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Abstract

This paper shows that the effect of price-cap (PC) regulation and modified price-cap (MPC) regulation on the allocative efficiency and diversification of core and non-core goods depends crucially on (i) whether core and non-core goods are complements, substitutes, or independent, and (ii) whether the non-core market is perfectly or imperfectly competitive. Under PC regulation, efficient production of the core good is impossible unless the non-core market is perfectly competitive. Further, we show that the regulated firm may or may not supply less output in the non-core market under MPC than under PC regulation, depending upon, in part, whether the scheme of common cost allocation is based on either a monotonic method or a relative revenue method. Also, a perfectly competitive non-core market implies core-market *over*production distortion under MPC. We discuss implications for the entry of the 'Baby Bells' into long-distance and cellular markets.

Key words: Price-cap regulation; Production efficiency; Diversification

JEL Classification: L00; L51; L96

1. Introduction

The question of whether price-cap (PC) regulation is superior to cost-based (CB) regulation has attracted considerable attention.[1] For example, Braeutigam and

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[1] See, for example, Braeutigam and Panzar (1989, 1993), Brennan (1989), and Federal Communications Commission (1988), 1992). As pointed out by Braeutigam and Panzar (1989), CB regulation combines elements of rate-of-return regulation with fully distributed cost pricing under which firms are subject to zero profit constraint in the regulated core market. PC regulation establishes a price cap constraint in the regulated core market where a firm can retain all of the profits it generates in the core market, and allows the firms to enter into non-core markets without any constraints.

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Panzar (1993) point out that the federal government and more than 30 state regulatory agencies in the telephone industry have adopted policies that involve some form of 'incentive regulation', i.e., regulatory schemes that contain, to some degree, PC rather than the traditional, strict CB features.[2] Braeutigam and Panzar (1989) develop a theoretical model to show that PC regulation can induce the regulated firm to achieve allocative efficiency in both core and non-core markets. In their analysis, Braeutigam and Panzar discuss the case where core and non-core goods are independent.

Recently, however, Weisman (1993) presents an example which shows that if one relaxes certain assumptions about PC regulation, then PC may not be superior to CB regulation. Specifically, Weisman discusses the so called modified price-cap (MPC) regulation under which firms are required to allocate costs common to both core and non-core goods and are allowed to retain a specified portion of profits earned in the core market. He also points out that MPC regulation combines elements of CB and PC regulation and that MPC regulation is pervasive in the telecommunications industry today. Weisman characterizes the non-core market as one in which prices are set competitively (the firm is a price taker), and he shows that there is an underproduction distortion in the non-core market. In his analysis, Weisman assumes that the core market is independent of the non-core market.

Several important questions remain unanswered. What is the effect of PC or MPC regulation on the allocative efficiency and diversification of core and non-core goods when these two goods are complements or substitutes and when the non-core market is characterized by imperfect competition? Is production of the core good efficient? If not, then what would be the amount of profit tax on the good in the core market that would lead the regulated firm under MPC regulation to efficiently supply the core good? Would the answers be affected by alternative schemes for common cost allocation? What would be the effect of the form of common cost allocation on the efficiency of the non-core good under MPC regulation? Further, what would be the effects of considering the non-core market in an oligopolistic framework, specifically as a duopoly in which firms either employ Cournot strategies or behave in a quasi-perfectly competitive fashion as special cases? The purpose of this paper is to present answers to these questions.

It should also be mentioned at the outset that, whereas Braeutigam and Panzar (1989) and Weisman (1993) consider the case in which the core market is independent of the non-core market, we develop a more general framework in which the core and non-core markets may be related to each other under the assumption of a duopolistic non-core market with special cases of Cournot competition and quasi-perfect competition.[3] These considerations are timely in view of recent news reports in the business press. Kupfer (1994) reports strenuous

[2] More recently, Sappington and Weisman (1996) have systematically examined alternative forms of incentive regulation that are employed in the telecommunications industry.

[3] It can be shown that our results can be generalized to the case of n non-regulated firms in the oligopolistic non-core market.

efforts by the 'Baby Bells' to enter the long-distance market prior to the legislation which enables them to do so (p. 95). Following this legislation, local service (core market) would be a *complement* to long-distance service (non-core market). Long-distance service (non-core market) would be either oligopolistic, as in the case of intercity calls, or monopolistic, as in the case of calls between a major city and its surrounding suburbs when the same firm serves both.[4]

Another relevant observation is that cellular phone service is an example of a non-core market which is a *substitute* for core-market local service, and this market is, in general, oligopolistic.[5] Thus we see that the incentive for the Baby Bells to expand into the substitute cellular market is great and merits careful analysis.

In this paper, we will show that the effect of a pure price-cap regulation and a modified price-cap regulation on the efficiency and diversification of core and non-core goods depends on whether these two goods are complements or substitutes and whether or not the market for the non-core good is characterized by perfect competition. If the core good and non-core goods are complements or substitutes and if the non-core market is imperfectly competitive, the firm under PC regulation will never produce the good efficiently in the regulated core market. In other words, efficiency in the core good can not be achieved unless the core and the non-core markets are assumed to be independent or the non-core market is assumed to be perfectly competitive, as in Braeutigam and Panzar (1989). In the case of perfect competition in the non-core market, the regulated firm under PC regulation will efficiently supply the non-core good, regardless of whether core and non-core goods are complements, substitutes, or independent under perfect competition. However, under the conditions of a Cournot game in the non-core market, we will observe both core and non-core market inefficiencies under PC regulation. Findings in the present paper suggest an interesting policy implication that is ignored in the literature on PC regulation. That is, under PC regulation, diversification in the non-core market is achieved at the expense of efficiency in the core market when demands for core and non-core goods are not independent and when the non-core market is characterized by imperfect competition.

We also attempt to investigate 'efficient' taxation under MPC regulation,[6] where the regulator allows the firm in the core market to retain only a share of profits

[4] "Such calls [between cities and their suburbs] are high-margin items: They cost about the same as a local call, yet regulators allow the Baby Bells to charge about five times as much" (Kupfer, 1994, p. 95).

[5] "Baby Bell executives go weak when they think what could happen if cellular phones become a hit in the mass market.... in New York City, cellular revenues rose 40% in the past year, while the Baby Bell revenues grew only slightly. The operating profit on cellular calls is nearly 25%, vs. 20% for the business as a whole" (Kupfer, 1994, p. 102). Further, Weisman has communicated to us that SBC Communications Inc. has expanded heavily to the cellular market.

[6] Although Weisman (1993) considers both a constant tax and a tax that rises as a function of profit in the core market, we will consider only the former case since, otherwise, problems of endogeneity arise.

earned by the firm. We will perform this investigation under two different methods for the allocation of costs common to production of core and non-core goods. They are based on fixed cost allocation by (1) a monotonic method[7] and (2) a relative revenue method. It will be shown that the regulated firm under MPC regulation will supply inefficiently less output in the non-core market than under PC regulation whenever a monotonic method of common cost allocation is used regardless of (i) how the core and non-core goods are related to each other and (ii) whether the non-core market is oligopolistic and represents a Cournot game or perfect competition. However, under the relative revenue method, the regulated firm may or may not supply less output in the non-core market under MPC than under PC regulation, depending upon a host of factors which we will develop later. Also, it will be shown that under MPC regulation, if the non-core market is perfectly competitive there will be an *overproduction* distortion in the *core* market.

Although the analysis in the paper is centered around two different methods of common cost allocation for MPC regulation with a positive profit tax on the good in the core market, the case of PC regulation can easily be analyzed by letting the profit tax equal zero. The rest of this paper is organized as follows. Section 2 discusses the case of common cost allocation based on a monotonic method. Section 3 considers the case of the relative revenue method. Concluding remarks appear in Section 4. Results are summarized in Tables 1 and 2.

2. Common cost allocation based on a monotonic method

Consider first a monotonic method defined for y_1 and y_{2a}, which are the output levels of core and non-core goods produced by the regulated firm. Let $f(y)$ be the fraction of fixed costs that are allocated to the core good, where $y \equiv (y_1, y_{2a})$. Following Sweeney (1982), we define fixed costs as allocated by a *monotonic method* if for each value of y, $f(y)$ satisfies the following conditions: (i) $f(y)>0$ for all y such that $y_1>0$ and $y_{2a}>0$; (ii) $f_1 \equiv \partial f/\partial y_1 > 0$ for all $y \geq 0$; and (iii) $f_{2a} \equiv \partial f/\partial y_{2a} < 0$ for all y such that $y_{2a}>0$. Again, from Sweeney (1982), we identify the 'relative output method' as

$$f(y) \equiv y_1/(y_1 + y_{2a}) \tag{1}$$

and the 'attributable cost method' as

$$f(y) \equiv C^1(y_1)/[C^1(y_1) + C^{2a}(y_{2a})], \tag{2}$$

[7] Although Braeutigam (1980) discusses the three cases of (1) relative output, (2) attributable cost, and (3) relative revenue, we follow Sweeney (1982) to combine the first two cases into one where the share of fixed costs attributable to core good is a monotonically increasing function of the amount of the core good sold and a monotonically decreasing function of the amount of non-core good sold. A formal definition appears in Section 2.

where $C^i(y_i)$ represents the total variable costs attributable to production of good i ($i=1, 2a$). These two methods are examples of a monotonic method since it is easily shown that they conform to (i)–(iii) of the definition.

In order to examine the general case in which core and non-core market goods are not independent, the market demands for the two types of goods produced by the regulated firm are specified as follows:

$$p_1 = p_1(y_1, y_2) \quad \text{and} \quad p_2 = p_2(y_1, y_2), \tag{3}$$

where p_1 is the price of core good, p_2 is the price of the non-core good, y_{2a} is the non-core output level of the regulated firm, y_{2b} is the output level of another firm producing the non-core good and $y_2 \equiv y_{2a} + y_{2b}$. The regulated firm faces a price-cap constraint in the core market which is given as $p_1 \leq p_1^*$, where p_1^* is a price cap set by the regulatory commission. In this case, even though there is a price cap, production of the core market good, y_1, can change. Following Braeutigam and Panzar (1989) and Weisman (1993), we assume that the price cap constraint binds, that is,

$$p_1 = p_1^*. \tag{4}$$

The problem facing the regulated firm then is to choose y_1 and y_{2a} in order to maximize its joint profit function subject to the binding price-cap constraint in Eq. (4). The Lagrangian function is:

$$\begin{aligned}\mathscr{L} = {} & (1 - \bar{T}_1)[p_1^* y_1 - f(y_1, y_{2a})F - C^1(y_1)] + p_2(y_1, y_{2a} + y_{2b})y_{2a} \\ & - [1 - f(y_1, y_{2a})]F - C^{2a}(y_{2a}),\end{aligned} \tag{5}$$

where $\bar{T}_1$ is profit tax on the core market good under MPC regulation and F is the regulated firm's common (fixed) cost. We assume that the marginal cost in each good is positive and increasing. Before examining the optimality conditions under MPC regulation, it should be noted that the case of PC regulation can easily be analyzed by setting $\bar{T}_1 = 0$ in Eq. (5), such that there is no profit tax on the core good and no common cost allocation problem.

The necessary conditions for profit maximization are:

$$\begin{aligned}\partial \mathscr{L} / \partial y_1 = {} & (1 - \bar{T}_1)[p_1^* - f_1 F - C_1^1(y_1)] \\ & + [\partial p_2 / \partial y_1 + (\partial p_2 / \partial y_2)(\partial y_{2b} / \partial y_1)]y_{2a} + f_1 F = 0,\end{aligned} \tag{6}$$

$$\begin{aligned}\partial \mathscr{L} / \partial y_{2a} = {} & (1 - \bar{T}_1)(-f_{2a} F) + p_2 + (\partial p_2 / \partial y_2)[1 + (\partial y_{2b} / \partial y_{2a})]y_{2a} + f_{2a} F \\ & - C_{2a}^{2a}(y_{2a}) = 0,\end{aligned} \tag{7}$$

where $C_1^1 \equiv dC^1 / dy_1$ and $C_{2a}^{2a} \equiv dC^{2a} / dy_{2a}$.

Two points with respect to the above conditions should be noted. First, we will assume that $\partial y_{2b} / \partial y_1 = 0$. That is, the regulated firm believes that the other firm's production level of the non-core good (y_{2b}) is independent of the regulated firm's production of the core good (y_1). Also, in order to examine market conduct in the non-core market we consider Cournot competition in which $\partial y_{2b}/\partial y_{2a}=0$, and (quasi) perfect competition in which $\partial y_{2b}/\partial y_{2a}=-1$.

The profit function of the unregulated firm in the non-core market is given as

$$\pi_b = p_2(y_1, y_{2a}+y_{2b})y_{2b} - C^{2b}(y_{2b}), \tag{8}$$

where $C^{2b}(y_{2b})$ is the firm's cost function with positive and increasing marginal cost. The firm is assumed to maximize its profit by producing the non-core good up to the level y_{2b} at which the following condition is satisfied:

$$p_2 + (\partial p_2/\partial y_1)(\partial y_1/\partial y_{2b})y_{2b} + (\partial p_2/\partial y_2)(1+\partial y_{2a}/\partial y_{2b})y_{2b} - C^{2b}_{2b}(y_{2b}) = 0 \tag{9}$$

where $C^{2b}_{2b} \equiv \mathrm{d}C^{2b}/\mathrm{d}y_{2b}$. For the case in which the unregulated firm believes that the regulated firm's choice of the core good is independent of its own choice of the non-core good, we have $\partial y_1/\partial y_{2b}=0$.

In what follows, we will discuss several cases concerning the effect on the production efficiency and diversification of the core and the non-core goods in terms of the relationship between y_1 and y_2, noting that $y_2 \equiv y_{2a}+y_{2b}$. We first consider the core market good. It follows from Eq. (6) that

$$(1-\bar{T}_1)[p_1^* - C^1_1(y_1)] = (1-\bar{T}_1)f_1F - [\partial p_2/\partial y_1 + (\partial p_2/\partial y_2)(\partial y_{2b}/\partial y_1)]y_{2a} - f_1F. \tag{10}$$

Assuming the regulated firm believes that the unregulated firm's choice of the non-core good (y_{2b}) is independent of its own choice of the core good (y_1), we have $\partial y_{2b}/\partial y_1 = 0$. Hence, we have

$$p_1^* - C^1_1(y_1) = [1/(1-\bar{T}_1)][-\bar{T}_1 f_1 F - (\partial p_2/\partial y_1)y_{2a}]. \tag{11}$$

Case I: y_1 and y_{2a} are complements. It follows from Eq. (11) that for $0<\bar{T}_1<1$, $p_1^* \geq C^1_1(y_1)$ if $-\bar{T}_1 f_1 F - (\partial p_2/\partial y_1)y_{2a} \geq 0$ or if

$$(1/y_1)[-\bar{T}_1 fF\epsilon_{f,1} - p_2 y_{2a}/\epsilon_{1,2}] \geq 0, \tag{12}$$

where $\epsilon_{f,1}$ $[\equiv(\partial f/\partial y_1)(y_1/f)=f_1(y_1/f)]$ is the elasticity of the common cost allocator of the core good with respect to its output level, and $\epsilon_{1,2}$ $[\equiv(\partial y_1/\partial p_2)(p_2/y_1)]$ is the cross elasticity of demand for the core good with respect to the price of the non-core good. Since $y_1>0$, we have $-\bar{T}_1 fF\epsilon_{f,1} \geq p_2 y_{2a}/\epsilon_{1,2}$, noting that $\epsilon_{f,1}>0$. Also, the assumption that y_1 and y_2 are complements implies that $\epsilon_{1,2}<0$. Hence, we have the following result:

$$p_1^* \geq (\leq) C_1^1(y_1) \text{ if } \bar{T}_1 \leq (\geq) \bar{T}_1^*, \quad \text{where} \quad \bar{T}_1^* = -p_2 y_{2a}/(Ff\epsilon_{f,1}\epsilon_{1,2}) > 0. \qquad 13)$$

Three possibilities exist. (i) If $\bar{T}_1 = \bar{T}_1^*$, then $p_1^* = C_1^1(y_1)$, which implies efficient pricing in the core market. (ii) If $0 < \bar{T}_1 < \bar{T}_1^*$, then $p_1^* > C_1^1(y_1)$, which implies that there is an underproduction distortion in the core market under MPC regulation. Finally, (iii) if $\bar{T}_1 > \bar{T}_1^*$, then $P_1^* < C_1^1(y_1)$, which implies that there is an overproduction distortion in the core market.

Case II: y_1 and y_{2a} are substitutes. When the two goods are substitutes, $\partial p_2/\partial y_1 > 0$. It follows from Eq. (11) that $p_1^* < C_1^1(y_1)$ since the right-hand side of Eq. (11) is always negative; hence this result holds for $\bar{T}_1 > 0$ or $\bar{T}_1 = 0$. In this case, the aforementioned overproduction distortion in the core market is implied. The above findings can be summarized in the following proposition:

Proposition 1. If an unregulated firm in the non-core market engages in a Cournot game with a firm which is regulated in the core market then:

(a) Under PC regulation ($\bar{T}_1 = 0$) with a monotonic method, the regulated firm will have an incentive to underproduce the core good (up to where $p_1^* > C_1^1(y_1)$ if core and non-core goods are complements; but the firm will have an incentive to overproduce the core good (up to where $p_1^* < C_1^1(y_1)$) if core and non-core goods are substitutes.

(b) Under MPC regulation ($\bar{T}_1 > 0$) with a monotonic method, if the core and non-core products are complements, efficient production of the core good obtains when $\bar{T}_1$ equals $\bar{T}_1^*$, where $\bar{T}_1^* = -p_2 y_{2a}/(Ff\epsilon_{f,1}\epsilon_{1,2}) > 0$. Otherwise, for $0 < \bar{T}_1 < \bar{T}_1^*$, there is an underproduction distortion; and for $\bar{T}_1 > \bar{T}_1^*$, there is an overproduction distortion in the core market. If core and non-core products are substitutes, efficient production is impossible since $p_1^* < C_1^1(y_1)$ for all $0 < \bar{T}_1 < 1$, and there is an overproduction distortion in the core market.

Now we consider the non-core market. The optimality condition in Eq. (7), under the assumption of a Cournot game in the non-core market (i.e., $\partial y_{2b}/\partial y_{2a} = 0$), can be rearranged to yield

$$\bar{T}_1 f_{2a} F + p_2 + (\partial p_2/\partial y_2) y_{2a} - C_{2a}^{2a}(y_{2a}) = 0. \qquad (14)$$

Since $f_{2a} < 0$, we have $(\partial p_2/\partial y_2) y_{2a} + p_2 - C_{2a}^{2a}(y_{2a}) = -\bar{T}_1 f_{2a} F > 0$. Letting the marginal revenue for the non-core market good be denoted as MR_{2a}, we have $MR_{2a} = \partial[p_2(y_1, y_2) y_{2a}]/\partial y_{2a} = (\partial p_2/\partial y_2) y_{2a} + p_2$. It follows from Eq. (14) that if the non-core market is characterized by Cournot competition, then $MR_{2a} > C_{2a}^{2a}$ for all $\bar{T}_1 > 0$. For the case in which the non-core market is quasi-perfectly competitive, we have $\partial y_{2b}/\partial y_{2a} = -1$; hence, $p_2 - C_{2a}^{2a}(y_{2a}) = -\bar{T}_1 f_{2a} F > 0$. This implies that under MPC regulation ($\bar{T}_1 > 0$) there is an underproduction distortion in the non-core market, regardless of whether the non-core market is characterized by Cournot competition or perfect competition. If the non-core market is perfectly competitive, then the regulated firm under PC regulation ($\bar{T}_1 = 0$) will have an incentive to efficiently supply the non-core good.[8] This is because in this case $p_2 = C^{2a}_{2a}(y_{2a})$. We therefore have the following proposition:

Proposition 2. In the case of a monotonic common cost allocation, the regulated firm will have an incentive to supply a smaller amount of the non-core good under MPC regulation than under PC regulation regardless of (i) whether core and non-core goods are complements, substitutes, or independent, and (ii) whether the non-core market is characterized by Cournot competition or perfect competition. If the non-core market is perfectly competitive, the regulated firm under PC regulation will efficiently supply the non-core good regardless of whether core and non-core goods are complements, substitutes, or independent.

Proposition 2 implies that under MPC regulation with a monotonic method the regulated firm tends to underproduce in the non-core market. As a result, MPC regulation is inferior to PC regulation as far as the underproduction distortion is concerned.

3. Common cost allocation based on the relative revenue method

Next, consider the relative revenue method defined as follows:

$$h \equiv p_1 y_1 / (p_1 y_1 + p_2 y_{2a}).$$

Given the price-cap constraint where $p_1 = p_1^*$ and substituting the demand function for the non-core good in Eq. (3) into Eq. (15), we have

$$h \equiv p_1^* y_1 / [p_1^* y_1 + p_2(y_1, y_2) y_{2a}]. \tag{15'}$$

The rate of change of the allocator h with respect to y_1 is given as

$$\begin{aligned} h_1 &= \partial h / \partial y_1 \\ &= \{p_1^* p_2(y_1, y_2) y_{2a} / [p_1^* y_1 + p_2(y_1, y_2) y_{2a}]^2\}(1 - 1/\epsilon_{1,2}) \quad (\epsilon_{1,2} \neq 0) \end{aligned}$$

where $\epsilon_{1,2}$ is defined as before as the cross elasticity of demand for y_1 with respect to p_2. In the relative revenue method with a price-cap constraint, the Sweeney (1982) conditions of monotonicity may be violated, depending upon whether the core and the non-core goods are complements or substitutes.

[8] This result is consistent with that of Braeutigam and Panzar (1989).

For the case in which y_1 and y_{2a} are complements ($\epsilon_{1,2}<0$), we have $h_1>0$. But for the case in which y_1 and y_2 are substitutes ($\epsilon_{1,2}>0$), h_1 can be positive, negative, or zero. That is, (i) $h_1>0$ if $\epsilon_{1,2}>1$, (ii) $h_1<0$ if $0<\epsilon_{1,2}<1$, and (iii) $h_1=0$ if $\epsilon_{1,2}=1$.

Next, we derive the rate of change of the allocator h with respect to y_{2a} as follows:

$$\begin{aligned} h_{2a} &= \partial h/\partial y_{2a} \\ &= -\{p_1^* p_2 y_1/[p_1^* y_1 + p_2(y_1,y_2)y_{2a}]^2\}[1 + y_{2a}/(y_2\epsilon_2)] \quad (\epsilon_2 \neq 0) \end{aligned} \tag{17}$$

where ϵ_2 $[\equiv(\partial y_2/\partial p_2)(p_2/y_2)]$ is the price elasticity of market demand for the non-core good. Hence, $h_{2a}<0$ when $\epsilon_2 \leq y_{2a}/y_2$, and $h_{2a}\geq 0$ when $-y_{2a}/y_2 < \epsilon_2 < 0$.

The Lagrangian function for the profit-maximizing regulated firm under MPC regulation with the relative revenue method is given as

$$\begin{aligned} \mathcal{L} = (1-\bar{T}_2)[p_1^* y_1 - h(y_1, y_{2a})F - C^1(y_1)] + p_2(y_1, y_{2a}+y_{2b})y_{2a} \\ - [1 - h(y_1, y_{2a})]F - C^{2a}(y_{2a}), \end{aligned} \tag{18}$$

where $\bar{T}_2$ is the profit tax on the core good. The necessary conditions in this case are similar to those in Eq. (5) and Eq. (7) except that the allocator f and its derivatives are replaced by the allocator h and its derivatives, and $\bar{T}_1$ is replaced by $\bar{T}_2$.

We first consider the core market good. The optimality condition with respect to y_1 can be rearranged as follows:

$$\begin{aligned} p_1^* - C_1^1(y_1) &= (1-\bar{T}_2)^{-1}\{-\bar{T}_2 h_1 F - (\partial p_2/\partial y_1)y_{2a}\} \\ &= [(1-\bar{T}_2)y_1]^{-1}[-\bar{T}_2 hF\epsilon_{h,1} - p_2 y_{2a}/\epsilon_{1,2}], \end{aligned} \tag{19}$$

where $\epsilon_{h,1}$ $[\equiv(\partial h/\partial y_1)(y_1/h)=h_1(y_1/h)]$ is the elasticity of the allocator h with respect to the output level of the core good.

If y_1 and y_2 are complements ($\epsilon_{1,2}<0$) such that $h_1>0$, then we have

$$p_1^* \geq (\leq) C_1^1(y_1) \text{ if } \bar{T}_2 \leq (\geq) \bar{T}_2^*, \quad \text{where} \quad \bar{T}_2^* = -p_2 y_{2a}/(hF\epsilon_{h,1}\epsilon_{1,2}) > 0, \tag{20}$$

which imply the same qualitative results as for the monotonic method for the core market.

However, if y_1 and y_2 are substitutes ($\epsilon_{1,2}>0$), we will have the following cases:

Case (1). For $\epsilon_{1,2}>1$ such that $h_1>0$ and $\epsilon_{h,1}>0$, we have from Eq. (19) that $p_1^*<C_1^1(y_1)$, which implies that there is an overproduction distortion in the core market.

Case (2). For $0<\epsilon_{1,2}<1$ such that $h_1<0$ and $\epsilon_{h,1}<0$, we have from Eq. (19) that

$$p_1^* \geq (\leq) C_1^1(y_1) \text{ if } \bar{T}_2 \geq (\leq) \bar{T}_2^*, \quad \text{where} \quad \bar{T}_2^* \equiv -p_2 y_{2a}/(hf\epsilon_{h,1}\epsilon_{1,2}) > 0.$$

There are three possibilities: (i) If $\bar{T}_2=\bar{T}_2^*$, then $p_1^*=C_1^1(y_1)$, and there is efficient pricing in the core market. (ii) If $0\leq\bar{T}_2<\bar{T}_2^*$, then $p_1^*<C_1^1(y_1)$, and there is overproduction distortion in the core market. Finally, (iii) if $\bar{T}_2>\bar{T}_2^*$, then $p_1^*>C_1^1(y_1)$, and hence there is an underproduction distortion in the core market under MPC regulation. The above results are summarized in the following proposition:

Proposition 3. Assume a Cournot game between an unregulated firm in the non-core market and a firm that is regulated in the core market. Under MPC regulation with the relative revenue method, we have the following results:

(a) If the core and non-core products are complements, efficient production of the core good obtains when $\bar{T}_2$ equals $\bar{T}_2^*$, where $\bar{T}_2^* = -p_2 y_{2a}/(hf\epsilon_{h,1}\epsilon_{1,2})>0$. Otherwise, for $0<\bar{T}_2<\bar{T}_2^*$ and $h_1>0$, there is an underproduction distortion; and for $\bar{T}_2>\bar{T}_2^*$ and $h_1<0$, there is an overproduction distortion in the core market.

(b) If the core and non-core products are substitutes, and if $\epsilon_{1,2}\geq 1$ such that $h_1\geq 0$, efficient production of the core good is impossible since for all $0<\bar{T}_2<1$, $p_1^*<C_1^1(y_1)$ and there is an overproduction distortion in the core market. But if $0<\epsilon_{1,2}<1$ such that $h_1<0$, efficiency of the core good obtains when $\bar{T}_2$ equals $\bar{T}_2^*$. Otherwise, for $0<\bar{T}_2<\bar{T}_2^*$, there is an overproduction distortion; and for $\bar{T}_2>\bar{T}_2^*$, there is an underproduction distortion in the core market.

Next, we consider the non-core market. The optimality condition with respect to y_{2a}, under the assumption of a Cournot game in the non-core market, can be rearranged to yield:

$$p_2 - C_{2a}^{2a}(y_{2a}) = -\bar{T}_2 h_{2a} F - (\partial p_2/\partial y_2) y_{2a}.$$

Although f_{2a} is in general negative (in the monotonic method), we find that the sign of h_{2a} is indeterminate when the non-core market is characterized by imperfect competition. For $h_{2a}\leq 0$, $p_2>C_{2a}^{2a}(y_{2a})$ and there is an underproduction distortion in the non-core market. But for $h_{2a}>0$, we have

$$p_2 \geq (\leq) C_{2a}^{2a}(y_{2a}) \text{ if } \bar{T}_2 \leq (\geq) \bar{T}_2^{**}, \quad \text{where} \quad \bar{T}_2^{**} \equiv -p_2 y_{2a}/(h_{2a} F \epsilon_2 y_2) > 0. \tag{23}$$

We therefore have the following proposition:

Proposition 4. Under MPC regulation, unlike a monotonic method (where there is always an underproduction distortion in the non-core market), the relative revenue method allows either efficiency, underproduction or overproduction distortion in the Cournot non-core market, depending upon the sign of h_{2a} and the size of $\bar{T}_2$.

If the non-core market is characterized by perfect competition, then $h_{2a}<0$ and $\partial p_2/\partial y_2=0$. It follows from Eq. (22) that $p_2>C_{2a}^{2a}(y_{2a})$ and there is an underproduction distortion in the non-core market.

It is interesting to examine the efficiency of the core market under MPC regulation when the non-core market is perfectly competitive. In this case, the first-order condition for the core good produced by the regulated firm is given by

$$p_1^* = C_1^1(y_1) - [\bar{T}/(1-\bar{T})](m_1 F), \tag{24}$$

where $\bar{T}$ (>0) is profit tax on the core good, m represents any of the above allocators ($m=f$ or h), and $m_1=\partial m/\partial y_1>0$.[9] It follows directly from Eq. (24) that there is an *over*production distortion in the *core* market under MPC regulation. The economic explanation is straightforward. The marginal cost that is directly attributable to producing the core good, $C_1^1(y_1)$, is offset by shared costs, $[\bar{T}/(1-\bar{T})](m_1 F)$, such that the 'effective' marginal cost is lower under MPC regulation ($\bar{T}>0$) as compared to the marginal cost under PC regulation ($T_i=0$). We therefore have the following proposition:

Proposition 5. Under MPC regulation, if the non-core market is perfectly competitive there will be an overproduction distortion in the core market.

Table 1 Table 2 summarize the results for the cases of PC regulation and MPC regulation, respectively.

4. Concluding remarks

This paper is concerned with the effect of PC regulation and MPC regulation on the allocative efficiency and diversification of core and non-core goods when regulated firms are allowed to retain all (pure PC case) or a predetermined portion (MPC case) of profits earned in the core market. It has been shown that whether core and non-core goods are substitutes or complements and whether the non-core market is characterized by imperfect or perfect competition play important roles in the analysis.

[9] The allocator based on the relative revenue in this case is $h=p_1^* y_1/(p_1^* y_1+p_2^c y_{2a})$, where p_2^c is the competitive price of the non-core good. As a result, h_1 Eq. ($=\partial h/\partial y_1$) is positive.

Table 1
Price-cap regulation (zero profit tax).[a]

	(1) Monotonic method or (2) relative revenue method
Under (1) and (2):	
y_1 and y_{2a} are complements	
(a)	
Core market	(+)
Cournot non-core market	(+)
(b)	
Core market	(0)
Competitive non-core market	(0)
y_1 and y_{2a} are substitutes	
(a)	
Core market	(−)
Cournot non-core market	(+)
(b)	
Core market	(0)
Competitive non-core market	(0)
y_1 and y_{2a} are independent goods	
(a)	
Core market	(0)
Cournot non-core market	(+)
(b)	
Core market	(0)
Competitive non-core market	(0)

[a] Sign$\{p_1^* - C_1^1(y_1)\}$ in the regulated core market; sign$\{p_2 - C_{2a}^{2a}(y_{2a})\}$ in the duopolistic (Cournot) non-core market; sign$\{p_2^e - C_{2a}^{2a}(y_{2a})\}$ in the competitive non-core market

Under PC regulation, if the core good and non-core goods are complements or substitutes under the assumption of a Cournot game in the non-core market, the regulated firm will never efficiently produce the good in the regulated core market. If the non-core market is perfectly competitive, the regulated firm under PC regulation will efficiently supply the non-core good, regardless of how the core and the non-core goods are related to each other. These findings suggest that under PC regulation diversification in the non-core market is achieved at the sacrifice of efficiency in the core market when demands for core and non-core goods are not independent and when the non-core market is imperfectly competitive.

Under MPC regulation, it has been shown that underproduction distortion occurs in the non-core market under a monotonic method of fixed cost allocation. However, under the relative revenue method, either efficiency or overproduction distortion may also occur in the non-core market if the market is imperfectly competitive. It has also been shown for all monotonic methods that the regulated firm will supply less output in the non-core market under MPC than under PC

Table 2
Modified price-cap regulation (positive profit tax).[a]

	Common cost allocation	
		(2) Relative revenue method
y_1 and y_{2a} are complements		
(a)		
Core market	(+) if $0<\bar{T}_1<\bar{T}_1^*$ (0) if $\bar{T}_1=\bar{T}_1^*>0$ (−) if $\bar{T}_1>\bar{T}_1^*>0$	(+) if $h_1>0$ and $0<\bar{T}_2<\bar{T}_2^*$ (0) if $\bar{T}_2=\bar{T}_2^*>0$ (−) if $\bar{T}_2>\bar{T}_2^*>0$
Cournot non-core market	(+)	(+), (0), or (−)
(b)		
Core market	(−)	(−)
Competitive non-core market	(+)	(+)
y_1 and y_{2a} are substitutes		
(a)		
Core market	(−)	(−) if $h_1>0$; or if $h_1<0$ and $0<\bar{T}_2<\bar{T}_2^*$ (+) if $h_1<0$ and $\bar{T}_2>\bar{T}_2^*>0$ (0) if $h_1<0$ and $\bar{T}_2=\bar{T}_2^*>0$
Cournot non-core market	(+)	(+), (0), or (−)
(b)		
Core market	(−)	(−)
Competitive non-core market	(+)	(+)
y_1 and y_{2a} are independent goods		
(a)		
Core market	(−)	(−)
Cournot non-core market	(+)	(+), (0), or (−)
(b)		
Core market	(−)	(−)
Competitive non-core market	(+)	(+)

[a] Sign$\{p_1^* - C_1^1(y_1)\}$ in the regulated core market; sign$\{p_2 - C_{2a}^{2a}(y_{2a})\}$ in the duopolistic (Cournot) non-core market; sign$\{p_2 - C_{2a}^{2a}(y_{2a})\}$ in the competitive non-core market

regulation regardless of (i) how the core and non-core markets are related to each other and (ii) whether the non-core market is represented by a Cournot game or by perfect competition. However, for the relative revenue method, the regulated firm may or may not supply less output in the non-core market.

In the core market, we observe several striking implications for MPC regulation, however. For instance, when core and non-core market products are complements, there appears to be no qualitative reason for the regulator to favor one common cost allocation method over the other two. But in general, estimates of the profit tax on a core good that would lead the regulated firm to approach efficiency in supplying the core good would appear to be useful to the regulator. Further, when the products are substitutes, we suggest that a richer assortment of choices is open to the regulator under the relative revenue method than under the monotonic method. This holds if (a) the signs of the rate of change of the allocator under the relative revenue method (h_1 and h_{2a}) can be ascertained, and if (b) the appropriate value of the profit tax can be estimated. Nonetheless, we suggest that past history could provide some basis for determining the signs of h_1 and h_{2a} and the value of the profit tax.

Although we find that the relative revenue method offers the regulator certain advantages under a particular set of conditions, we note with interest the findings of Foreman (1995). He uses a two-period model with independent core and non-core markets under zero fixed costs. He demonstrates where the regulator should favor the relative output method over the relative revenue method in determining weights for prices on core and non-core goods in calculating a price cap. Foreman's two-period framework may suggest a future extension of our analysis.

Our analysis is of particular relevance to regulation of the Baby Bells, which has historically been characterized by MPC regulation. Our finding of underproduction distortion in the non-core market is in agreement with the Weisman (1993) result for MPC regulation with independent demands between core and non-core markets under the relative output method. We further show that it also holds when core and non-core goods are complements or substitutes under the monotonic method, regardless of whether the market for the non-core good is characterized by Cournot competition or by quasi-perfect competition. However, we have identified deviation from this result for the relative revenue method. Perhaps, more importantly, under MPC regulation, if the non-core market is perfectly competitive there will be *over*production distortion in the core market. We observe that recently enacted legislation has largely deregulated the telecommunications industry. Nonetheless, this paper has important implications for the entry of Baby Bells into long-distance and cellular markets. Our analysis suggests that under either PC or MPC regulation, diversification into long-distance service (non-core market) by the Baby Bells is achieved at the sacrifice of efficiency in local service (core market) when these two markets are not independent and when the long-distance market is imperfectly competitive. Moreover, our findings imply that efficient production of the core good will not be observed for the case of substitutes where the core market pertains to local service and non-core market pertains to cellular telephone service.

Given the enormous cost of duplicating the infrastructure for existing local service, we would look to other possibilities, such as adapting cable television service to local telephone service or the legislative mandate that the Baby Bells must make local service sufficiently available to long-distance companies before the Baby Bells can enter long-distance markets. Hence, we suspect that traditional providers of local telephone service would retain some level of monopoly power and would engender continued demand for regulatory activity.

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