discuss.

¹³ “[W]e define the ‘core’ or ‘designated’ services that will receive universal service support as: single-party service; voice grade access to the public switched network; Dual Tone Multifrequency (“DMTF”) signaling or its functional equivalent; access to emergency services including, in some circumstances, access to 911 and Enhanced 911 (“E911”); access to operator services; access to interexchange service; access to directory assistance; and toll-limitation services for qualifying low-income

but it also seems off the policy agenda. Finally, the Act mandates that the Universal Service Fund be financed by providers of inter-state telecommunications services¹⁴ and is thus independent of the subsidization of local services in high-cost areas.

The problem is thus reduced to one of finding a mechanism that guarantees the fulfillment of the USO while respecting the other provisions of the Act.¹⁵ As mentioned above, the FCC is investigating the use of engineering cost-proxy models to estimate the cost of providing core services in any given area. Such estimates would determine the compensation (if any) due to those eligible¹⁶ firms who will provide supported services. Given the inevitable imprecision of any cost model, there will be areas where costs are underestimated¹⁷ and where no firm voluntarily provides “affordable” service. The Act states that in such areas the regulator must appoint a Carrier of Last Resort (COLR), i.e. a carrier who undertakes the USO.¹⁸ The Act does not say, however, how such appointment is to be made, nor how the appointed carrier is to be compensated.¹⁹ One possibility is to keep raising the subsidy until some firm is willing to take it, but this is likely to lead to delays and grossly inflated subsidies. Using auctions seems a more promising alternative as it all but eliminates delays and introduces a powerful incentive to accept lower subsidies, namely the fear of losing subsidies altogether.

The Universal Service problem, as defined above, can be viewed as a non-standard procurement problem. The object that the regulator wants to procure is not a “real” good, but the guarantee that consumers in a given area will have the possibility to buy “core services” at an “affordable” price. In other words, the regulator wants to procure at least one COLR in every area and COLR auctions can be used to find out who

consumers” (par. 56 of the Universal Service Order).

¹⁴ Section 254(d). Note however that this restriction would not apply to the financing of enhancements to the Universal Service package mandated at the State level.

¹⁵ Among those, the fact that regulators cannot impose artificial entry barriers into local telephony market and, in particular, cannot award monopoly franchises. This restriction is at the root of many technical complications in the analysis of COLR auctions.

¹⁶ For the definition of “eligible carrier”, see 47 U.S.C. 214 (e).

¹⁷ Or, more generally, it gives a lower subsidy than what firms can get by raising prices above the affordable level (see Section 5 below).

¹⁸ See Section 214 (e) (2). The term “Carrier of Last Resort” is not used in the Act.

¹⁹ The problem is, of course, that compensation must be adequate to avoid running foul of the XIV Amendment's “takings” clause.

is willing to do the job for the lowest subsidy. But then why not use auctions instead of cost-proxy models to begin with?²⁰

The next two sections of the paper discusses alternative specifications of what the object of COLR auctions exactly are (Section 3) and what kind of auction format is appropriate to determine who is the best suited contractor (Section 4). The rest of this section is devoted to a brief description of GTE's COLR auction proposal, setting the scene for the discussion that follows.

2.1. A Sketch of COLR auctions according to GTE Corp.

The following is an overview of the proposal for COLR auctions presented by GTE at a workshop organized by the California Public Utility Commission on May 8 and 9, 1997.²¹

First, the proposal identified service areas with Census Block Groups (CBGs). CBGs were at the time the smallest geographical unit for which the existing cost-proxy models were able to provide cost-estimates.²² Second, subsidies would be paid on a per-subscriber basis. Third, Incumbent Local Exchange Carriers (ILECs) would be allowed *una tantum* to partially redistribute the existing level of Universal Service support (determined by a cost-proxy model) across the CBGs they currently serve. The new "rebalanced" rates would be used as interim support levels until a CBG were put up for auction and would form the basis for the auction's reserve prices. This "rebalancing" phase, intended to correct possible errors in the existing support levels, was criticized by some as giving ILECs an opportunity to stash away subsidies in CBGs where they felt less threatened by competition. It must be noted, however, that concentrating subsidies in some CBGs may simply attract competitors there. If competitors fail to materialize in a

²⁰ Auctions and cost-proxy models are not mutually exclusive: the latter can be used to determine the reserve prices (i.e., the maximum bids) in the former.

²¹ I emphasize that the following is *not* GTE's official statement on the matter, but just my interpretation of what GTE presented at the workshop. The actual proposal and later comments of GTE and other participants in the workshop are part of CPUC's record in Universal Service Proceeding R. 95-01-020/021.

²² The FCC's most recent Hybrid Cost Proxy Model, however, is not constrained to operate on

given CBG, it can be assumed that the forward-looking cost of providing service must be higher than the amount of subsidies stashed away there. If subsidies must reflect forward-looking costs (as the FCC agrees), the rebalancing phase seems justified.

Fourth, and even more controversial, GTE suggested that an ILEC who loses a COLR auction should be relieved of the obligation to provide Unbundled Network Elements at regulated prices.²³ The evaluation of this provision depends on a general analysis (legal, as well as economic) of interconnection regulation beyond the domain of the Universal Service policy, and thus beyond the scope of this paper.

Fifth, every six months there would be a "nomination phase". During this phase, existing COLRs would be able to resign their position in any of "their" CBGs. If a COLR resigned, other qualified firms that were not COLRs in the same CBG could apply to take its place at the existing support level. If more than one firm offered to do so, an auction would be conducted between them. If no firm came forward, than the CBG would be put up for auction and the reserve price would be set at a higher level than the existing subsidy. A CBG could also be put up for auction if some firm (possibly one of its COLRs) or the regulator nominated it. This would not be permitted, however, if less than three years had passed since the last change in the set of COLRs for that CBG.

Finally, the auction would be run in a sealed-bid format. The proposed allocation rule was rather complex. All bids within a pre-specified range of the lowest bid would be accepted. If no other bid was within that range, then the second lowest bid would be accepted if it was within a broader range. The winning bidders would be appointed as COLRs at a support level equal to the highest accepted bid.²⁴

CBG-level data.

²³ The obligation is described in Section 251 of the Act.

²⁴ Special rules were suggested for the case in which bids for zero subsidy were submitted. Moreover, bid withdrawals were allowed.

3. The Objects of COLR Auctions

One may think of the number of Carriers Of Last Resort to be appointed as the number of objects in a COLR auction. This would not be an entirely adequate characterization. The territory for which the regulator wishes to appoint COLRs can be divided in many service areas. Theoretically, one may run an auction for every single consumer. In a sense, the number of objects is really the number of potential consumers in the territory. The choice of how many consumers to bundle in a service area is part of the auction design problem as much as the choice of the number of COLRs that will compete for that bundle after the auction. Similarly, the duration of the COLR “franchise” can also be seen as a (temporal) bundling decision variable.

In COLR auctions, moreover, the form of support payments can affect the final allocation and is thus an integral part of the specification of the auction object. Since the choice of payment format is closely related to that of the number of COLRs, it will be discussed in this section.

3.1. Size of service areas

There are two main factors in favor of dividing the territory into many small service areas.

First, small areas are usually more homogeneous.²⁵ It is therefore less likely that some “niche player” (i.e., a firm who could efficiently serve a given market niche, but not a whole large service area) would be excluded from the market. The consequent increase in efficiency may also reduce the total amount of subsidies. The effects of service area size on the level of subsidies, however, are not clear. The increase in efficiency from small areas may be more than matched by informational gains from bundling small areas into larger ones.²⁶

²⁵ Especially if their boundaries are designed with that goal in mind! Note also that the division of the market into service areas does not have to be on a geographical basis.

²⁶ Indeed, as shown in (Milgrom, 1998), the revenue-efficiency trade-off from bundling the objects

Second, small areas may make entry into the market easier, regardless of heterogeneity problems. A new entrant would need to make investments on a smaller scale and would be able to accumulate experience (and money) in serving the area before expanding its operations.²⁷ This is not only a direct advantage (also from a political point of view), but can also contribute to lower the level of subsidies because it can increase the competitiveness of the auction.

The main potential drawback of small service areas is that a larger fraction of costs might be shared across several areas.²⁸ This would complicate the problem of efficiently allocating COLRs to different areas and might make entry harder instead of easier. According to several numerical simulations with cost-proxy models run by GTE, however, it seems that cost synergies across CBGs are quite small.²⁹ Perhaps more importantly, one must recognize that using larger service areas would not necessarily solve this problem. The optimal way to group many small areas into few large ones is not known in advance, especially because different firms will generally prefer different groupings.³⁰

of an auction may be dollar-for-dollar!

²⁷ This may be particularly important for small carriers who are more likely to face an increasing cost of capital schedule.

²⁸ The degree to which costs are fixed with respect to the area(s) serviced depends also on the possibility of buying the corresponding services from other carriers. The rules concerning competitors' access to the incumbent's network are crucial in this regard.

²⁹ In 1997 GTE ran several simulations to compute "synergy indexes" across CBGs. These indexes were equal to the ratio between the estimated cost of serving a set of CBGs (e.g., the CBGs numbered {1, 2, 3, 4, 5}) and the sum of the estimated costs of serving the elements of a partition of that set (e.g., the estimated cost of serving {1, 2, 3} plus the estimated cost of serving {4, 5}). Savings above ten percent were extremely rare. These results, however, must be taken with the customary grain of salt. The cost-proxy models available at the time may have been biased against the finding of synergies. Moreover, even current cost-proxy models are based on wire-line technology and thus give no indication about the potential for synergies in the cost structure of some of the most likely new entrants in the local phone market. Ausubel et al. (1997) find small geographical synergies from their analysis of PCS spectrum auctions, but they are concerned with much larger areas than CBGs.

³⁰ In theory, the division of territory in smaller service areas may also make collusion marginally easier, but only in so far as it allows finer divisions of the market among would-be colluders. This is unlikely to be a problem of much practical relevance.

3.2. Duration of COLR franchise

The problem of determining the duration of the franchise is not specific to COLR auctions. The choice between short-term and long-term contracts generally involves a trade-off between maintaining flexibility and providing good incentives for long-term illiquid investments. The trade-off may be particularly uncertain in the COLR context. Technological progress is expected to be quite intense and unpredictable in the telecommunications market and this seems a point in favor of short-term contracts. On the other hand, the currently standard technology for providing telephone services still involves burying cables in the ground, largely a sunk investment. Especially because of the uncertainty about future technologies, firms may demand a high premium to make those investments unless they are given a long-term contract.

Perhaps the most important factor in favor of long COLR franchises is the threat of collusion, especially because it is quite likely that just a few firms will compete to become COLRs. Collusive equilibria may be made less likely by decreasing the frequency of the auctions (i.e., by increasing the duration of the COLR franchise) and by holding all auctions at the same time.³¹

The GTE proposal deals with this flexibility-incentives trade-off by giving longer franchises to new COLRs as an extra incentive to enter the market. Although this may bias the outcome of the auction, the advantage thus given to entrants could lower the expected level of subsidy if entrants are likely to be at a cost disadvantage with respect to the incumbent (Rothkopf et al., 1996).

3.3. The number of COLRs and how to pay them

There are three potential reasons for appointing more than one COLR per service area. The first and most direct reason is that it may be technologically efficient to do so. Although diseconomies of scale are very unlikely (indeed, the likely relevance of fixed

³¹ This would increase the gains from undercutting a collusive agreement and postpone the cartel's punishment.

costs is an argument in favor of single COLRs), it may still be efficient to appoint several COLRs if different consumers are served at lowest cost by different firms and/or if firms' products are differentiated. The second reason is that it may reduce the amount of subsidy determined by the auction. This is theoretically possible, but the opposite effect seems more likely.³²

The third reason for appointing multiple COLRs is that it may be the cheapest way to guarantee that COLRs do not shirk their responsibilities. If the regulator does not observe the quality of the service offered by COLRs, they may be tempted to get rid of high-cost customers by providing them with extremely low-quality service. More generally (and, in particular, if the USO includes a target for market penetration), COLRs may try to save money by providing service whose quality is lower than the minimum specified in the USO, though still good enough for people to buy it.³³

This is also the main rationale for GTE's proposal to use per-subscriber subsidies (so that serving consumers is more likely to be profitable) and to allow for multiple COLRs in the same service area (so that consumers are not captive of a monopolistic COLR). The idea is to trade-off the benefits of competition between COLRs with the increased cost (in terms of larger subsidies) from accepting higher bids.³⁴

If fixed costs are important, however, the appointment of several COLRs may do more damage than just increasing total production costs. It also makes bidders' valuations of the COLR franchise depend on the number of subsidized competitors with whom they will have to share the market. This requires more sophisticated bidding and may result in inefficient assignment of COLR franchises.³⁵

³² Seshadri et al. (1991) argue that risk-aversion and participation costs may favor multiple source procurement even if sole sourcing is technologically more efficient. In a model of auctions for the sale of operating licenses or production capacity, Gale (1990) shows that "Expected revenue is maximized when they are all sold to a single bidder" if monopoly maximizes industry profits. In a similar context, Dana-Spier (1994) show that incomplete information about firms' cost type biases regulatory choices against dual sourcing.

³³ McGuire-Riordan(1995) provide another "moral hazard" story in favor of dual sourcing.

³⁴ The rule is similar to the optimal mechanism derived in Dana and Spier's (1994) model of auction for licenses. Note that the problem could not be solved just by having multiple COLRs if they were paid a lump sum. Moreover, in a similar duopoly context, Wolinsky (1997) shows that the regulator may sometimes achieve better outcomes by using only price, instead of relying on both price and quantity regulation.

³⁵ Recourse to a more complex auction design may alleviate this (potential) problem (see the following section).

The choice of per-subscriber subsidies is also less than innocuous as it may distort competition for the low-cost consumers in a service area that has both high-cost and low-cost ones. An efficiency-distribution trade-off similar to the one involved in the bundling of service areas may thus lurk here, too. There is also another (perhaps less obvious) similarity with the previous discussion, namely that *both total production costs and total subsidies may be higher under per-subscriber subsidies than in the lump sum case.*³⁶ The following example illustrates these possibilities.

Example: Consider a service area for which the "affordable price" has been set at p . There are two firms (Alpha and Beta) who sell homogeneous products and compete Bertrand-like in prices. There is a unit mass of consumers and they all have a perfectly inelastic unit demand. Consumers can be of two types: low-cost consumers can be served by both firms at (constant) unit costs that are lower than p ; high-cost consumers can only be served at a unit cost that is higher than p . The firms (but not the regulator) can distinguish the two types and can charge different prices to each consumer. Let a and b be the cost of serving low-cost consumers for Alpha and Beta, respectively. Let A and B be the corresponding values for high-cost consumers. Both firms know each other's cost structure.³⁷ If one firm could serve both types of consumers at a lower cost than its competitor, it would always win the auction and there would be no essential difference between lump sum and per-subscriber subsidies. Let us assume instead that Alpha is more efficient at serving high-cost consumers and Beta is more efficient at serving the low-cost ones: $0 < b < a < p < A < B$. Let q be the fraction of low-cost consumers. The regulator appoints only one COLR per service area using a second-price auction.

If lump sum subsidies are used, there is no distortion in the competition for low-cost consumers: Beta will always serve them at a price equal to Alpha's cost (i.e., at price a). The value of the COLR obligation is just the cost of selling (below cost) to the high-

³⁶ I thank Padmanabhan Srinagesh for suggesting this possibility.

³⁷ In theory, the regulator could use this fact to obtain full information about the firm's costs, too. This example, however, restricts the regulator to choose between just two second-price, sealed-bid COLR auctions: the one for lump sum subsidies or the one for per-subscriber subsidies.

cost consumers. Alpha will win the second-price auction and get a subsidy equal to Beta's cost of serving as COLR: $(B - p)(1 - q)$.

In the case of per-subscriber subsidies we must distinguish two cases. If the equilibrium subsidy s is lower than the firms' difference in the cost of serving low-cost consumers (i.e., if $s < a - b$), then Beta will keep serving those consumers even if Alpha wins the auction. If $s \geq a - b$ instead, the winner of the auction will serve the whole market - even if the winner is Alpha.

If $(B-p) < (a-b)$, then the second-price COLR auction has a pure-strategy equilibrium in which Alpha bids $(A-p) < (B-p) < (a-b)$ and wins the auction against Beta's bid of $(B-p)$.³⁸ Since the winner of the auction only serves high-cost consumers, the total amount of subsidies is $(B-p)(1-q)$ as in the case of lump sum subsidies. Since total production costs are also unchanged and the price paid by low-cost consumers is lower (it is $a-s = a-B+p < a$), total welfare increases (decreases) if consumer surplus is given a higher (lower) social value than profits.

If $2(a-b)q < (B-A)(1-q)$, there is a pure strategy equilibrium with Alpha winning the auction with a bid of $(a-b)q + (A-p)(1-q)$ against Beta's bid of $(B-p)(1-q) - (a-b)q$. Alpha would serve the whole market and total subsidies would be *less* than in the lump sum case. The decrease in the level of subsidies is exactly equal to the increase in total production costs. Total welfare increases, unless the social value of profits is sufficiently larger than the social value of consumer surplus and the shadow price of public (Universal Service) funds.

If $(B-p)(1-q) \leq (a-b)q \leq (A-p)q$ instead,³⁹ then there is a pure strategy equilibrium with Beta bidding zero and Alpha bidding $(a-b)q + (A-p)(1-q)$. Beta wins and serves the whole market. The total amount of subsidies is $(a-b)q + (A-p)(1-q)$, which is *more* than the amount of subsidies in the lump sum case. In this case, since consumer surplus is unchanged and total production costs increase, a sufficient condition for total welfare to

³⁸ I will only consider *some* pure-strategy equilibria of second-price auctions. Note that there are a lot of other equilibria. For example, when $(B - p) < (a - b)$, Beta may bid zero and Alpha can bid anything above $(B - p)$. However, bidding more than $(A - p)$ is always a weakly dominated strategy for Alpha.

³⁹ This condition is incompatible with the one in the previous paragraph. In particular, it requires that the area has a sufficiently large majority of low-cost consumers (i.e., that q is sufficiently larger than $1/2$.)

decrease with respect to the case of lump sum subsidies is that the social value of profits is lower than the shadow value of public (Universal Service) funds.

4. The Bidding and Allocation Rules

The GTE proposal calls for a relatively simple bidding format. As noted in the previous section, however, it may be too simple a format if there are large fixed costs to operate in a service area.

For this reason, GTE's proposal to the California Public Utility Commission suggested that an alternative bidding format could be adopted if fixed costs are an important concern. Firms would submit two-dimensional bids that approximately represent demand functions for the number of COLRs. The first bid component would specify the subsidy requested for being the sole COLR, while the second component would be for the appointment as one of several COLRs. The auctioneer would then choose the combination of bids that generates the highest value, taking into account the welfare advantage of having several winners.

If fixed costs are shared across several service areas, a different form of multidimensional bidding may be considered: bidding for COLR franchises in combinations of service areas. The choice of relatively small service areas (as the CBGs in GTE's proposals) may increase the likelihood of shared costs, but it also increases the number of such areas, possibly to the point of making full combinatorial bidding computationally intractable.⁴⁰ The computational problem could be particularly severe if ascending auctions were used. Some of the FCC spectrum auctions (which did not even allow combinatorial bids) took months to complete. That is simply not an option for the case of COLR auctions, especially if, as in GTE's proposals, they may be run twice a year.⁴¹

⁴⁰ See Rothkopf et al.(1995) for some examples of restrictions on the structure of allowed combinations that guarantee the existence of a polynomial time algorithm that finds the winning combination of bids (or, equivalently, that finds the least cost bid combinations that win a set of objects, given the opponents' bids.)

⁴¹ In principle, one could run ascending auctions of considerable complexity in relatively short time by asking firms to submit bidding programs as opposed to simple (numerical) bids. As far as I know, however, no auction of this kind has ever been run, possibly because it puts an excessive computational burden on the bidders - as well as demanding a lot of trust in the software designers.

There are, of course, factors other than speed and simplicity at play. Common value elements or bidders' risk aversion may push for ascending auctions (Milgrom and Weber, 1982), while the threat of collusion may suggest the use of first-price sealed-bid auctions (Graham and Marshall, 1987; Milgrom, 1987). It must be ultimately recognized, however, that the theoretical and experimental properties of multi-unit auctions, combinatorial or otherwise, are not well understood.⁴²

Even if one abstracts away from fixed or shared costs and assumes that the regulator always appoints only one COLR per service area, the unusual structure of bidders' valuation considerably complicates the analysis of COLR auctions. Unlike the designer of more standard procurement auctions, the COLR auctioneer does not have the legal authority to forbid entry in the market. The market structure can only be controlled via the auction rules determining the number of COLRs and their compensation. Even if the regulator appoints only one COLR per area, COLRs may still have to share the market with other carriers.⁴³ The firms' valuation of different auction outcomes would then depend on how these outcomes affect the equilibrium in the market after the auction. Since a firm's equilibrium profit depends on the types (e.g., the cost parameters) of all other active firms, this amounts to a violation of the independent private value assumption. The relation between a firm's profit and the opponents' type will generally be much more complex than the one considered in the existing literature on auctions with affiliated values.⁴⁴

For the same reasons, there is an externality in COLR auctions, since players may care about which (type of) competitor wins the auction. There is also another type of

⁴² As shown, for example, by Rochet-Choné (1998) and Sibley-Srinagesh (1997), optimal mechanisms with multi-dimensional types do not admit easy characterizations. The recent FCC spectrum auctions have stimulated a considerable amount of research on practical implementations of multi-unit auctions. Here I can only refer the reader to the special issue of the *Journal of Economics and Management Strategy* (6:1997), to Milgrom's (1988) paper and to the other papers available on the World Wide Web site of Market Design, Inc. at <http://www.market-design.com/library.html>.

⁴³ A necessary condition for this to happen is that there are profitable consumers in the area and that not all of them can be served most efficiently by the (best) COLR.

⁴⁴ The following paragraph on auction externalities is illustrative of the interdependence of firms' valuations, too. This is not to deny that real world COLR auctions would have elements of affiliated values in the traditional sense: after all, the bidders are competing for the same market!

externality, at least in the case in which subsidies are paid on a per-subscriber basis.⁴⁵ A sufficiently large unit subsidy given to a COLR may induce the latter to price below the regulated price (or offer higher quality than the required minimum) and affect the market niches of other carriers. Therefore, subsidies given to a firm may have external effects on other firms.⁴⁶

These external effects may be enough to make the revenue equivalence result fail even in this simple environment. Intuitively, second-price COLR auctions for per-subscriber subsidies should lead to lower support payments than their first-price counterparts. The reason is that second-price auctions give an extra incentive to bid aggressively. Should one lose the auction, it would be better if the losing bid were low, so that the winner would get a lower subsidy and be a less fearsome competitor after the auction. This intuition could be proved if bidding equilibria were achieved by strictly increasing (in own types) strategies and the bid functions were strategic complements. Unfortunately, a general theorem to this effect is unavailable. Bid functions are *not* strategic complements in COLR auctions for per-subscriber subsidies (at least in the standard pointwise partial order on the space of bid functions) and it is not possible to derive closed form solutions.⁴⁷

COLR auctions for lump sum subsidies are somewhat more tractable, but also for them bid functions are not necessarily strategic complements. It is therefore impossible to obtain robust rankings of first- and second-price auctions in terms of expected levels of subsidies.

⁴⁵ The externality to be described may be present also in the case of lump-sum subsidies, e.g., if firms face an increasing cost of capital and the subsidy is paid in advance.

⁴⁶ Both these external effects and the value a firm puts on its own subsidy will depend on the shape of the firms' cost and demand functions. The relation between a firm's valuation and its opponents' subsidy levels may even be non-monotonic. Consider the case of two competing COLRs who would be glad to have the opponent receive enough incentives to serve some particularly high-cost customer, but would not like the opponent to receive so much support that she monopolizes the market.

Note also that this is a different form of externality from the one studied by Gale (1990), Jehiel, Moldovanu, and Stacchetti (1996), or Segal (1997). They consider externalities that depend on the allocation of the auction/contractual object(s), but do not depend on the size of the payments. In the case of unit subsidies, payments are not merely monetary transfers: they affect the real allocation.

⁴⁷ Except (trivially) when it is known in advance that no firm is willing to provide service without a subsidy. In this case, only the COLR will provide service and the cost of the COLR obligation is independent of the other bidders' types. The auction then becomes a standard procurement problem and the revenue equivalence theorem applies.

5. COLR Auctions vs. Cost-Proxy Models

The previous sections of this paper have discussed how to best design a COLR auction. This section uses a simple model to compare COLR auctions and uniform subsidy schemes based on cost-proxy models (CPM). It can be easily seen that the two mechanisms cannot be ranked on purely theoretical grounds. A COLR auction would be pointless if only one firm could reasonably offer service in the area and the CPM estimates were accurate. On the other hand, a wildly inaccurate CPM may make a COLR auction attractive even with a modicum of potential competition. The interesting fact, as shown in the model below, is that *a COLR auction may lead to higher welfare levels than a CPM-based scheme even if the CPM is extremely accurate.*

A few comments about the CPM-based scheme considered in the following model are in order. According to the FCC's Universal Service Order, "federal support should be calculated by determining the forward-looking economic cost of providing the supported services reduced by a nationwide revenue benchmark calculated on the base of average revenue per line" (par. 223). This approach would not ensure that the support payments in a given area would be "sufficient" (as required by the Act) and that the area would be voluntarily served by some carrier. Therefore it must rely on imposing an asymmetric (hence not entirely "competitively neutral") burden on some carriers (the ILECs) without the guarantee of sufficient compensation. In the following, instead, I will consider only CPM-based schemes that pay the minimal subsidy for which one or more firms *voluntarily* serve the whole market. I will also assume that the CPM-based scheme pays the same subsidy for all sales of service at the affordable price or less, even if the selling carrier does not pledge to serve all consumers at that price. This agrees with the description of the subsidy scheme in the FCC's Universal Service Order - and it allows a starker contrast with the analysis of auctions when subcontracting is not possible.⁴⁸

⁴⁸ In the following model, this will guarantee that adoption of the uniform subsidy scheme never causes any production inefficiencies. In the absence of subcontracting, COLR auctions will always be

5.1. Model set-up

As in the previous example, there are two firms (now called Left and Right) competing Bertrand-like for a unit mass of consumers who can be of two types (Western and Eastern). Let q be the fraction of Western consumers in the service area and p the "affordable price". Both types of consumers have inelastic unit demands for the firms' (homogeneous) services. The regulator cannot distinguish between the two types, nor does she know how to separate them by partitioning the service area. Firms, however, can distinguish the two types of consumers. For the Left firm, the (constant) marginal cost of serving a consumer is l if the consumer is a Westerner and $L > l$ if the consumer is an Easterner. The opposite ranking of consumers holds for the Right firm: serving an Easterner costs r and serving a Westerner costs $R > r$.⁴⁹

I assume that all consumers are high-cost and, to make things interesting, that neither firm has an absolute cost advantage over the other:

ASSUMPTION: $0 < p < l \leq r < R \leq L$.

Consumers		Firm	
		Left	Right
Type	Share		
Western	q	l	R
Eastern	$1 - q$	L	r

Table 1.

technically inefficient.

⁴⁹ See table 1 below. For mnemonic purposes, capital letters denote higher numbers than the corresponding lower case letter and I use boldface for the cost of serving Western consumers.

5.2. Cost-Proxy Model Schemes

Let us consider a scheme that pays a uniform subsidy of s for any sale at a price no higher than p . The minimal subsidy level that can satisfy the Universal Service goal is then $\underline{s}^{\text{CPM}} = r - p$. There is in fact a Nash equilibrium in which both firms offer service at price p , take the subsidy and divide the market efficiently.⁵⁰ The Left firm gets a profit of $P_L = q(r - l) \geq 0$ and the Right firm gets $P_R = 0$.

This equilibrium, however, is Pareto-dominated by many others in which the firms forsake the subsidy and set prices higher than p . For example, the firms are much more likely to coordinate on the equilibrium in which they price-discriminate and offer service at price R to the Westerners and L to the Easterners. The firms would divide the market efficiently⁵¹ and obtain profits $P_L = q(R - l) > q(r - l)$ and $P_R = (1 - q)(L - r) > 0$. Even if firms were unable to price-discriminate, they would still be likely to coordinate to an equilibrium that fails to satisfy the Universal Service goal. They would both set a price equal to R (hence larger than the affordable price p), divide the market efficiently, and obtain profits $P_L = q(R - l)$ and $P_R = (1 - q)(R - r)$.⁵²

In sum, it seems reasonable to assume that the lowest uniform subsidy that can satisfy the Universal Service goal is $s^{\text{CPM}} = R - p$.⁵³

⁵⁰ Since they set the same price, consumers gain nothing from going to the "wrong" supplier (note that this would not be true if the firms' products were differentiated). As for the firms, setting any price higher than p would send all consumers to the other firm and result in zero profits. Lower prices would attract all consumers and net negative profits. Price-discrimination would not help either.

⁵¹ To avoid tie-breaking problems, the Left firm may offer a slightly lower price to the Westerners and the Right firm may offer a slightly lower price to the Easterners.

⁵² Again, the consumers have no incentive to shift. Setting higher prices would give zero profits and lower prices would only bring in unprofitable consumers.

⁵³ Of course, if the regulator really knew the firm's cost structure (i.e., if she knew q, l, L, r , and R), she would like to stop worrying about incentives, simply order the firms to set prices equal to p , and pay compensation ql and $(1 - q)r$ to the Left and Right firm respectively.

5.3. Carrier Of Last Resort Auctions

Let us now consider an auction for a single COLR position. Since no consumer is profitable without subsidies and every consumer is willing to buy at the affordable price, there is no difference between per-subscriber and lump sum payments. For simplicity, and without loss of generality, consider a second-price auction and let us assume that the reserve price, if there is one, is higher than L . If firms cannot negotiate resale agreements after the auction, the Left firm will bid $[(l-p)q + (L-p)(1-q)]$ and the Right firm will bid $[(R-p)q + (r-p)(1-q)]$. The firm with lower average total costs ($\text{Min}\{[lq + L(1-q)], [Rq + r(1-q)]\}$) wins, serves the whole market, and gets a subsidy equal to

$$\begin{aligned} s^{\text{NR}} &= \text{Max}\{[lq + L(1-q)], [Rq + r(1-q)]\} - p = \\ &= lq + r(1-q) - p + \text{Max}\{(L-r)(1-q), (R-l)q\}. \end{aligned}$$

The auction outcome without resale is surely inefficient: production costs are larger than in the first-best case by $\text{Min}\{(L-r)(1-q), (R-l)q\}$. The inefficiency, however, may be compensated by lower subsidies. In fact, although $s^{\text{NR}} > \underline{s}^{\text{CPM}}$, we have $s^{\text{NR}} < s^{\text{CPM}}$ if and only if $[lq + L(1-q)] < R$. Therefore, *if the shadow value of public (Universal Service) funds is sufficiently high, a COLR auction may be welfare-superior to a CPM-based scheme even if the CPM is accurate and there is no possibility of subcontracting.*

5.4. COLR auctions with resale

COLR auctions' production inefficiency disappears (in our perfect information model) if one considers the possibility of resale. In the COLR context, resale can be achieved in three ways: directly, if COLR status is transferable; by subcontracting the provision of service to some or all consumers in the service area; or by renting or buying other firms' productive assets. The Telecommunications Act mandates that incumbent Local Exchange Carriers make resale of their services possible by providing competitors with wholesale discounts and access to their Unbundled Network Elements at regulated prices. Although no similar obligation exists for other carriers, resale can be the outcome

of voluntary bargaining. If post-auction bargaining is efficient, consumers will be served by the firm that is most efficient at doing so.

The possibility of resale surely reduces total production costs. What about the level of subsidies? Milgrom (1987) has shown that, in a standard auction with complete bidder information, the possibility of resale increases the auctioneer's revenue - even if the auction without resale was already efficient.⁵⁴ This is not necessarily true in the COLR auction context, however, as it depends on how winning the auction affects bargaining power: if COLR status causes a sufficiently strong loss in bargaining power, then the possibility of resale may increase the subsidy level.⁵⁵

Let us consider the previous example and assume that, after the auction, firms' bargaining leads to the efficient allocation.⁵⁶ For notational simplicity, let us assume that a firm's bargaining power (measured by the share of the gains from trade that the firm gets from the post-auction bargaining) depends only on whether that firm is a COLR. Let a be the bargaining power of a COLR and consider the Left firm first. If it wins the auction, it will serve the Westerners directly and pay the Right firm to serve the Eastern consumers. The resale price will be $r + (1-a)(L-r) = ar + (1-a)L$ and Left's profit will be $P_L(\text{wins}) = p + s - [ql + (1-q)(ar + (1-a)L)]$. If Left loses the auction, it will be paid by Right to serve the Western consumers. The resale price will be $l + (1-a)(R-l) = (1-a)R + al$ and Left's profit will be $P_L(\text{loses}) = q(1-a)(R-l)$. Left's bid in the auction will then be $P_L(\text{loses}) - P_L(\text{wins}) = \{a[ql + (1-q)r] + (1-a)[qR + (1-q)L]\} - p$. A similar calculation shows that the Right firm will bid exactly the same,⁵⁷ so the level of subsidies will be

$$s(a) = \{a[ql + (1-q)r] + (1-a)[qR + (1-q)L]\} - p.$$

⁵⁴ Haile (1997), however, shows that resale may reduce revenues in some environment where bidders have private uncertainty over the value of the object.

⁵⁵ Kamien, Li, and Samet (1989) make a similar point in a somewhat different model of bidding with subcontracting.

⁵⁶ The welfare ranking of COLR auctions and CPM-based schemes then depends only on which of them leads to lower subsidy levels (at least in the standard case in which the social value of profits is lower than the shadow value of public funds).

⁵⁷ The fact that the firms will bid the same amount does not depend on the number of consumer types, the initial bargaining power, or on how winning the auction affects bargaining power. It does depend, however, on the perfect efficiency of post-auction bargaining and (unless there is enough *ex-ante*

It is easy to see that if the COLR obtains all the gains from subcontracting ($a = 1$), the possibility of resale *lowers* the level of subsidy

$$s(1) = [ql + (1 - q)r] - p < \text{Max}\{[lq + L(1-q)], [Rq + r(1-q)]\} - p = s^{\text{NR}}$$

and makes it no higher (and almost always strictly lower) than under the cost-proxy scheme

$$s(1) = [ql + (1 - q)r] - p \leq r - p = \underline{s}^{\text{CPM}} < R - p = s^{\text{CPM}}.$$

If instead the COLR loses all bargaining power ($a = 0$), the possibility of resale *increases* the level of subsidies

$$s(0) = [qR + (1 - q)L] - p > \text{Max}\{[lq + L(1-q)], [Rq + r(1-q)]\} - p = s^{\text{NR}}$$

and makes it no lower (and almost always strictly higher) than under the cost-proxy scheme

$$s(0) = [qR + (1 - q)L] - p \geq R - p = s^{\text{CPM}} > r - p = \underline{s}^{\text{CPM}}.$$

Finally, if $a = 1/2$ or, more generally, if bargaining power is independent of COLR status, similar calculations show that the possibility of resale reduces (almost always strictly) the level of subsidy. The comparisons with both s^{CPM} and $\underline{s}^{\text{CPM}}$ become ambiguous.⁵⁸

6. Conclusions

The preceding discussion has highlighted three classes of variables that can affect the design of auctions for Universal Service subsidies: the presence of fixed and shared

symmetry in bargaining power) on having only two bidders. The proof is available upon request.

⁵⁸ If \square is the Left firm's bargaining power, the level of subsidy is

$$s(\square) = ql + (1-q)r - p + \text{Max}\{[\square q(R - l) + (1 - \square)(1 - q)(L - r)], [(1 - \square)q(R - l) + \square(1 - q)(L - r)]\} \leq \\ \leq ql + (1-q)r - p + \text{Max}\{q(R - l), (1-q)(L - r)\} = s^{\text{NR}}.$$

As q and \square tend to $1/2$, $s(\square)$ tends to $(l + r + R + L)/4 - p$ which may be larger than $R - p = s^{\text{CPM}}$ or even smaller than $r - p = \underline{s}^{\text{CPM}}$.

costs, the heterogeneity of service areas, and the regulators' ability to control market outcomes after the auction.

The design variables whose choice depends on these factors include, *inter alia*, the division of the territory into different service areas, the form in which subsidies should be paid, the number of supported firms, and the bidding format. The interaction between these variables is quite complex and the following is only a rough summary.

Per-subscriber subsidies and competing Carrier Of Last Resort (COLRs) are favored when the regulator cannot cheaply enforce the provision of adequate service quality and they can be more efficient than the use of quantity targets. The appointment of multiple COLRs may result in higher subsidies, either because of fixed costs or simply because less efficient firms would be supported. It may also be preferable, however, when cost heterogeneity and/or product differentiation are such that different consumers in the service area are best served by different firms. Heterogeneity can be a factor militating in favor of lump-sum (i.e., per service area) subsidies, because they do not distort the post-auction competition between COLRs and other firms. On the other hand, it is possible that such distortions generate extra-profits for the COLRs and thus reduce the amount of subsidy they need. If that is the case, and the shadow price of subsidies is high, heterogeneity may favor per-subscriber subsidies after all.

It seems reasonable to assume that much service area (cost) heterogeneity could be eliminated by reducing the size of service areas. This would probably improve the allocative efficiency of the post-auction competition, although it might carry a price in terms of higher subsidies and bidding complications due large fixed costs shared across several bidding areas. The choice of small, hence numerous, service areas favors the use of a sealed-bid auction format with limited possibilities for combinatorial bidding. Theoretically, a sealed-bid first-price format may also help reduce the potential for collusion, but probably the most effective practical antidote to collusion in COLR auctions lies probably in the choice of long COLR franchises. Finally, the regulator should try to strengthen the COLRs' bargaining power in subcontracting (i.e., resale) markets as this reduces the equilibrium level of subsidies.

In sum, COLR auctions can be adapted to a variety of economic environments. The question is whether they would work better than a system based on engineering cost models as the one currently envisioned by the FCC. It is not a question that can be answered on purely theoretical grounds. The cost model approach has the advantage of achieving perfect competitive neutrality (everyone gets the same per-subscriber subsidy) and thus avoiding any distortions in the post-auction market. In general, however, this comes at the price of higher subsidies, hence greater distortions in the low-cost markets that are taxed to finance the Universal Service Fund.

I conclude by mentioning a few items on the research agenda. The first, and perhaps most obvious, item is to consider explicitly non-linear production functions and product differentiation. Second, it is necessary to extend the analysis to the asymmetric information case, to find conditions under which COLR auctions (especially auctions for per-subscriber subsidies) admit Bayes-Nash equilibria - and to develop algorithms that compute them. Third, and perhaps most importantly, the analysis must be extended to include the fact that ILECs have obligations (and, maybe, rights) not shared by other carriers. ILECs already have a network in place and they must provide access to its elements at regulated rates to any competitor. On the other hand, they may be entitled to recover the investments they have already made to build their network.⁵⁹ The existence of the ILEC's network may also suggest the use of more complex regulatory schemes - for example,⁶⁰ schemes that can endogenously allocate the ownership of existing assets.

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⁵⁹ See (Sidak-Spulber, 1997).

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⁶⁰ See (Stole, 1994).

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