Dynamic Effects of Price Cap and Rate of Return Regulation on Exchange Carrier Incentives

Neal C. Stolleman

Columbia Institute for Tele-Information
Graduate School of Business
809 Uris Hall
Columbia University
New York, New York 10027
(212) 854-4222

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Dr. Neal C. Stolleman[1]

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I Introduction

The purpose of this paper is to examine the effects of alternative regulatory forms and cost allocation rules on an exchange carrier's pricing, investment and innovation incentives. In particular, two forms of regulation are considered: traditional rate of return rate base regulation and price cap regulation. Also, when an exchange carrier operates in both regulated and unregulated markets[2], cost allocation rules may come into play, determining the method whereby a portion of the costs of network resources used in the joint production of several services is allocated among those services for purposes of setting rates. Regulation and cost allocation rules can have an important influence on an exchange carrier's incentives.[3]

The analytical model developed for exploring these issues represents a stylized version of an exchange carrier in which the firm sells a generic basic service arrangement to retail customers in a regulated market, and also sells the same basic service arrangement to other entities who apply their own value added resources to produce enhanced services for sale in an unregulated, competitive retail market. The exchange carrier itself may be affiliated with one of these enhanced retail operations. For this exercise, it is assumed the exchange carrier is subject to an effective Open Network Architecture (ONA) constraint, and charges the same uniform price for the generic underlying service arrangement, regardless of who the customer is.[4]

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[1]This paper is based on work the author completed for the Economic Analysis Subcommittee of USTA (Broad band ISDN Work group), and before coming to Bellcore in February, 1990. The views expressed are those of the author and are not intended to represent the views of Bellcore nor any of its owner/client companies.

[2]For example, an exchange carrier might provide a form of basic access on a retail basis to "traditional" telephone company customers, while selling the same access arrangements on a wholesale basis to entities who apply their own value added resources to produce an enhanced service for retail consumption. This kind of integrated industry structure seems most likely to emerge, given the apparent regulatory trend in the direction of opening up local exchange networks, as well as development of wireless technologies that can be overlaid on the wireline infrastructure.

[3]For the most part, results related to cost allocation derived in previous work will be assumed to hold. See: Stolleman, Some Dynamic Effects of Cost Allocations Between Regulated and Non-Regulated Exchange Carrier Operations, Proceedings of the Bellcore-Bell Canada Conference on Telecommunications Costing, San Diego, CA., 1989

[4]The use of non-linear pricing is not considered here. In a previous paper, the author discussed the properties of a pricing structure that would maximize economic welfare by explicitly reflecting cross elasticities of demand and cost complementarities in determining marginal prices (see Stolleman, A Generalized Non-Linear Price Structure with Application to Open Network Architecture, presented at the International Telecommunications Society meetings, Cambridge, MA, 1988).

II Model Structure

The list of variables and functions used in the model are as follows:

1)

Glossary

$Q^R = BasicOutput = Q^{R1} + Q^{R2}$

$Q^{R1} = \text{Re}\,tail$

$Q^{R2} = Wholesale$

$VC = VC(Q^R, K, I^N)$

$VC = VariableCost$

$K = EffectiveCapital$

$I^N = No\min alGrossInvestment$

$B = EfficiencyParameter$

$K^N = No\min alCapital$

$K = K^N B$

$\dot{B} = BG - hB$

$BG = GrossChange$

$h = ObsolesenceRate$

$C = C(BG), AdjustmentCost$

$\dot{K} = I^N B - \delta K$

$\delta = Depreciation$

The exchange carrier is assumed to produce a generic type of basic service arrangement, part of which is sold to retail customers in a regulated market, while the remaining portion is sold to enhanced service providers who apply their own value added resources. The basic service arrangement can be thought of as being designed for narrow band transmission, while the enhanced service can be interpreted as broad band.

The exchange carrier uses capital and labor resources to produce its generic basic output. It augments and/or replaces its capital stock each year by engaging in a rate of gross investment. When the firm changes the rate of additions to its capital base it incurs two kinds of cost. The first is an acquisition cost associated with purchasing new assets. The second is an internal adjustment cost associated with integrating the new capital into ongoing operations. The firm also augments or maintains the quality of its network capital[5] by undertaking expenditure that increases its state of technical knowledge. Technical knowledge is summarized by a single variable termed an efficiency parameter which services to convert nominal physical assets into effective, or quality adjusted units. In particular, costs are incurred when the firm changes the rate at which it adds to its technical knowledge, i.e., the rate of change in the efficiency parameter.[6] Each year, the firm's gross investment in capital embodies the current state of technical knowledge. The assumption is maintained that the exchange carrier strives to maximize the present value of its profit stream, and that it chooses its investment rate and level of quality so as to achieve this goal subject to its internal cost structure and any external regulatory constraints.

The rate of return constraint sets the authorized rate of return equal to the ratio of gross profit divided by the regulated rate base. Gross profit is defined as regulated revenue less (the allocated portion of)[7] variable resource and innovation related adjustment costs. The regulated rate base is the fraction of the nominal capital base assigned to regulated operations. The rate of return constraint is expressed as:

2)

$$ROR\ Constraint: \quad P_q(Q^{R1}+Q^{R2}) - VC(Q^R, K, I^N) - C(BG) = S\alpha_K P_K K^N$$

$$S = Authorized\,Return$$

$$\alpha_K = AllocatedRateBase$$

The price cap constraint is specified as a generic relationship between the expected cap placed on the basic service arrangement and the following current period variables: basic output, quality adjusted capital stock, rate of nominal gross investment, level of technical knowledge (or efficiency parameter) and the rate of change in the efficiency parameter. Hypotheses are presented with respect to how changes in these variables are ultimately reflected in changes in the expected price cap applied to the basic service. For example, if output were to increase, all other variables held constant, one would expected the calculated level of productivity to be higher, hence the cap would be lowered through the operation of regulatory procedures. Those procedures are not examined explicitly, but

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[5]Generic quality, in the context of this stylized model, can represent 1) an increase in capacity on the same nominal physical transmission facility, 2) an increase in reliability through greater redundancy or 3) Software enhancements that support service creation, efficient routing or self-diagnostic repair functions. Whatever the form quality manifests itself, there is an associated cost of adjusting the state of technical knowledge to a higher level, analogous to the cost of adjusting the stock of capital.

[6]The firm decides the rate of gross investment in technical knowledge, where gross equals net new increments to knowledge plus replacement knowledge necessary just to offset obsolescence.

[7]The allocated portion is set equal to unity, based on previous work (see fn.).

the expected outcomes are expressed in terms of the direction in which the cap is changed.

Another decision variable of the exchange carrier is the price it charges for its underlying, basic service arrangement. Although ONA constraints may force the uniform price to be the same for all types of customers, the price level is subject to the firm's discretion, depending upon the form of regulation and cost allocation rules in place.

Therefore, pricing, investment and quality are decisions that are made jointly as part of the firm's profit maximizing behavior. For the exchange carrier under consideration, the profit maximization problem to be solved is:

3)

$$ProfitMaximization:$$

$$\int e^{-rt}\{(1-\lambda_1)[P_q(Q^{R1}+Q^{R2})-VC(Q^R,K,I^N)-C(BG)-\alpha_K U_K K]+$$
$$\lambda_1\left[S\frac{P_K}{B}-U_K\right]\alpha_K K+P_x X^T-P_q q^T-P_t Z^T-(1-\alpha_K)U_K K+$$
$$\lambda_2\left(P_q-\vartheta(Q^R,K,I^N,B,BG)\right)\}dt$$

$$P_x = EnhancedService\,Price$$
$$X^T = EnhancedServiceQuantity$$
$$Z^T = ValueAdded\,Resources$$
$$P_t = Price$$
$$\lambda_1 = LagrangeMultiplier, ROR$$
$$\lambda_2 = LagrangeMultiplier, PriceCap$$
$$\vartheta(Q^R,K,I^N,B,BG) = PriceCapFunction$$

and

$$U_K = \frac{P_K}{B}(r+\delta+\frac{\dot{B}}{B}-\frac{\dot{P}_K}{P_K})$$
$$U_K = Rental\,Price$$
$$r = discountrate$$

III Pricing Decision for the Basic Service Arrangement

In the absence of regulation, a profit maximizing firm would equate the marginal revenue to the marginal cost of the service in question. Alternatively, this means that the percent mark-up of price over marginal cost would be equal to the inverse of the elasticity of demand for the service. The existence of rate of return and/or price cap regulation and cost allocation[8] rules, along with a vertically integrated exchange carrier production structure leads to a more complicated decision rule, as shown by equation (4) below:

(4)

Pricing Rule:

$$(P_q - \frac{\partial VC}{\partial Q^R}) / P_q = -\left[\frac{1 + \left(\frac{1}{1-\lambda_1}\right)\left(\frac{X^T \partial P_x}{q^T \partial P_q} - 1\right) S_{qt}}{\eta_{Q^R}} \right] + \left(\frac{\lambda_2}{1-\lambda_1}\right)\left[\frac{\partial \vartheta}{\partial Q^R} - \frac{\partial P_q}{\partial Q^R}\right]\frac{1}{P_q}$$

The first point to note is that the percent mark-up of price over marginal cost will be smaller to the extent the exchange carrier uses its own basic service in the production of its own enhanced service, X_t, because the mark-up affects the exchange carrier's profit. (S_{qt} is the share of the exchange carrier's basic service used in its own production). On the other hand, to the extent its self-induced cost increases can be passed onto the retail market, its incentive to behave as an unconstrained profit maximizing firm is strengthened. If this flow through effect were completely effective, the ratio shown in the numerator of (4) would be equal to unity, and the pricing rule would resemble the usual inverse elasticity rule. This means that the extra cost the exchange carrier imposes

[8]In previous work, (see fn. 3) it was shown that the distorting effects of cost allocation rules would be lowered if allocating percentages were "frozen",i.e., not sensitive to the mix of services produced. It was also shown that all of the non-rate base costs (expenses) associated with producing the basic service arrangement should be allocated to the regulated sector, and none of the costs allocated to the unregulated sector, so that accurate marginal cost consequences of production decisions would be revealed These results have already been imposed on equations 3 and 4.

on itself by virtue of increasing the price of the basic service is reflected, dollar for dollar, in higher enhanced service revenue. Such a one for one correspondence, however, is not very likely. The extent of the flow through effect depends on the market conditions for the enhanced service, and the propensity of other retail entities to either substitute to their own facilities or leave the industry entirely.[9]

Secondly, the elasticity of demand for the basic service arrangement is a weighted average of the elasticities in the retail and wholesale markets. The derived elasticity of demand for the basic output as a factor of production, in turn, depends on the share of that factor in the cost of producing the enhanced service and the availability of substitutes, i.e., the propensity of retail firms to build their own facilities.[10]

It is noted that the "tighter" the regulatory constraint, the lower the mark-up of price over marginal cost. Thus, the mark-up is influenced by rate of return regulation, the market structure for the enhanced service and the degree of the exchange carrier's participation in that market.[11] The more severe the rate of return constraint the lower the price mark-up over marginal cost. On the other hand, the smaller the exchange carrier's participation in the enhanced service market, or the larger the price flow-through effect, the higher is the price mark-up for the basic service. [12]

The effect of price cap regulation on the pricing decision depends on how a change in basic output affects the price cap applied to the output, relative to the market clearing price.. For example, if the price cap were not very sensitive to changes in the level of output, the firm's pricing solution would be characterized an equilibrium price below the pure profit maximizing price, and correspondingly higher production. This would represent a stable solution. On the other hand, if regulatory procedures were such that the price cap were extremely sensitive to the level of production, the firm would have an incentive to raise the price-marginal cost mark-up. By doing so, the level of output would be reduced and the calculated price cap would increase faster than the market

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[9]If facility substitution is easy, an increase in the underlying access service price will not result in any significant decrease in enhanced service supply, and the flow through effect will be negligible.

[10]The market for the generic enhanced service is assumed to be competitive in that there are a large number of firms with access to the same technology. However, firms may be distributed according to a managerial "quality" parameter reflected in the fixed cost component of their cost functions. Therefore, the industry supply curve could be upward sloping, although no firm is large enough to exert any influence over market price. When the exchange carrier raises the price of its basic service arrangement, certain firms on the margin (due to low managerial efficiency) will be induced to exit the industry. This effect is included implicitly in the derived elasticity for the exchange carrier's service, as well as the marginal flow through effect on the equilibrium price of the enhanced service.

[11]As was stated earlier, certain results derived with respect to cost allocation mechanisms are imposed on the pricing (as well as investment and innovation) solutions (see fn. 7). For example, if cost share of costs allocated to the regulated operations were sensitive to the mix of basic regulated and enhanced service output (leaving aside the issue of units of measurement) there would be an additional term in the equation.

[12]It is important to recognize that marginal cost itself is conditional on the prevailing level of the capital stock. Therefore, even if the mark-up reduced to the inverse elasticity rule because the firm was not producing any enhanced service with its own basic service, resource use would still not be efficient if rate of return regulation resulted in a sub optimal capital base that distorted marginal cost calculations.

clearing price, leading to a loosening of the price constraint. If the cap were expected to exactly match variations in the basic service price, as a function of quantity, effectively there would be no constraint.[13]

The qualitative conclusion to be drawn is that if the policy goal is to induce a lower price for the basic service then downward cap adjustments in response to increases in output (and presumably productivity) should be restrained to be less than the variation in the market clearing price.

Over time, the pricing solution and incentives just described would be re calibrated as the capital base and rate of investment changed, leading to different marginal cost calculations. Different prices would lead to changes in output and price cap adjustments as well.

IV Investment Decision

The first order condition determining the rate of investment is:

5)

$$
\begin{aligned}
-\frac{\partial VC}{\partial K} = {} & \frac{P_K}{B}\left(r+\delta+\dot{B}/B-\dot{P}_K/P_K\right)+ \\
& \frac{\partial VC}{B\,\partial I^N}\left(r+\delta+\dot{B}/B-\dot{VC}_{I^N}/VC_{I^N}\right)- \\
& \left(\frac{\lambda_1}{1-\lambda_1}\right)\left(S\alpha_K-(r+\delta+\dot{B}/B-\dot{P}_K/P_K)\right)\frac{P_K}{B}+ \\
& \left(\frac{\lambda_2}{1-\lambda_2}\right)\left[\frac{\partial \vartheta}{B\,\partial I^N}\left(r+\delta+\dot{B}/B-\dot{\vartheta}_{I^N}/\vartheta_{I^N}\right)+\frac{\partial \vartheta}{\partial K}\right]
\end{aligned}
$$

In the absence of regulation, investment at each point in time on the firm's optimal trajectory would be determined by a balancing of marginal costs and benefits. The benefit of the investment decision in this model is the marginal savings in variable resource expenditure, made possible by the substitution towards more (quality-adjusted) capital intensive methods of production.[14]

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[13] Asymmetrics built into the price cap rules would probably prevent the upward pricing strategy described. However, if the cap is extremely sensitive to changes in the level of output, there would be instability in the downward direction. For example, the decline in service price to meet the cap would increase output, leading to such a significant downward cap adjustment that the basic service price would have to be lowered again, and so on.

[14] In addition to increasing the capital/labor ratio, the capital stock is defined in quality-adjusted or effective units of capital, not nominal units. For example, the substitution effect could be in terms of reduced maintenance and network administrative expenses due to the addition of capital that embodied automated self-diagnostic and repair procedures, and optimal routing

The first element on the cost side consists of the one time cost of acquiring a capital asset, converted into a rental flow. Since the capital stock is being measured here in effective units, its nominal acquisition cost is also expressed as a cost per effective unit of capital, simply by dividing the nominal price by the efficiency parameter being used to represent an index of quality. The conversion of this quality-adjusted price into a rental cost is achieved by applying the discount rate and rate of depreciation. In addition, the expected rate of change in the quality-adjusted acquisition cost of capital is included in the rental price calculation. Thus, the cost of investing in a dollar's worth of capital today, as opposed to deferring the investment one time period, includes the foregone interest income, depreciation on the asset and the avoidance of next period's capital price inflation. If the level of quality of capital is expected to increase faster than the nominal acquisition cost, however, the rental cost of investing today is increased in the sense that the firm is foregoing the purchase of a higher quality asset next time period.

The second cost element is the firm's internal adjustment cost associated with integrating the added capacity into ongoing operations. As with the acquisition cost discussed above, the internal adjustment cost is expressed in quality adjusted terms,[15] and is also converted into a rental equivalent. The conversion from a stock to a flow cost utilizes the discount rate and depreciation rate. In addition, the expected inflation in resource prices associated with the marginal adjustment (quality adjusted) is included in the rental cost calculation. This is analogous to the expected change in the external acquisition price of capital.

In the absence of regulation, benefits and costs would be equalized at the margin, at each point on the firm's trajectory. The distortion introduced by rate of return regulation is that a differential is opened up between the authorized rate of the return and the rental cost of acquiring capital. In the traditional one sector A-J model[16] this differential provides an incentive for the firm to over invest. In this two sector model, a portion of the rate base is allocated to the regulated side of the business, leading to a lower effective authorized rate of return. It is possible, therefore, if the allocation percent is low enough, to apparently eliminate the incentive to over invest. The allocation ratio that achieves this balance turns out to be the ratio of the rental price of acquiring capital divided by the authorized rate of return.

This outcome, however, is only superficially correct. On the surface, it might appear that by setting the effective authorized rate of return equal to the rental cost of acquiring

algorithms.

[15]Technically, the variable cost function of the firm depends on output, quality-adjusted capital stock and nominal units of gross investment. Nominal units of gross investment are used because there are costs associated with adjusting nominal capital that are independent of the quality of the assets; for example, costs of digging up a street to lay conduit may be essentially independent of the type of transmission medium pulled through the conduit. Quality related costs are included in a separate cost function.

[16]See Baily, The Economic Theory of the Regulatory Constraint, 1973

capital the excess investment incentive is removed, and only "true" marginal benefits and costs enter the investment decision. The problem is that capital and its price are quality adjusted, and the level of quality, (i.e., the efficiency parameter) may in fact be distorted by the regulatory framework. To reiterate, pricing, investment and quality decisions are jointly determined, although for exposition they are being discussed one at a time. The issue of whether the investment and innovation decisions can both be made efficient by manipulating the control variables of the regulatory system will be discussed below.

As far as price cap regulation is concerned, the distortion introduced into the investment decision depends on how the cap is adjusted in response to certain variables. Specifically, the expected price cap is assumed to be a function of the level of the quality adjusted capital stock and also the rate of investment in new capital. Loosely speaking, one would expect an increase in the capital stock to be associated with an increase in observed total factor productivity, and therefore a decline in the expected cap on the basic service price. This inverse relationship is assumed to hold. In addition, to the extent that a firm's rate of investment increases one might also expected an upward adjustment in the cap, to compensate the firm for the cash flow consequences of its investment outlay which is undertaken in support of network modernization. Such a process would correspond to the "exogenous" cost adjustment that has been mentioned with respect to price cap regulation.[17] Admittedly, this particular structure for the price cap adjustment process is conjectural, although in the author's opinion eminently logical. It will be taken as a maintained hypothesis for now.

Thus, the net effect on investment incentives depends on whether the investment flow or capital stock dominates the price cap adjustment. The investment flow impact on the cap turns out to have a structure very similar to the rental costs associated with augmenting capital. The marginal change in the expected cap is quality adjusted by the efficiency parameter, and then converted into a flow rate by the discount rate, depreciation rate and expected rate of change in the marginal cap adjustment. The upward cap adjustment is essentially an offset to the internal adjustment cost of adding capital.

One clear result from this derivation is that if the firm expects regulators to allow it a higher marginal cap adjustment in response to investment next year, its incentive to invest this year will be reduced. If there is an explicit policy goal of stimulating investment for network modernization, then raising expectations for an accommodating cap adjustment in the future leads to a deferral of investment in the nearer term.

[17]FCC reference [to be added]

V Innovation Decision

The rate of change in the efficiency parameter is determined by:

6)

$$-\left(\frac{\partial VC}{\partial I^N}+P_K\right)\frac{\partial I^N}{\partial B}=\frac{\partial C(BG)}{\partial BG}\left(r+h-\dot{C}_{BG}/C_{BG}\right)+$$
$$\left(\frac{\lambda_1}{1-\lambda_1}\right)\left(P_K\frac{\partial I^N}{\partial B}-S\alpha_K P_K\frac{\partial K^N}{\partial B}\right)+$$
$$\left(\frac{\lambda_2}{1-\lambda_1}\right)\left(\frac{\partial\vartheta}{\partial BG}(r+h-\dot{\vartheta}_{BG}/\vartheta_{BG})+\frac{\partial\vartheta}{\partial B}+\frac{\partial\vartheta}{\partial I^N}\frac{\partial I^N}{\partial B}\right)$$

Innovation refers to the firm's decision as to the rate of change in the efficiency parameter, which is being used here as a proxy for an index of the quality of network capital. As with investment, the decision would be a matter of balancing marginal benefits and costs along the firm's trajectory, if it were not for the vagarics of regulation.

The benefit of increasing the quality embodied in the last unit of investment is that less investment in nominal assets is needed. At the margin, this saves both external acquisition costs and internal adjustment costs.

The cost side reflects the marginal adjustments associated with increasing the rate of change in the efficiency parameter. Such costs would include the cost of developing new splicing and pulling methods for deploying fiber optics, rewiring of customer premises and switch related software development. These marginal adjustment costs are converted into rental equivalents by the discount rate, rate of depreciation on the efficiency parameter and expected price changes of resources related to this adjustment process.[18]

The distortion introduced by rate of return regulation is twofold. An increase in capital's quality means less of it is needed, so that the regulated rate base would be smaller over time than it otherwise would. This creates an incentive to innovate less than is optimal. On the other hand, higher quality reduces the expenditure made on nominal assets at the margin, improving the firm's cash flow position. The rate base effect pertains to the firm's gross profit performance. Adding in the cash flow is equivalent to evaluating net profit performance.[19] Therefore, it is possible, for a firm in a rapid growth mode to

[18]The depreciation rate applied to the efficiency parameter refers to secular rate at which the firm would have to replenish its state of technical knowledge just to keep pace with the ongoing trends in the industry.

[19]Mathematically, maximizing the firms inter temporal cash flow stream yields the same solution as maximizing an inter

engage in excess innovation, because the marginal cash flow benefits dominate the negative impacts on a rate base that is growing in any event.

To return briefly to an earlier point, it was mentioned that the incentive to over invest might be eliminated if the ratio of the rental price of acquiring capital over the authorized rate of return were used to determine the fraction of the capital stock included in the regulated rate base. In order for this procedure to simultaneously eliminate the rate of return distortion in both the investment and innovation decision, the dollar value of the firm's nominal capital stock would have to be growing at a rate just equal to the discount rate.[20] This "golden rule" growth path seems to be a very restrictive requirement in order for the firm to be on a relatively efficient trajectory under rate of return regulation.

With respect to innovation, or quality incentives under price cap regulation, the general structure used here for relating changes in the expected cap to certain variables allows for three possible influences. First, since an increase in the quality of capital would tend to be associated with an increase in observed productivity one would expect an inverse relationship between the level of the efficiency parameter and the allowed cap. Second, an increase in the efficiency parameter reduces the amount of nominal investment required at the margin, and, to be consistent with the discussion on investment incentives, this effect would lower the expected price cap since the firm's cash flow position would be improved. Third, regulators may compensate the firm for increasing the rate of change in the efficiency parameter (analogous to the previous investment discussion) because of the higher adjustment cost the firm absorbs as it speeds up the rate of quality improvement. As before, this adjustment related effect is converted into an equivalent flow by the discount rate, depreciation rate on the efficiency parameter and the expected change in the allowed marginal cap adjustment stemming from faster quality improvement. Again, this particular mechanism for the price cap formula is conjectural, but seems to make sense, especially if there is an explicit policy goal of stimulating a modern network infrastructure. If the expectation is that the allowed marginal cap adjustment will be improved later on, then nearer term quality enhancements will be delayed.

VI Modifying The Price Cap System to Eliminate Distortions

It is of some interest to explore, briefly, under what conditions a price cap system would lead to a restoration of the usual first order profit maximizing conditions.

Recall that under rate of return regulation , if the fraction of the capital stock assigned to

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temporal net income stream.

[20]Derived in Stolleman, Some Dynamic Effects of Cost Allocations Between Regulated and Non-Regulated Exchange Carrier Operations, Proceedings of the Bellcore-Bell Canada Conference on Telecommunications Costing, San Diego, CA., 1989. This solution appears to be unstable, in that a faster growth rate would lead to excess innovation, lower quality adjusted capital price and excess investment.

the regulated rate base was set equal to the ratio of the rental price of acquiring capital divided by the authorized rate of return, and if growth in the dollar value of the capital stock was equal to the discount rate, a relatively efficient trajectory would be achieved.

To specify a price cap system that would not lead to any distortions, it was first assumed that the elasticity of the price cap with respect to the rate of investment is equal to the elasticity of the cap with respect to the capital stock (only because symmetry might be a desirable attribute in terms of implementation, and because it leads to intuitive interpretations). If growth in the shadow value of the nominal capital stock were to equal the discount rate, there would be no distortion in the investment decision. "Shadow" means that the nominal stock is weighted by the expected change in the marginal (investment) cap adjustment. In other words, the shadow value of changes in the stock depend on how the cap adjustment is expected to be changed. Intuitively, it determines a critical expectation regarding the investment related cap adjustment. If the expectation is too high(low) investment this time period will be too low(high). Formally,

7) $$r = dLn(K^N)/dt + \frac{\dot{\vartheta}_{I^N}}{\vartheta_{I^N}}$$

Similarly, if the growth in the shadow value of the efficiency parameter equals the discount rate, then there will be no distortion is the innovation decision. Shadow value means the rate of change in the efficiency parameter is weighted by the expected change in the related marginal cap adjustment In this case, the simplifying assumptions were made that the elasticity of the cap adjustment with respect to changes in the efficiency parameter equaled the elasticity with respect to gross investment, and that no adjustment was made to the cap due to level changes in efficiency. If the expectation regarding the cap adjustment is too high(low) innovation this time period will be too low(high), or:

8) $$r = dLn(B)/dt + \frac{\dot{\vartheta}_{BG}}{\vartheta_{BG}}$$

VII Conclusion

If there is a policy goal of moving in the direction of a modernized infrastructure, then it seems logical that price cap regulation should embody mechanisms that support investment embodying state of the art innovations, as well as stimulation of newer innovations.[21] A review of the discussion would indicate that a pure price cap model[22] offers a cleaner way to achieve this policy goal as compared with a rate of return model, or even a hybrid model, with its attendant distortions. Price cap regulation also contains distortions, as would any system of constraints. Whether the parameters of a price cap model would ever have the required symmetry properties, and whether expectations about future cap adjustments would ever attain their "critical" values (as discussed above) is problematical. However, purposeful distortions in the direction of what might appear to be "excess" innovation may in fact be sound policy when the eternality benefits of rapid network modernization are considered.

[21]This paper does not address explicitly the issue of what constitutes the most efficient industry structure. There are of course many entities who will play a role in the evolution of the industry, including cable companies, interexchange carriers, cellular firms and alternative access providers. This paper is a partial analysis, from the exchange carrier perspective. Nevertheless, an implicit theme is that minimizing the distortion in the price of basic exchange carrier service reduces the extent of uneconomic investment of enhanced service providers in their own facilities.

[22]"Pure" means placing a cap on a set of basic core, non-competitive services (that might change over time), allowing complete pricing flexibility on the remaining services and eliminating all market and/or jurisdictional cost allocation procedures (see, Stollcman, Policy Position: Alternative Regulatory Frameworks (1989), unpublished manuscript, on file with the *George Mason University Law Review*) This approach would allow the exchange carrier's price structure to more nearly reflect its underlying economies of scope, and reduce the extent of uneconomic alternative investments.

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Dr. Neal C. Stolleman
*Bellcore**

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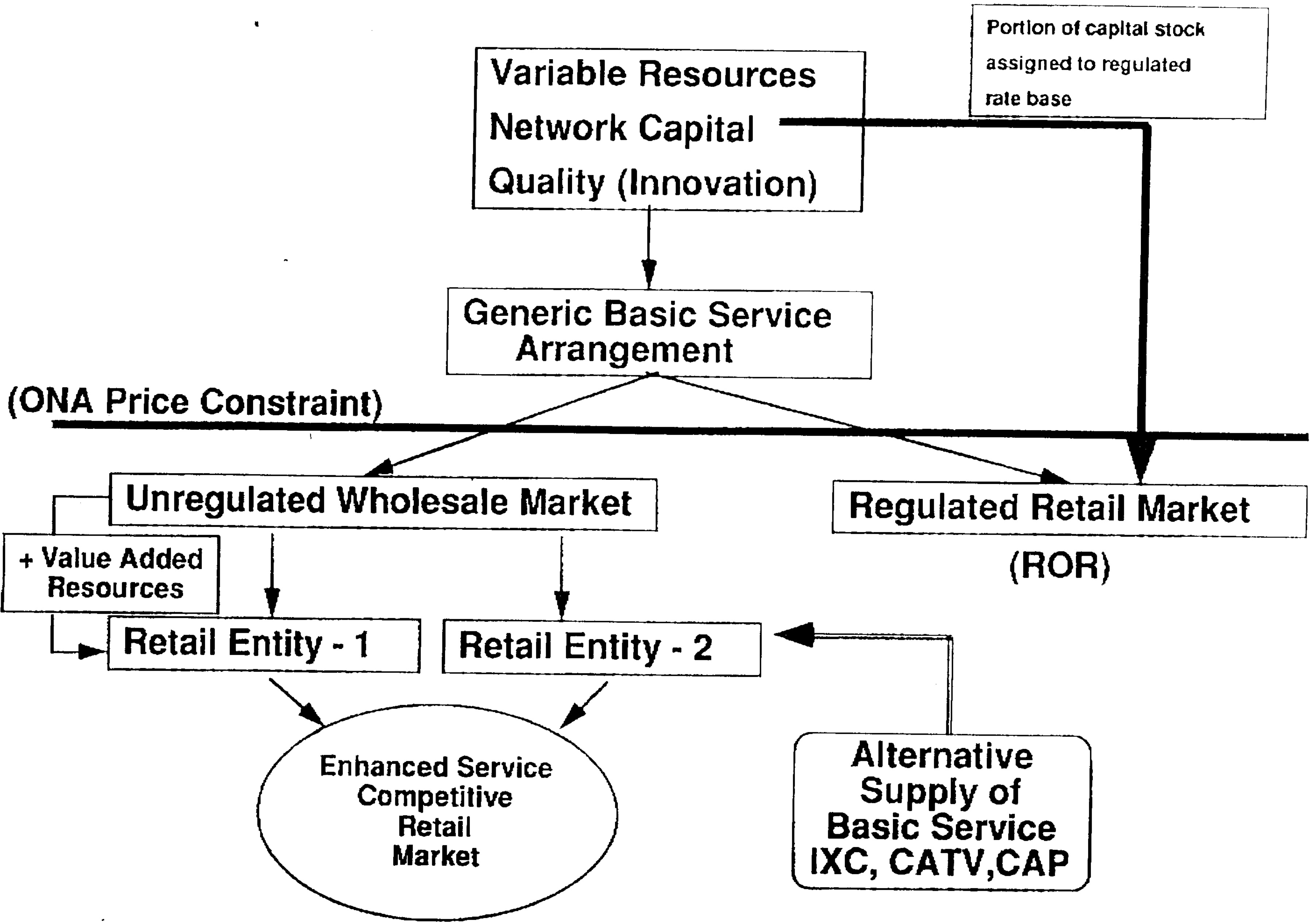
Stylized Exchange Carrier



Economic Assumptions

- Exchange Carrier maximizes the present value of its net profit stream (including profit on unregulated operations, if any)

- Costs are incurred when the rate of addition to network capital is changed

$$VC = VC(Q^R, K, I^N)$$

- Additions to network capital embody the current state of technical efficiency (quality)

$$\dot{K} = I^N B - \delta K$$

- Costs are incurred when the rate of addition to the state of technical efficiency or quality is changed

$$C = C(BG), AdjustmentCost$$

$$\dot{B} = BG - hB$$

Regulatory Assumptions

- ROR Constraint: Regulated revenues less (variable + quality related costs) = regulated rate base x authorized rate of return

- Regulated rate base is the portion of the capital stock allocated to regulated operations

Gross Profit

$$P_q(Q^{R1}+Q^{R2})-VC(Q^R,K,I^N)-C(BG)=S\alpha_K P_K K^N$$

- Expected Price Cap on the basic service is functionally related to:
  - (-) amount of service produced
  - (-) cumulative capital stock
  - (+) rate of change in capital stock
  - (-) state of technical efficiency (quality)
  - (+) rate of change in technical efficiency

→ Implictly captured in price cap adjustment formula

$$\vartheta(Q^R,K,I^N,B,BG)=PriceCapFunction$$

Exchange Carrier Incentives

Decision Variable	Unconstrained Solution
Pricing of basic service:	Price mark-up over marginal cost = inverse of elasticity of demand $(P_q - \frac{\partial VC}{\partial Q^R}) / P_q = \frac{1}{\eta_{Q^R}}$
Investment in network capital:	Marginal Savings in variable resources = costs of acquiring and integrating new capital into operations
Rate of change in quality:	Marginal savings in capital acquisition and integration costs = costs of developing and integrating innovation

Pricing Incentive

$$\left(P_q - \frac{\partial VC}{\partial Q^R}\right) / P_q = -\left[\frac{1 + \left(\frac{1}{1-\lambda_1}\right)\left(\frac{X^T \partial P_x}{q^T \partial P_q} - 1\right) S_{q1}}{\eta_{Q^R}}\right] + \left(\frac{\lambda_2}{1-\lambda_1}\right)\left[\frac{\partial \vartheta}{\partial Q^R} - \frac{\partial P_q}{\partial Q^R}\right]\frac{1}{P_q}$$

R.O.R. and Market Structure Related

- The greater the ability of the exchange carrier to flow through changes in the basic service price to changes in the enhanced service price, the greater the price mark-up
- The greater the share of basic service used in exchange carrier's own enhanced service production, the smaller the price mark-up
- The greater the ability of retail entities to substitute to other facilities, the smaller the price mark-up
- The "tighter" R.O.R. regulation, the lower the price mark-up

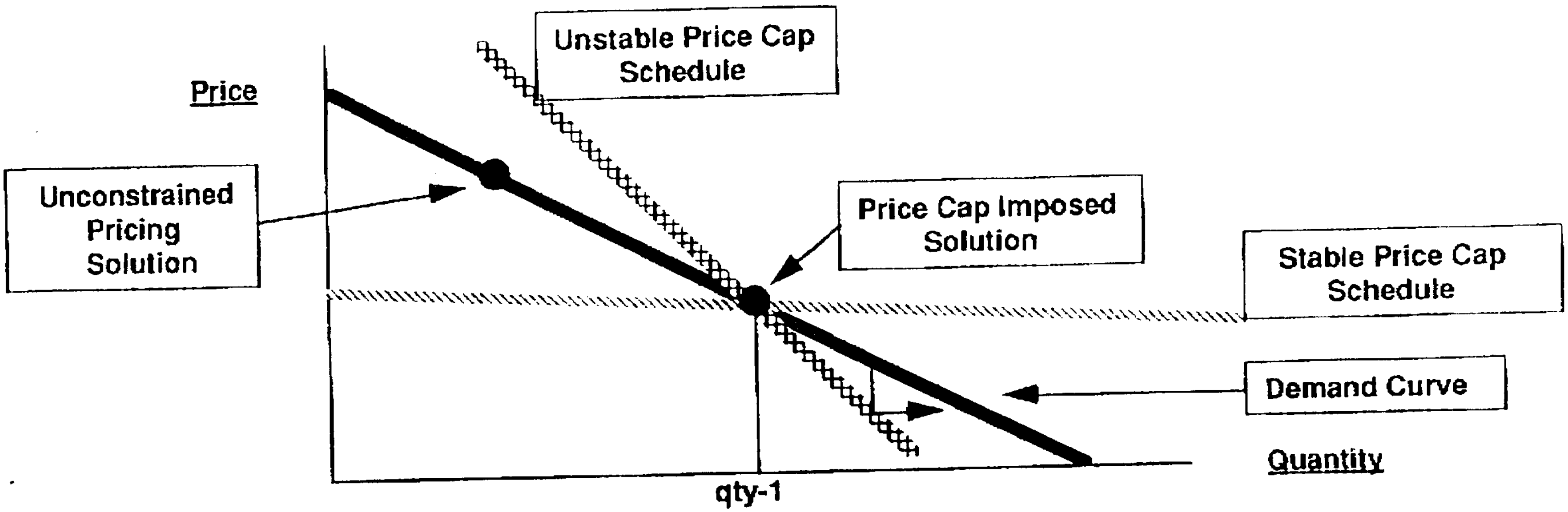
Pricing Incentive

Price Cap

Related

$$(P_q - \frac{\partial VC}{\partial Q^R}) / P_q = -\left[\frac{1 + \left(\frac{1}{1-\lambda_1}\right)\left(\frac{X^T \partial P_x}{q^T \partial P_q} - 1\right) S_{qt}}{\eta_{Q^R}} \right] + \left(\frac{\lambda_2}{1-\lambda_1}\right)\left[\frac{\partial \vartheta}{\partial Q^R} - \frac{\partial P_q}{\partial Q^R}\right]\frac{1}{P_q}$$

- Price Cap effect on price mark-up solution depends on sensitivty of cap to increases in basic service output:
  - Low sensitivty leads to a stable solution of increased production and lower equilibrium price
  - High sensitivty may lead to an unstable solution: Upward movement and loosening of constraint, or downward spiral of cap



Investment Incentive

$$
\begin{aligned}
-\frac{\partial VC}{\partial K} = \frac{P_K}{B}\left(r+\delta+\dot{B}/B-\dot{P}_K/P_K\right) &+ \\
\frac{\partial VC}{B\partial I^N}\left(r+\delta+\dot{B}/B-\dot{VC}_{I^N}/VC_{I^N}\right) &- \\
\left(\frac{\lambda_1}{1-\lambda_1}\right)\left(S\alpha_K-(r+\delta+\dot{B}/B-\dot{P}_K/P_K)\right)\frac{P_K}{B} &+ \\
\left(\frac{\lambda_2}{1-\lambda_1}\right)\left[\frac{\partial\vartheta}{B\partial I^N}\left(r+\delta+\dot{B}/B-\dot{\vartheta}_{I^N}/\vartheta_{I^N}\right)+\frac{\partial\vartheta}{\partial K}\right]
\end{aligned}
$$

- R.O.R. regulation may create differential between authorized return and the rental pricing of acquiring capital - depends on fraction of network capital assigned to rate base

- Price Cap impact depends on <u>positive</u> cap adjustment due to increased rate of addition to network capital vs <u>negative</u> cap adjustment due to higher level of cumulative capital

- If the expected change in the investment related, positive price cap adjustment is sufficiently high (low), the incentive to invest today will be lowered (raised)

- If capital is valued in terms of the expected price cap adjustment to be applied, the critical expectation equates the rate of change in value to the discount rate

$$r = dLn(K^N)/dt + \frac{\dot{\vartheta}_{I^N}}{\vartheta_{I^N}}$$

Critical expected change in the investment related cap adjustment

Quality Incentive

$$-\left(\frac{\partial VC}{\partial I^N}+P_K\right)\frac{\partial I^N}{\partial B}=\frac{\partial C(BG)}{\partial BG}\left(r+h-\dot{C}_{BG}/C_{BG}\right)-$$
$$\left(\frac{\lambda_1}{1-\lambda_1}\right)\left(P_K\frac{\partial I^N}{\partial B}-S\alpha_K P_K\frac{\partial K^N}{\partial B}\right)+$$
$$\left(\frac{\lambda_2}{1-\lambda_1}\right)\left(\frac{\partial\vartheta}{\partial BG}(r+h-\dot{\vartheta}_{BG}/\vartheta_{BG})+\frac{\partial\vartheta}{\partial B}+\frac{\partial\vartheta}{\partial I^N}\frac{\partial I^N}{\partial B}\right)$$

- Under R.O.R. regulation, quality improvement lowers the nominal value of the rate base (and gross profit), but improves marginal cash flow, strengthening the present value of net profit.

- Price Cap impact depends on <u>positive</u> cap adjustment due to the increased rate of addition to quality of network capital vs <u>negative</u> cap adjustments due to 1) higher level of quality, and 2) reduced need for physical investment.

- If the expected change in the quality related, positive price cap adjustment is sufficiently high (low), the incentive to raise quality today will be lowered (raised)

- If the level of quality is valued in terms of the expected price cap adjustment to be applied, the critical expectation equates the rate of change in value to the discount rate

$$r=dLn(B)/dt+\frac{\dot{\vartheta}_{BG}}{\vartheta_{BG}}$$

Critical expected change in the investment related cap adjustment

Summary and Recommendations

- The Price Cap should be relatively insensitive to changes in the level of basic service production to ensure a stable pricing solution.
- Near term incentives to invest and improve the quality of network capital will be lowered if there are sufficiently strong expectations regarding future price cap adjustments related to these activities.
- If increasing the rate of investment and innovation are deemed policy goals, then price cap rules must be designed to at least partially offset the extra costs of these activities.
- In the longer run, as the level of network capital and innovation stabilize, the cumulative effects on productivity will dominate the price cap formula, leading to reductions in the cap.
- Reliance on hybrid Price Cap/R.O.R. models, with attendant cost allocation rules, sustain investment / innovation distortions, reducing likelihood of efficient network evolution.