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**VOLKSWIRTSCHAFTLICHE
DISKUSSIONSBEITRÄGE**



TELEVISION, ADVERTISING AND
PROGRAM QUALITY

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(revised)

DISCUSSION PAPER No. 45-93

UNIVERSITÄT - GESAMTHOCHSCHULE - SIEGEN
FACHBEREICH WIRTSCHAFTSWISSENSCHAFTEN

Television, Advertising and Program Quality¹

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Abstract: A monopolistic advertiser-supported television station chooses the program quality to serve (potential) viewers whose preferences may be skewed towards low or high program quality. The monopolist's profit-maximizing choice of program quality is completely characterized for fixed advertising time and different parameter constellations. The welfare implications of monopolistic supply are investigated, and the market allocation turns out to be significantly biased with the size and direction of allocative displacement depending on the values of demand and supply parameters. In some cases monopoly is shown to undersupply program quality, while under different parameter constellations the monopolistic program quality is greater than the welfare-maximizing one.

1. Introduction

The economic literature on advertiser-supported television has two major strands. The first was originated by Steiner (1954) and is reviewed in Owen, Beebe & Manning (1974). This approach considers consumers with all-or-none preferences for programs and ignores variation in preference intensities which is hardly in line with conventional microeconomics and welfare analysis. In contrast, Spence & Owen (1977) modeled programming choice in the framework of monopolistic competition thus integrating television economics into the broad field of industrial organization applied to an industry whose products (services), technologies and markets exhibit a number of unique characteristics. In the Spence-Owen model, the number of suppliers (broadcasters) is predetermined, the set of heterogeneous programs is assumed to be given, and the microfoundations of the demand side are not explicitly investigated. Broadcasters do not choose among different programs.

Similarly as in Noam (1987) the present paper considers programming characteristics a continuous entrepreneurial decision variable as well as advertising time (i.e. the number of commercials) by means of which the broadcaster determines both its audience size and its revenue. Moreover, the model offers a microeconomic approach to the demand side of the TV market with an explicit investigation of the consumer's option of watching TV or not. However, increasing the model's complexity in some regards – and maintaining the

¹ Helpful suggestions by Jens Büring are gratefully acknowledged, but remaining errors are the author's sole responsibility, of course.

analysis tractable at the same time — requires to reduce complexity in other aspects. This is done by constraining the analysis to monopolistic supply.

Section 2 develops the demand side of the model. Consumers have parametric preferences for program quality that is assumed to be continuous on a closed interval. Consumer types are ranked according to their favorite program quality on that interval, and the distribution (density) of consumer types may be flat or skewed either towards low or towards high program quality. Section 2 investigates how these different cases affect the broadcaster's audience for any predetermined program quality and advertising time.

In Section 3 the next step is to determine the monopolist's profit-maximizing choice of program quality for fixed advertising time where operating costs are assumed to be either linear or quadratic in program quality. Independent of the distribution of consumer types the revenue turns out to be increasing for small and decreasing for large program qualities. However, it is not concave on its entire domain and it is not everywhere differentiable. Despite these complications the profit maximizing program quality is completely characterized for different parameter constellations.

In Section 4 the welfare implications of monopolistic supply are investigated. Though welfare is a cubic function in program quality (except for an intermediate domain in which it is linear) it is feasible to compare the market solution with the welfare maximum. Under some conditions the market allocation turns out to be significantly biased with the size and direction of allocative displacement depending on both the values of individual utility parameters and on the distribution of consumer types. In some cases monopoly is shown to undersupply program quality, while under different parameter constellations the monopolistic program quality is greater than the welfare-maximizing one. More specifically, if raising program quality does not go along with a significant increase in programming costs, the monopolist is reluctant of taking the mass preferences appropriately into account, if the distribution of consumer types is skewed either towards low or towards high program qualities. In case that costs rise sharply with program quality, the monopolist tends to undersupply program quality.

2. The Model

The broadcasting firm (*broadcaster*) offers a television *program* (α, w) whose characteristics are the advertising time w and an index $\alpha \in [0, 1]$ of programming characteristics. The introduction of the index α is a very simple if not rudimentary way of capturing the diversity of real-world multidimensional heterogeneous television services. In

case of a news channel or a sports channel, α may be interpreted as measuring the degree of professional competence or the relevance and completeness of coverage etc. Other examples are channels that mix education and entertainment, or information and entertainment, so that α might measure the convex combination of time devoted to these two types of programming. We refer to α as '*program quality*' for notational convenience keeping in mind, however, that α is related to a measurable product characteristic but does not involve value judgments of the (potential) viewers or anybody else. Noam (1987) uses a similar concept of ordering programs along an axis (without lower and upper bounds) ranging from 'low culture' to 'high culture', and he emphasizes that an ordinal rather than a cardinal ranking is sufficient.² The broadcast is "on the air" for one time unit, say 24 hours, and it consists of w minutes of commercials and $1-w$ minutes of program proper (contents), i.e. information, culture, entertainment etc.

The demand side of the TV market is characterized by infinitely many *consumers* who are potential TV viewers. A *consumer of type β* is a point in the interval $[0, 1]$, and consumer types are distributed on this interval according to the density function

$$(1) \quad \Psi(\beta) = h + 2(1-h)\beta \quad \text{with } \beta \in [0, 1] \text{ and } h \in [0, 2].$$

By parametric variation of h it is possible to generate, in a very simple and stylized way, different linear distributions of consumers: for $h = 2$ consumers are clustered at low values of β and for $h = 0$ at high values of β . $h = 1$ characterizes the intermediate case of a flat distribution.

Each consumer is assumed to have the all-or-nothing option of either watching TV during the entire time period or not watching TV at all³. The consumer of type β has *utility*

$$(2) \quad \begin{aligned} &u = 0, \text{ if she does not watch TV;} \\ &u = V(\alpha, w; \beta) := v_1 - v_2 w - \frac{|\alpha - \beta|}{v_3}, \quad (v_1, v_2, v_3 > 0), \text{ otherwise.} \end{aligned}$$

– Figure 1: Consumer's preferences of watching TV –

As illustrated in Figure 1, $\alpha = \beta$ is the favorite program quality for each consumer of type β , but consumers of that type still derive positive utility from program qualities in the

² According to Noam (1987, p. 165), "for most programs such classification is possible; in some instances, a program speaks on several levels, and an ordinal assignment is more difficult, but it is in the nature of modeling to simplify."

³ For an effort to relax this standard assumption see Wildman & Owen (1985).

interval $[\underline{\alpha}, \bar{\alpha}]$ around β . This interval is the larger the greater is $v_3 = \tan \delta$. The assumption (2) implies that for each program the consumer's satisfaction from watching TV is diminished by increased broadcasting of commercials. The change from w to $w' > w$ causes a downward shift of the graph of function V in Figure 1.⁴ In view of (2), utility maximization means that for any given program (α, w) the consumer of type β chooses to watch or not according to $\max [0, V(\alpha, w; \beta)]$.

For convenience of exposition we first restrict our attention to those programs (α, w) and to those utility functions V which satisfy $\{ \beta \mid V(\alpha, w; \beta) \geq 0 \} \subset (0, 1)$. If β_0 is in this set, the consumer of type β_0 derives non-negative utility from watching a program (α, w) if and only if $\alpha \in [\beta_0 - \gamma, \beta_0 + \gamma]$, where $\gamma := v_3(v_1 - v_2 w)$. Conversely, for any predetermined program (α_0, w_0) the utility of consumer type β from watching that program is $V(\alpha_0, w_0; \beta)$. Hence a consumer of type β derives non-negative utility from watching the program (α_0, w_0) , if and only if $\beta \in [\alpha_0 - \gamma_0, \alpha_0 + \gamma_0]$ with $\gamma_0 := v_3(v_1 - v_2 w_0)$.

– **Figure 2:** The domain of and the utility distribution for a television program –

This *dual* relationship is illustrated in Figure 2, where ABC is the 'utility cone' of that particular consumer type β_0 whose favorite program is (α_0, w_0) , i.e. who satisfies $\beta_0 = \alpha_0$. Consumers of type β_0 are indifferent with respect to viewing or not the two programs $(\alpha_0 - \gamma_0, w_0)$ and $(\alpha_0 + \gamma_0, w_0)$. Conversely, consumers of type $\beta_\ell = \alpha_0 - \gamma_0$ and of type $\beta_u = \alpha_0 + \gamma_0$ are indifferent of watching the program (α_0, w_0) . Hence these consumer types are, respectively, the *upper marginal viewers* and the *lower marginal viewers* of program (α_0, w_0) . All types $\beta < \beta_\ell$ and all types $\beta > \beta_u$ are not viewers of program (α_0, w_0) , whereas all $\beta \in (\alpha_0 - \gamma_0, \alpha_0 + \gamma_0)$ derive positive utility from watching that program. In other words, the line ABC does not only indicate the utility consumers of type β_0 derive from alternative programs (α_0, w_0) , but it also represents the *utility distribution* of all consumer types for the program (α_0, w_0) .

⁴ This negative impact of commercials on utility does not necessarily imply negative marginal utility from commercials. Indeed, (2) is compatible with positive marginal utility from watching commercials as long as the viewers experience a net marginal increase of utility from substituting one minute of advertising by one minute of program proper (Schmitz 1989).

Unfortunately, the condition $\{ \beta \mid V(\alpha, w; \beta) \geq 0 \} \subset (0, 1)$ cannot be satisfied for all programs (α, w) and not for all utility functions (2). To see this, define $\bar{\beta}$ and $\underline{\beta}$ implicitly by the conditions " $V(\alpha, w, \underline{\beta}) = 0 \ \& \ \underline{\beta} < \alpha$ " and " $V(\alpha, w, \bar{\beta}) = 0 \ \& \ \bar{\beta} > \alpha$ ", respectively. Obviously, in view of (2) these conditions yield $\bar{\beta} = \alpha + \gamma$ and $\underline{\beta} = \alpha - \gamma$. We clearly have $\bar{\beta} = \beta_u$ and $\underline{\beta} = \beta_\ell$ for program (α, w) if $\bar{\beta}, \underline{\beta} \in [0, 1]$. But if $\bar{\beta} > 1$ or $\underline{\beta} < 0$ the marginal viewers are $\beta_u = 1$ or $\beta_\ell = 0$, respectively. To handle these boundary problems observe first that the parameter constellation $\gamma < 0$ is irrelevant, because in this case there would not exist any program quality $\alpha \in [0, 1]$ and not any consumer $\beta \in [0, 1]$ such that the utility $V(\alpha, w; \beta)$ is non-negative. Hence we restrict the analysis to $\gamma \geq 0$ and w to the interval $[0, v_1/v_2]$. From the above discussion it is clear that boundary solutions are the more likely, the greater is γ . It will be convenient to distinguish the following intervals of γ .

Assumption 1 (H1): $\gamma \in [0, 1/2]$;

Assumption 2 (H2): $\gamma \in [1/2, 1]$;

Assumption 3 (H3): $\gamma > 1$.

H1 implies $0 \leq \gamma < 1 - \gamma \leq 1$, H2 implies $0 \leq 1 - \gamma \leq \gamma \leq 1$, and H3 implies the inequalities $1 - \gamma < 0 < 1 < \gamma$. All this information is captured in the following subsets of the interval $[0, 1]$:

$$A_{1\ell} := [0, \gamma], \quad A_{1m} := [\gamma, 1 - \gamma] \quad \text{and} \quad A_{1u} := [1 - \gamma, 1];$$

$$A_{2\ell} := [0, 1 - \gamma], \quad A_{2m} := [1 - \gamma, \gamma] \quad \text{and} \quad A_{2u} := [\gamma, 1];$$

$$A_{3\ell} = \emptyset, \quad A_{3m} := [0, 1] \quad \text{and} \quad A_{3u} = \emptyset.$$

For $j = 1, 2$ and for $x = \ell, m, u$ the set A_{jx} tells us that assumption H_j applies and that if $\alpha \in A_{jx}$ then $\beta_\ell = 0$ for $x = \ell$ and $\beta_u = 1$ for $x = u$. In case of H3, the upper and lower marginal viewers are $\beta_u = 1$ and $\beta_\ell = 0$, respectively, for all $\alpha \in [0, 1]$. These considerations are formalized as follows: Define the set-valued function $B^{jx} : A_{jx} \rightarrow [0, 1]$ by

$$B^{jx}(\alpha, w) := [\beta_\ell, \beta_u] \{ \beta \in [0, 1] \mid Z(\beta; \alpha, w) \geq 0 \text{ and } (\alpha, w) \in A_{jx} \times [0, v_1/v_2] \}$$

i.e. by the set of consumer types who are viewers, if the program is $(\alpha, w) \in A_{jx} \times [0, v_1/v_2]$. Hence for given $w \in [0, v_1/v_2]$ one obtains $\alpha \in A_{jx}$ if and only if $\beta \in B^{jx}(\alpha, w)$, where $B^{jx}(\alpha, w)$ is the subset of consumer types whose utility is non-negative for program (α, w) . The concept of the *support set* $B^{jx}(\alpha, w)$ is illustrated in Figure 2 for the assumption A1 and for $\alpha \in A_{1m}$. The utility cone is given by ABC so that all consumers of type $\beta \in [0, \beta_\ell) \cup (\beta_u, 1]$ are no viewers whereas all others are in the support set $B^{1m}(\alpha_0, w_0) = [\alpha - \gamma, \alpha + \gamma]$. All this information enables us to determine the audience size or *domain* of program (α, w) , for $\alpha \in A_{jx}$ as

$$(3) \quad D^{jx}(\alpha, w) := \int_{B^{jx}(\alpha, w)} \Psi(\beta) d\beta.$$

If H1 applies, it is straightforward that $B^{1\ell}(\alpha, w) = [0, \alpha + \gamma]$, $B^{1m}(\alpha, w) = [\alpha - \gamma, \alpha + \gamma]$ and $B^{1u}(\alpha, w) = [\alpha - \gamma, 1]$. Hence (3) takes the form

$$(3a) \quad D^{1\ell}(\alpha, w) \quad := (\alpha + \gamma)[h + (1-h)(\alpha + \gamma)] \\ = \gamma(h + \gamma - \gamma h) + (h + 2\gamma - 2\gamma h) \cdot \alpha + (1-h) \cdot \alpha^2;$$

$$(3b) \quad D^{1m}(\alpha, w) \quad := 2\gamma[h + 2\alpha(1-h)] = 2\gamma h + 4\gamma(1-h)\alpha;$$

$$(3c) \quad D^{1u}(\alpha, w) \quad := 1 - (\alpha - \gamma)[h + (1-h)(\alpha - \gamma)] \\ = (1+\gamma)(1 - \gamma + \gamma h) + (2\gamma - h - 2\gamma h) \cdot \alpha - (1-h) \cdot \alpha^2.$$

The following analysis is restricted to the assumption H1 and the superscript 1 is suppressed, for convenience of notation.

The costs of broadcasting the program (α, w) depend, in general, both on the length of program (exclusive of commercials), $1-w$, and on its quality⁵. These costs are specified as

$$(4) \quad C(\alpha, w) = (1-w)(c_0 + c_1 \cdot \alpha + c_2 \cdot \alpha^2).$$

⁵ These costs may consist of operating costs, program production costs and/or costs of purchasing the rights for broadcasting programs. The broadcaster's decision between self-production or purchase from program brokers is not addressed in the present paper.

Let p be the price charged by the broadcaster to the advertising firm for contacting the total potential audience per minute of commercials. If the broadcaster's audience is the fraction⁶ $D(\alpha, w)$ of all consumers, the price to be paid per time unit of commercials by the advertising firm is $p \cdot D(\alpha, w)$. The price p is assumed to be positive and *exogenous*. Therefore the broadcaster's *revenue* from selling advertising time is

$$R(\alpha, w) := p \cdot w \cdot D(\alpha, w)$$

The broadcaster aims at choosing (α, w) as to

$$(5) \quad \underset{(\alpha, w)}{\text{Maximize}} \quad \Pi(\alpha, w) := R(\alpha, w) - C(\alpha, w) \quad \text{on } [0, 1] \times [0, \frac{v_1}{v_2}],$$

where for $x = u, m, \ell$ we specify $R(\alpha, w) = pwD^x(\alpha, w)$, if and only if $(\alpha, w) \in A_x \times [0, v_1/v_2]$. As far as Π is differentiable (see below) the first and second order conditions for solving (5) are⁷

$$(5a) \quad \Pi_{\alpha} = pw \cdot D_{\alpha} - C_{\alpha} = 0 \quad \text{and} \quad \Pi_{\alpha\alpha} = pw \cdot D_{\alpha\alpha} - C_{\alpha\alpha} \leq 0,$$

$$(5b) \quad \Pi_w = pD + pw \cdot D_w - C_w = 0 \quad \text{and} \quad \Pi_{ww} = p(2D_w + wD_{ww}) - C_{ww} \leq 0.$$

3. Profit-maximizing Choice of Program Quality

3.1 The revenue function

It is not a trivial exercise to determine the maximizers of Π , because the shape of function R (as part of function Π) depends on whether α is an element of A_u , A_m or A_{ℓ} and the bounds of these intervals depend on the value of w , in turn. To cope with these difficulties we keep w constant in the present model and proceed step wise as follows: First, we investigate the properties of the revenue function R (Lemma 1). Then we calculate the maximizers of Π for each interval A_x ($x = u, m, \ell$) specifying the broadcasting costs as a linear function of α (Lemma 2); third, the maximizer of Π is determined by eliminating those 'local' maximizers which are not global (Propositions 1). After that, the entire procedure is repeated for the case of quadratic production cost (Lemma 3 and Proposition 2).

⁶ The superscript x ($x = \ell, m, u$) is dropped whenever this does not cause ambiguities.

⁷ Functions are represented by upper case letters, and subscripts attached to them indicate partial derivatives, e.g. $\Pi_{\alpha} := \partial\Pi/\partial\alpha$ etc.

Lemma 1: For given $w \in [0, 1)$, the revenue function R has the following properties:

- (i) R is continuous on $[0, 1]$ and $R(\alpha) > 0$ for all $\alpha \in [0, 1]$ and all $h \in [0, 2]$;
- (ii) $h \in [0, 1)$: R is strictly convex and increasing on A_ℓ , linear and strictly increasing on A_m , and strictly concave and decreasing on A_u .
- (iii) $h = 1$: R is piecewise linear on $[0, 1]$; R is strictly increasing on A_ℓ , constant on A_m , and strictly decreasing on A_u .
- (iv) $h \in (1, 2]$: R is strictly concave and increasing on A_ℓ , linear and strictly decreasing on A_m , and strictly convex and decreasing on A_u .

Proof: Ad (i): According to (5) R is differentiable on each subset A_ℓ , A_m and A_u . Moreover, by definition of D^x and B^x ($x = \ell, m, u$) the equalities $R^\ell(\alpha = \gamma, w) = R^m(\alpha = \gamma, w)$ and $R^m(\alpha = 1 - \gamma, w) = R^u(\alpha = 1 - \gamma, w)$ hold. This proves continuity. For every $x = \ell, m, u$ and for every $\alpha \in A_x$ the support set $B^x(\alpha, w)$ has a non-empty interior. Hence $\Psi(\alpha) > 0$ (except at boundary points) for all α implies $D^x(\alpha, w) > 0$ and $pwD^x(\alpha, w) > 0$, all x , all α , all $w > 0$.

The proof proceeds by investigating the shape of R on the subsets A_ℓ , A_m , A_u for alternative ranges of h .

(a) **R on A_ℓ** In view of (5a) the derivatives of R^ℓ are $R_\alpha^\ell(\alpha) = pw[h + 2\gamma(1-h)] + 2pw(1-h)\alpha$ and $R_{\alpha\alpha}^\ell(\alpha) = 2pw(1-h)$.

- If $h \in [0, 1)$, R^ℓ is strictly convex and attains its minimum at $\hat{\alpha} = -\frac{h + 2\gamma(1-h)}{2(1-h)} < 0$. Hence R^ℓ is strictly increasing on A_ℓ .

- For $h = 1$, R^ℓ is linear with slope $R_\alpha^\ell = pw > 0$.

- In case of $h \in (1, 2]$ the function R^ℓ is strictly concave and attains its maximum at $\alpha^* = -\frac{h + 2\gamma(1-h)}{2(1-h)} > 0$.

- One has $\alpha^* \geq \gamma$ iff $h(1 - 4\gamma) + 4\gamma \geq 0$ which holds true if either " $4\gamma \leq 1$ " or " $4\gamma > 1$ & $h \in (1, \frac{4\gamma}{4\gamma-1}]$ ". Under these conditions R^ℓ is strictly increasing on A_ℓ .

- One has $\alpha^* \leq 0$ iff $h \leq -\frac{2\gamma}{1-2\gamma}$. But in view of $1 > 2\gamma$, this inequality cannot be

satisfied. Hence $\alpha^* > 0$, i.e. R^ℓ cannot be strictly decreasing on A_ℓ .

- One has $\alpha^* \in (0, \gamma)$, iff $h(1 - 4\gamma) + 4\gamma < 0$ which holds true if " $4\gamma > 1$ & $h > \frac{4\gamma}{4\gamma-1}$ ". But $4\gamma/(4\gamma-1) > 2$, and therefore $\alpha^* \notin (0, \gamma)$.

(b) **R on A_m .** In view of (5b) R^m is clearly linear in α and its first derivative is $R_\alpha^m(\alpha) = 4\gamma(1-h)pw$. Obviously, on its domain A_m the function R^m is strictly increasing for $h \in (0, 1]$, constant for $h = 1$ and strictly decreasing for $h \in (1, 2]$.

(c) **R on A_u .** In view of (5c) the derivatives of R^u are $R_\alpha^u(\alpha) = -pw[h(1 + 2\gamma) - 2\gamma] - 2pw(1-h)\alpha$ and $R_{\alpha\alpha}^u(\alpha) = -2pw(1-h)$.

• If $h \in [0, 1)$, R^u is strictly concave and attains its maximum at

$\alpha^* = -\frac{h(1 + 2\gamma) - 2\gamma}{2(1-h)}$. One has $\alpha^* \geq 1-\gamma$ iff $h(1 - 4\gamma) \geq 2 - 4\gamma$. Clearly, $4\gamma < 1$ is a necessary condition for $\alpha^* \geq 1-\gamma$. Hence $\alpha^* \geq 1-\gamma$ iff " $4\gamma < 1$ & $h \geq \frac{2 - 4\gamma}{1 - 4\gamma}$ ". But $(2 - 4\gamma)/(1 - 4\gamma) > 1$ and $h < 1$ by assumption. Hence $\alpha^* < 1 - \gamma$, and therefore R^u is strictly decreasing on A_u .

• For $h = 1$, R^u is linear with slope $R_\alpha^u = -pw < 0$.

• In case of $h \in (1, 2]$, R^u is strictly convex and attains its minimum at

$\hat{\alpha} = -\frac{h(1 + 2\gamma) - 2\gamma}{2(1-h)} > 0$. One has $\hat{\alpha} \geq 1$ iff $h \leq \frac{2 - 2\gamma}{1 - 2\gamma}$. From $(2 - 2\gamma)/(1 - 2\gamma) \geq 2$ it follows that $\hat{\alpha} \geq 1$. Hence R^u is strictly decreasing on A_u . \square

Except for the concavity–convexity properties of the revenue function, Lemma 3 confirms one's intuition : Whenever α is in A_ℓ or in A_u and tends to an extreme value ($\alpha = 0$ or $\alpha = 1$) then revenue shrinks towards zero. This is so independent of whether the viewers' density is highest or lowest at that extreme value.

The revenue attains its maximum always in the intermediate interval A_m . If the distribution is flat, that maximum is indeterminate. Otherwise it occurs at that boundary point of A_m which is next to the highest–density point. More specifically, if $\alpha = 1$ has highest density (i.e. $h = 0$ in (1)), then $\arg \max R(\alpha) = 1-\gamma$; if $\alpha = 0$ has highest density ($h = 2$) then $\arg \max R(\alpha) = \gamma$. This is easy to comprehend, because at $\alpha = 1-\gamma$ for $h = 0$ and at $\alpha = \gamma$ for $h = 2$ the respective support set $B(\alpha, w)$ is the largest of all those support sets which include all high–density consumer types. Every attempt to move from $\alpha = 1 - \gamma$

to higher program qualities in case of $h = 2$ (or from $\alpha = \gamma$ to lower values of α in case of $h = 0$) reduces the audience and hence revenue.

– **Figure 3:** Revenue depending on the viewers' distribution and program quality –

As can be readily seen from Figure 3, the revenue curves are completely symmetric with respect to (linear) biases from the flat distribution. Hence the results do not depend on calling $\alpha = 1$ the highest and $\alpha = 0$ the lowest quality. If the broadcaster's cost should turn out to increase with decreasing α [substituting, e.g., (6) by $(1-w)(c_0 + c_1(1-\alpha) + c_2(1-\alpha)^2)$] the results would not change qualitatively.

3.2 Profit maximization with linear costs

Lemma 2: Suppose, $w \in [0, 1)$ is fixed (and hence γ) and $c_1 \geq 0$, $c_2 = 0$, i. e. the cost function (6) is linear in program quality. Denote by $\hat{\alpha}_x$ the maximizer of $\Pi(\alpha, w)$ on A_x ($x = u, m, \ell$) and define $mc := (1-w)c_1$, $y := 2(1-h)pw$ and $z := hpw + \gamma y$ for convenience of notation.

(i) For $h \in [0, 2]$ and $A_x = A_u$: $\hat{\alpha}_u = \min A_u = 1-\gamma$.

(ii) For $h \in [0, 2]$ and $A_x = A_m$: $\left\{ \begin{array}{l} \hat{\alpha}_m = 1-\gamma = \max A_m, \\ \hat{\alpha}_m \in A_m \text{ (arbitrary)} \\ \hat{\alpha}_m = \gamma = \min A_m. \end{array} \right\} \Leftrightarrow mc \begin{cases} < \\ = \\ > \end{cases} 2\gamma y.$

(iii) Suppose $A_x = A_\ell$

(a) $h > 1$ implies $\left\{ \begin{array}{l} \hat{\alpha}_\ell = \gamma = \max A_\ell \\ \hat{\alpha}_\ell = \frac{mc - z}{y} \\ \hat{\alpha}_\ell = 0 = \min A_\ell \end{array} \right\} \Leftrightarrow \begin{cases} mc \leq z + \gamma y; \\ mc \in (z + \gamma y, z); \\ mc \geq z > pw; \end{cases}$

(b) $h = 1$ implies $\left\{ \begin{array}{l} \hat{\alpha}_\ell = \gamma \\ \hat{\alpha}_\ell \in A_\ell \text{ (arbitrary)} \\ \hat{\alpha}_\ell = 0 \end{array} \right\} \Leftrightarrow mc \begin{cases} < \\ = \\ > \end{cases} pw = z + \gamma y;$

$$(c) \ h < 1 \text{ implies } \left\{ \begin{array}{l} \hat{\alpha}_\ell = \gamma \\ \hat{\alpha}_\ell = \gamma \text{ and } \hat{\alpha}_\ell = 0 \\ \hat{\alpha}_\ell = 0 \end{array} \right\} \Leftrightarrow mc \left\{ \begin{array}{l} < \\ = \\ > \end{array} \right\} z + \frac{\gamma y}{2}.$$

Proof: Ad (i): Differentiation of (5c) yields

$$D_\alpha^u = -[2(1-h)(\alpha - \gamma) + h] = -[2(\alpha - \gamma) + h(1 - 2(\alpha - \gamma))].$$

Since $A_u = [1-\gamma, 1]$ by definition, one obtains

$$(\alpha - \gamma) \in [1-2\gamma, 1-\gamma] \text{ for all } \alpha \in A_u.$$

Recall that A1 implies $\gamma < 1-\gamma$ with $\gamma := v_3(v_1 - v_2w)$. Hence $v_1v_3 < 1/2$. Since $w \geq 0$ and $\gamma = v_3(v_1 - v_2w)$ it follows that $\gamma \leq v_1v_3 < 1/2$ or $[1-2\gamma, 1-\gamma] \subset (0, 1]$ which in turn yields $D_\alpha^u \leq 0$ for all $\alpha \in A_u$ and for all $h \in [0, 2]$. From this observation Lemma 2i is straightforward.

Ad (ii): The function Π is linear in α on A_m . Hence the condition $2\gamma y > mc$ means that $\Pi_\alpha(\alpha, w) > 0$ for all $\alpha \in A_m$, i. e. one obtains the "corner solution" $\hat{\alpha}_m = 1-\gamma$. In case of $2\gamma y = mc$ (presupposing $h < 1$ as a necessary condition) any $\alpha \in A_m$ maximizes Π . From the above, the case $2\gamma y < mc$ is obvious.

Ad (iii): For $h > 1$, Π is strictly concave in α on A_ℓ . Suppose first, $\Pi_\alpha > 0$ for all $\alpha \in \text{int } A_\ell$. Then $\hat{\alpha}_\ell = \gamma$, and $\Pi_\alpha(\hat{\alpha}_\ell = \gamma, w) \geq 0 \Leftrightarrow mc \leq z + \gamma y$. Conversely, if $\Pi_\alpha(\alpha, w) \leq 0$ for $\alpha = 0$, then $\hat{\alpha}_\ell = 0$ and $\Pi_\alpha \leq 0 \Leftrightarrow mc \geq z$. For $h = 1$, Π is linear in α on A_ℓ . Hence the proof is like that of Lemma 2ii. For $h < 1$, Π is strictly convex in α on A_ℓ . Therefore, a maximizer of Π on A_ℓ is either $\alpha = 0$ or $\alpha = \gamma$. It is easy to calculate $\Pi(\alpha=0, w) = hpw\gamma + \gamma^2y/2 - (1-w)c_0$ and $\Pi(\alpha=\gamma, w) = 2hpw\gamma + 2y\gamma^2 - (1-w)c_0 - (1-w)\gamma c_1$. Hence

$$\Pi(\alpha=0, w) \left\{ \begin{array}{l} \leq \\ \geq \end{array} \right\} \Pi(\alpha=\gamma, w) \Leftrightarrow mc \left\{ \begin{array}{l} \leq \\ \geq \end{array} \right\} z + \frac{\gamma y}{2}.$$

This proves Lemma 2iiic. □

The maximizers $\hat{\alpha}_x$ ($x = u, m, \ell$) in Lemma 2 have been calculated independently of the sign of $\Pi^X(\hat{\alpha}_x, w)$. Of course, the broadcaster would not supply any program if $\Pi^X(\hat{\alpha}_x, w) < 0$. But we know from Lemma 1i that revenue is strictly positive for all $\alpha \in [0, 1]$ and for $\gamma > 0$. Hence $\Pi^X(\hat{\alpha}_x, w) < 0$ cannot occur unless the revenue at $\alpha = 0$ is less than the fixed cost $c_0(1-w)$.

Lemma 2 is only a first step for finding the solution to (7) under fixed w , because the maximization procedure has been artificially restrained to the compact subsets A_u , A_m and A_ℓ . We know that if $\tilde{\alpha}$ solves (7), then $\tilde{\alpha} \in \{\hat{\alpha}_u, \hat{\alpha}_m, \hat{\alpha}_\ell\}$. But it remains to be shown which $\hat{\alpha}_x$ can be identified as the maximizer of α over $[0, 1]$.

Proposition 1: Denote by $\tilde{\alpha}$ the solution of (7) for predetermined $w \in [0, 1)$ and by $\hat{\alpha}_x$ the maximizer of Π on A_x ($x = u, m, \ell$) as determined in Lemma 2.

(i) If $h \geq 1$ and $c_1 > 0$, then $\tilde{\alpha} = \hat{\alpha}_\ell$

(ii) For $h < 1$ and $c_1 > 0$:

$$(a) \quad \tilde{\alpha} = 1 - \gamma, \quad \text{if } mc < \min \left\{ 2\gamma y, \frac{2z + \gamma y}{2} \right\};$$

$$(b) \quad \tilde{\alpha} \in A_m \text{ (arbitrary)}, \quad \text{iff } mc = 2\gamma y;$$

$$(c) \quad \tilde{\alpha} = \gamma, \quad \text{if } mc \in \left[2\gamma y, \frac{2z + \gamma y}{2} \right] \neq \emptyset;$$

$$(d) \quad \tilde{\alpha} = \begin{cases} \gamma \\ 0 \end{cases} \Leftrightarrow \begin{cases} mc \in \left[\frac{2z + \gamma y}{2}, \frac{\gamma pw}{1-\gamma} [(1-h)(4-5\gamma)+h] \right] \neq \emptyset, \\ mc \in \left[\frac{\gamma pw}{1-\gamma} [(1-h)(4-5\gamma)+h], 2\gamma y \right] \neq \emptyset. \end{cases}$$

$$(e) \quad \tilde{\alpha} = 0, \quad \text{if } mc > \max \left\{ 2\gamma y, \frac{2z + \gamma y}{2} \right\};$$

(iii) Suppose, $c_1 = 0$ (i.e. cost is independent of program quality):

$$(a) \quad \tilde{\alpha} = \gamma \quad \text{for } h > 1;$$

$$(b) \quad \tilde{\alpha} \in A_m \text{ (indeterminate) for } h = 1;$$

$$(c) \quad \tilde{\alpha} = 1 - \gamma \quad \text{for } h < 1.$$

Proof: Since $\Pi^\ell(\alpha=\gamma, w) = \Pi^m(\alpha=\gamma, w) = 2\gamma z - (1-w)c_0 - \gamma mc$ for all $h \in [0, 2]$, one has $\tilde{\alpha} = \gamma$, whenever $\hat{\alpha}_\ell = \gamma$ and $\hat{\alpha}_m = \gamma$ are the unique maximizers on A_m and A_ℓ , respectively.

Ad (i): For $h \geq 1$ and $mc > 0$, $\hat{\alpha}_m = \gamma$ is the unique maximizer of Π on A_m . If $h = 1$, Lemma 2iii b implies $\tilde{\alpha} = \gamma$ if $mc < pw$. In case of $\hat{\alpha}_\ell = 0$ (and $h = 1$) one obtains $\Pi^\ell(\hat{\alpha}=0, w) = \gamma pw - (1-w)c_0$ and therefore $\Pi^\ell(\hat{\alpha}=0, w) \geq \Pi^m(\hat{\alpha}=\gamma, w) \Leftrightarrow mc \geq pw$. This proves Proposition 1i for $h = 1$. If $h > 1$, it is straightforward that $\tilde{\alpha} = \hat{\alpha}_m = \hat{\alpha}_\ell$ for $mc \leq z + \gamma y$. Since Π^ℓ is strictly concave on A_ℓ for $h > 1$, the equality $\Pi^\ell(\alpha=\gamma, w) = \Pi^m(\alpha=\gamma, w)$, when combined with Lemma 2iii a, implies that $\alpha = \gamma$ is not the maximum on $A_m \cup A_\ell$ whenever $mc > z + \gamma y$.

Ad (ii): For $h < 1$ and $mc < 2\gamma y$ one obtains $\hat{\alpha}_m = 1 - \gamma$, and $mc < z + \gamma y/2$ yields $\hat{\alpha}_\ell = \gamma$. Since for $h < 1$ Π is strictly increasing in A_u , Proposition 1iia is straightforward in view of the continuity of function Π . Proposition 1iib is a direct consequence of Lemma 2ii. If $mc < z + \gamma y/2$ and $mc > 2\gamma y$ (which is satisfied simultaneously, if $(1-h)\gamma < h$), then $\hat{\alpha}_\ell = \gamma$ and $\hat{\alpha}_m = \gamma$ are the unique maximizers on A_ℓ and A_m respectively. Hence $\tilde{\alpha} = \gamma$ (Proposition 1iic). To prove Proposition 1iid observe that if $mc > (2z + \gamma y)/2$ and $mc < 2\gamma y$ (which is satisfied simultaneously, if $3(1-h)\gamma > h$), then $\hat{\alpha}_\ell = 0$ and $\hat{\alpha}_m = 1 - \gamma$ are the unique maximizers on A_ℓ and A_m , respectively. Since both $\Pi^\ell(0, w) > \Pi(\gamma, w)$ and $\Pi^m(1-\gamma, w) > \Pi(\gamma, w)$, the profits $\Pi^\ell(0, w)$ and $\Pi^m(1-\gamma, w)$ must be calculated and directly compared. One obtains

$$\Pi^\ell(0, w) = \frac{2z - \gamma y}{2} \cdot \gamma - (1-w) \cdot c_0 \quad \text{and}$$

$$\Pi^m(1-\gamma, w) = 2\gamma (hpw + y - \gamma y) - (1-w) \cdot c_0 - (1-\gamma) \cdot mc \quad \text{and hence}$$

$$\Pi^\ell(0, w) \geq \Pi^m(1-\gamma, w) \Leftrightarrow mc \geq \frac{\gamma pw}{1-\gamma} \cdot [(1-h)(5\gamma - 4) + h].$$

Finally, if $mc > (2z + \gamma y)/2$ and $mc > 2\gamma y$, Lemmata 2iiic and 2ii yield $\hat{\alpha}_\ell = 0$ and $\hat{\alpha}_m = \gamma$. Proposition 1iie follows easily from continuity of Π .

Ad (iii): Proposition 1iii is straightforward from Lemma 2 for $mc = 0$. □

Observe that the profit function is not everywhere differentiable, and it is not concave. Despite these inconvenient properties, however, its shape and the associated maximum can be completely characterized. Figure 4 illustrates in a straightforward way what the profit function looks like for alternative distributions of consumer types and for alternative marginal costs. The message of Figure 4 is summarized as follows:

(i) With consumer types clustering at low qualities ($h > 1$) there is mc_0 such that the profit-maximizing quality is $\tilde{\alpha} = \gamma < 1-\gamma$ for all $mc \leq mc_0$. Moreover, $mc \geq mc_0$ and $mc \rightarrow \infty$ implies that $\tilde{\alpha}$ tends to zero in a strictly monotone way.

(ii) With consumer types clustering at high qualities ($h < 1$) there is mc_1 and mc_2 satisfying $0 < mc_1 < mc_2$ such that the profit-maximizing quality is $\tilde{\alpha} = 1-\gamma$ for all $mc \leq mc_1$, $\tilde{\alpha} = \gamma$ for all $mc \in [mc_1, mc_2]$, and $\tilde{\alpha} = 0$ for all $mc \geq mc_2$ (Note that the profit maximizer is not unique if and only if $mc = mc_1$ and $mc = mc_2$).

– Figure 4: Profit maxima for linear quality costs –

In Table 1 the constellation $h > 1$, $mc \in (z+\gamma y, z)$ and $mc > 0$ is denoted *case 1*, and the first row of Table 1 reports the pertinent impact on $\tilde{\alpha}$ of parameter changes. *Case 2* corresponds to Proposition 1ii with $\tilde{\alpha} = \gamma$.

response	shock	Δv_1	Δv_2	Δv_3	Δh	Δc_1	Δp	Δw
	$\Delta \tilde{\alpha}$	case 1	–	+	–	–	–	+
	case 2	+	–	+	0	0	0	–

Table 1: Comparative statics related to Proposition 1⁸

As Table 1 shows, in case 1 the broadcaster reacts by reducing program quality

- if the consumers' overall preference for watching TV rises ($\Delta v_1 > 0$);
- if the consumers' marginal disutility of commercials decreases ($\Delta v_2 < 0$);
- if the consumers' aversion to programs other than their favorites declines ($\Delta v_3 > 0$);

⁸ For $\Delta \tilde{\alpha} / \Delta h$ one obtains $\Delta \tilde{\alpha} / \Delta h \geq 0 \Leftrightarrow mc \geq p \cdot w$. Since $p \cdot w < mc$ implies $\Pi(\alpha, w) < 0$ for $c_0 \geq 0$, $c_1 > 0$ and $c_2 = 0$, it clearly follows that $\Delta \tilde{\alpha} / \Delta h < 0$.

- if the consumers' taste shifts towards low quality programs ($\Delta h > 0$);
- if the marginal production costs of program quality increase ($\Delta c_1 > 0$);
- if the price for advertising is reduced ($\Delta p < 0$);
- if total advertising time decreases ($\Delta w < 0$);

In sharp contrast, if case 2 applies, i.e. if consumers tend to prefer high quality ($h < 1$) and marginal production costs of program quality are not too high, then the broadcaster's response to parameter shifts is either the opposite to its reactions in case 1 (when v_1 , v_2 , v_3 or w is changed) or zero (when h , c_1 or p is changed). The opposite effects on program quality of changes in total advertising time in cases 1 and 2 is particularly intriguing, because w can be considered a regulatory policy instrument. If the regulator should aim at rising program quality by changing w , it is not clear whether the advertising time limit should be expanded or reduced.

Proposition 1iii explores the solution $\tilde{\alpha}$ under the hypothesis that cost is independent of program quality ($c_1 = mc = 0$). In that case the broadcaster's profit is proportional to its revenue which had been characterized in Lemma 1. As is obvious from Figure 3, the broadcaster chooses its program quality from the intermediate interval A_m only. It selects the upper bound $1-\gamma$ if consumers cluster at high values of β ($h > 1$) and the lower bound γ , if $h < 1$. The broadcaster is indifferent between all $\alpha \in A_m$ if the distribution of consumers on $[0, 1]$ is flat.

3.3 Profit maximization with quadratic costs

Zero or linear program quality costs, as assumed in Proposition 1, may not be always empirically relevant. We therefore proceed to solve (7) for fixed w and $c_2 > 0$ (quadratic program quality costs). Analogous to the preceding analysis, we first identify the maximizers of α on the subsets A_u , A_m and A_ℓ

Lemma 3: *Suppose $w \in (0, 1)$ is fixed (and hence γ) and $c_1 = 0$, $c_2 > 0$, i. e. the production cost is quadratic in program quality. Denote by $\hat{\alpha}_x$ the maximizer of $\Pi(\alpha, w)$ on A_x ($x = u, m, \ell$) and define $e := 2(1-w)c_2$, $y := 2(1-h)pw$ and $z := hpw + \gamma y$ for convenience of notation. Then (for $\gamma \neq 0$, $\gamma \neq 1$)*

- (i) $\hat{\alpha}_u \in A_u$ implies $\hat{\alpha}_u = 1-\gamma = \min A_u$.

$$(ii) \quad \hat{\alpha}_m \in A_m \text{ implies } \hat{\alpha}_m = \frac{2\gamma y}{e} \text{ and } \left\{ \begin{array}{l} \hat{\alpha}_m = 1-\gamma \\ \hat{\alpha}_m \in \text{int } A_m \\ \hat{\alpha}_m = \gamma \end{array} \right\} \Leftrightarrow \left\{ \begin{array}{l} e \leq \frac{2\gamma y}{1-\gamma}, \\ e \in \left[\frac{2\gamma y}{1-\gamma}, 2y \right], \\ e \geq 2y. \end{array} \right.$$

$$(iii) \quad \hat{\alpha}_\ell \in A_\ell \text{ implies } \left\{ \begin{array}{l} \hat{\alpha}_\ell = \gamma \\ \hat{\alpha}_\ell = \frac{z}{e-y} \in \text{int } A_\ell \end{array} \right\} \Leftrightarrow \left\{ \begin{array}{l} e \in \left[0, \frac{z+\gamma y}{\gamma} \right], \\ e > \frac{z+\gamma y}{\gamma}. \end{array} \right.$$

Proof: Ad (i): See the proof of Lemma 2i.

Ad (ii): Consider $D_\alpha^m = 4(1-h)\gamma$ in (7a) to obtain $\hat{\alpha}_m = 2\gamma y/e$ for all $\hat{\alpha}_m$ satisfying $\Pi_\alpha^m = 0$. Since $\hat{\alpha}_m$ is presupposed to be in the interval $A_m = [\gamma, 1-\gamma]$, the assignment of $\hat{\alpha}_m$ and $e \in [2\gamma y/(1-\gamma), 2y]$ as listed in Lemma 3ii follows immediately.

Ad (iii): In view of (5a) for $\alpha \in A_\ell$ the equation (7a) can be turned into

$$\Pi_\alpha^\ell = z + (y-e)\alpha \quad \text{and} \quad \Pi_{\alpha\alpha}^\ell = y-e$$

so that Π is $\left\{ \begin{array}{l} \text{strictly concave} \\ \text{linear} \\ \text{strictly convex} \end{array} \right\}$ in α on A_ℓ , if $e \left\{ \begin{array}{l} > \\ = \\ < \end{array} \right\} y$.

Suppose first $e > y$ and $\hat{\alpha}_\ell = \gamma$. Then $\Pi_\alpha^\ell(\gamma, w) \geq 0$ or $e \leq (z + \gamma y)/\gamma$. For $e \leq y$ one has $\Pi_\alpha^\ell(\alpha, w) \geq z > 0$ for all $\alpha \in A_\ell$ and hence $\hat{\alpha}_\ell = \gamma$. If $\Pi_\alpha^\ell(\hat{\alpha}, w) = 0$ for $\hat{\alpha}_\ell < \gamma$, it follows necessarily that $e > (z + \gamma y)/\gamma$ and $\hat{\alpha}_\ell = z/(e - y)$. $\hat{\alpha}_\ell > 0$, if $z > 0$. Suppose $z < 0$. In view of the definitions of z and y one has $z < 0 \Leftrightarrow h(1-2\gamma) + 2\gamma < 0$ for $w > 0$. But $2\gamma \in [0, 1)$ by assumption. This contradiction proves $\hat{\alpha}_\ell > 0$ for $z > 0$.

Suppose finally that $e < y$. Since Π is strictly convex in α on $[0, \gamma]$ there are at most two local maxima at $\alpha = 0$ and/or $\alpha = \gamma$. The associated profits are, respectively, $\pi_0 := \gamma h p w + \gamma^2 y/2$ and $\pi_\gamma := 2\gamma h p w + 2\gamma\gamma^2 - e\gamma^2/2$. Observe that $e < y$ implies $\pi_\gamma > 2\gamma h p w + (3/2)\gamma^2 y$ and therefore $\pi > \pi_0$. Hence $\hat{\alpha}_\ell = \gamma$ is the unique maximizer of Π on A_ℓ . \square

Proposition 2: Denote by $\tilde{\alpha}$ the solution of (7) for predetermined w and by $\hat{\alpha}_x$ the maximizer on A_x ($x = u, m, \ell$) as determined in Lemma 3.

(i) If $h \geq 1$, then $\tilde{\alpha} = \hat{\alpha}_\ell$

(ii) For $h < 1$: (a) $\tilde{\alpha} = \hat{\alpha}_m \in (\gamma, 1-\gamma]$, if $e \in (0, 2y)$;

(b) $\tilde{\alpha} = \hat{\alpha}_m = \hat{\alpha}_\ell = \gamma$, if $e \in \left[2y, \frac{z+\gamma y}{\gamma}\right]$;

(c) $\tilde{\alpha} = \hat{\alpha}_\ell \in (0, \gamma)$, if $e > \frac{z + \gamma y}{\gamma}$.

Proof: Proposition 2i follows immediately from the observation that $h \geq 1$ implies $y \leq 0$. Since $2y < (z + \gamma y)/\gamma$ for $e \in (0, 2y)$, one has $\hat{\alpha}_m > \gamma$, but $\hat{\alpha}_\ell = \gamma$. Hence $\tilde{\alpha} = \hat{\alpha}_m$ follows from continuity of Π in α . This continuity property also proves the Propositions 2iib and 2iic. \square

Figure 5a illustrates Proposition 2ii in a self-explanatory way.

– Figure 5: Profit maxima for quadratic quality costs ($h < 1$) –

The comparison of Proposition 1 ($c_1 > 0$ and $c_2 = 0$) with Proposition 2 ($c_1 = 0$ and $c_2 > 0$) reveals the following similarities and differences:

- For $h \geq 1$ the solution is qualitatively very similar in both cases;
- For $h < 1$, linear program quality costs implied a bang-bang solution ($\tilde{\alpha} = 0$ or $\tilde{\alpha} = \gamma$) in A_ℓ . In contrast, quadratic costs imply that the solution value $\tilde{\alpha}$ increases continuously with decreasing parameter e over the range $\text{int}(A_m \cup A_\ell)$.

4. Welfare-maximizing Program Quality

The debate in welfare economics about how to handle advertising has been long-lasting and controversial. Wildman & Owen (1985, p. 254) argue that "welfare results are somewhat clouded by the traditional difficulties in dealing with advertising", and Orr (1987, p. 81) observes that "it does not appear that any reliable conclusions have been reached regarding the welfare effects of advertising; certainly none that can be used to appraise the welfare effects of the media". Rather than elaborating on this topic (which would make it necessary to take the market for commercials explicitly into consideration)

we assume that some value $w \geq 0$ is the efficient level of the negative externality 'advertising'. The consumers' rent from program α , denoted by $K(\alpha)$, depends on whether α is in A_u , A_m or A_ℓ .

Recalling the concept of utility distribution, consider the functions

$$Z^\ell(\alpha, \beta, w) := \frac{\gamma - \alpha + \beta}{v_3} \quad \text{and} \quad Z^u(\alpha, \beta, w) := \frac{\gamma + \alpha - \beta}{v_3}$$

to define *consumer rent* as

$$(6a) \quad K^u(\alpha, w) := \int_{\beta=\alpha-\gamma}^{\beta=\alpha} Z^\ell(\alpha, \beta, w) \Psi(\beta) d\beta + \int_{\beta=\alpha}^{\beta=1} Z^u(\alpha, \beta, w) \Psi(\beta) d\beta \quad \text{for } \alpha \in A_u,$$

$$(6b) \quad K^m(\alpha, w) := \int_{\beta=\alpha-\gamma}^{\beta=\alpha} Z^\ell(\alpha, \beta, w) \Psi(\beta) d\beta + \int_{\beta=\alpha}^{\beta=\alpha+\gamma} Z^u(\alpha, \beta, w) \Psi(\beta) d\beta \quad \text{for } \alpha \in A_m,$$

$$(6c) \quad K^\ell(\alpha, w) := \int_{\beta=0}^{\beta=\alpha} Z^\ell(\alpha, \beta, w) \Psi(\beta) d\beta + \int_{\beta=\alpha}^{\beta=\alpha+\gamma} Z^u(\alpha, \beta, w) \Psi(\beta) d\beta \quad \text{for } \alpha \in A_\ell$$

In view of (1) the integrals in (6) turn out to be

$$(7) \quad \int Z^u(\alpha, \beta, w) \Psi(\beta) d\beta = \frac{h(\alpha + \gamma)}{v_3} \cdot \beta + \frac{2(1-h)(\alpha + \gamma) - h}{2v_3} \cdot \beta^2 - \frac{2(1-h)}{3v_3} \cdot \beta^3,$$

$$(8) \quad \int Z^\ell(\alpha, \beta, w) \Psi(\beta) d\beta = \frac{h(\gamma - \alpha)}{v_3} \cdot \beta + \frac{2(1-h)(\gamma - \alpha) + h}{2v_3} \cdot \beta^2 + \frac{2(1-h)}{3v_3} \cdot \beta^3.$$

Suppose first that $\alpha \in A_u$. In that case, one obtains from (6a), (7) and (8), after some rearrangement of terms,

$$(9a) \quad K^u(\alpha, w) = \frac{1}{6v_3} \cdot \{ \gamma^2 [3h - 2\gamma(1-h)] + 6\gamma + h - 4 \} + \\ + \frac{1}{v_3} \cdot [1 - \gamma h + \gamma^2(1-h)] \cdot \alpha - \frac{h + 2\gamma(1-h)}{2v_3} \cdot \alpha^2 - \frac{1-h}{3v_3} \cdot \alpha^3.$$

For $\alpha \in A_m$, the equations (6b), (7) and (8) yield, after some tedious calculations,

$$(9b) \quad K^m(\alpha, w) = \frac{\gamma^2}{v_3} [h + 2(1-h)\alpha].$$

If $\alpha \in A_{\ell}$, then (6c), (7) and (8) give us

$$(9c) \quad K^{\ell}(\alpha, w) = \frac{\gamma}{6v_3} \cdot [3h + 2\gamma(1-h)] + \frac{\gamma}{v_3} \cdot [\gamma(1-h) + h] \cdot \alpha + \\ + \frac{2\gamma(1-h) - h}{2v_3} \cdot \alpha^2 - \frac{1-h}{3v_3} \cdot \alpha^3.$$

We are now in the position to investigate the properties of the consumer rent function.

Lemma 4: For given w and $\gamma \in (0, 1/2)$ the function of consumer rent, K , has the following properties:

(i) $h \in [0, 1]$: On $A_{\#}$, K is strictly increasing. It is strictly concave, if

$$h > \frac{2}{1-2\gamma} \in \left[0, \frac{1}{2}\right).$$

Otherwise there is $x(h, \gamma) \in (0, 1)$ such that K is strictly convex on $[0, x(h, \gamma))$ and strictly concave on $(x(h, \gamma), 1)$. $x(h, \gamma)$ converges to 1 when h tends to zero. K is linear and strictly increasing on A_m , and strictly concave on A_u , and it attains its unique maximum in the interior of A_u .

(ii) $h = 1$: K is strictly concave and increasing on A_{ℓ} constant on A_m , and strictly concave and decreasing on A_u .

(iii) $h \in (1, 2]$: K is strictly concave on A_{ℓ} and it attains its unique maximum in the interior of A_{ℓ} . K is linear and strictly decreasing on A_m . On the set A_u , K is strictly decreasing. It is strictly concave, if

$$h < \frac{2 + 2\gamma}{1 + 2\gamma} \in \left[\frac{3}{2}, 2\right).$$

Otherwise, there is $y(h, \gamma) \in (1, 2)$ such that K is strictly concave on $(1, y(h, \gamma))$ and strictly convex on $(y(h, \gamma), 2)$. $y(h, \gamma)$ converges to 2 if h tends to 2.

(iv) K is differentiable on $[0, 1]$ and $K(\alpha) > 0$ for all $\alpha \in [0, 1]$ and all $h \in [0, 2]$.

Proof: We begin with identifying the shape of K on the subsets A_{ℓ} , A_m , A_u for alternative ranges of h .

(a) K on A_{ℓ} In view of (9c), the derivatives of K^{ℓ} are

$$K_{\alpha}^{\ell}(\alpha) = \frac{\gamma^2(1-h) + \gamma h}{v_3} + \frac{2\gamma(1-h) - h}{v_3} \alpha - \frac{1-h}{v_3} \alpha^2 \quad \text{and}$$

$$K_{\alpha\alpha}^{\ell}(\alpha) = \frac{2\gamma(1-h) - h}{v_3} - \frac{2\alpha(1-h)}{v_3} = \frac{1}{v_3} [2(1-h)(\gamma - \alpha) - h].$$

If $\alpha \in A_{\ell}$ (hence $\alpha \leq \gamma$) and $h \geq 1$ then obviously $K_{\alpha\alpha}^{\ell} < 0$. For $h < 1$ one has

$$K_{\alpha\alpha}^{\ell} \geq 0 \Leftrightarrow \alpha \geq \gamma - \frac{h}{2(1-h)}.$$

Note that $K_{\alpha\alpha}^{\ell} < 0$, if $\gamma < h/[2(1-h)]$ or equivalently, $h > 2\gamma/(1+2\gamma)$. Since $\gamma < 1/2$, $h > 1/2$ is sufficient for $K_{\alpha\alpha}^{\ell} < 0$ for all $\alpha \in A_{\ell}$. Moreover, $h = 0$ yields $K_{\alpha\alpha}^{\ell} > 0$ for all $\alpha \in A_{\ell}$. In summary, for $h > 2\gamma/(1+2\gamma)$, K^{ℓ} is strictly concave on A_{ℓ} . For small values of h the function K^{ℓ} has an convex segment for low values of α and this segment increases with decreasing h up to the polar case $h = 0$, where K^{ℓ} is convex for all $\alpha \in A_{\ell}$.

Consider, finally, the derivatives

$$K_{\alpha}^{\ell}|_{\alpha=0} = \frac{\gamma}{v_3} [\gamma(1-h) + h] = \frac{\gamma}{v_3} [\gamma + h(1-\gamma)] > 0 \quad \text{and} \quad K_{\alpha}^{\ell}|_{\alpha=\gamma} = \frac{2\gamma^2(1-h)}{v_3}.$$

It follows that $K_{\alpha}^{\ell}|_{\alpha=0} > 0$ for all $h \in [0, 2]$ and $K_{\alpha}^{\ell}|_{\alpha=\gamma} \geq 0$ for $h \leq 1$. Therefore, K^{ℓ} is strictly increasing on A_{ℓ} if $h > 1$ and it attains a maximum in the interior of A_{ℓ} for all $h \in (0, 1)$.

(b) **K on A_m** . The derivative of K^m from (9b) is $K_{\alpha}^m(\alpha) = 2\gamma^2(1-h)/v_3 = K_{\alpha}^{\ell}|_{\alpha=\gamma}$

(c) **K on A_u** . In view of (9c), the derivatives of K^u are

$$K_{\alpha}^u(\alpha) = \frac{1 - \gamma h + \gamma^2(1-h)}{v_3} - \frac{h + 2\gamma(1-h)}{v_3} \alpha - \frac{1-h}{v_3} \alpha^2 \quad \text{and}$$

$$K_{\alpha\alpha}^u(\alpha) = -\frac{h + 2\gamma(1-h)}{v_3} - \frac{2(1-h)}{v_3} \alpha = \frac{1}{v_3} [h + 2(1-h)(\alpha + \gamma)].$$

For $h \leq 1$ one obviously has $K_{\alpha\alpha}^u < 0$. If $h > 1$ then

$$K_{\alpha\alpha}^u \geq 0 \Leftrightarrow \alpha \geq \frac{h}{2(h-1)} - \gamma.$$

Note that $K_{\alpha\alpha}^u < 0$, if $h/[2(h-1)] > 1 + \gamma$ or, equivalently, if $h < (2+2\gamma)/(1+2\gamma)$. Since $\gamma < 1/2$, $h < 3/2$ is sufficient for $K_{\alpha\alpha}^u < 0$ for all $\alpha \in A_u$. Moreover, $h = 2$ yields $K_{\alpha\alpha}^u > 0$ for all $\alpha \in A_u$. Consider, finally the derivatives

$$K_{\alpha}^u|_{\alpha=1} = -\frac{\gamma}{v_3} [1 + (1-h)(1-\gamma)] < 0 \quad \text{and} \quad K_{\alpha}^u|_{\alpha=1-\gamma} = -\frac{2\gamma^2(1-h)}{v_3}.$$

The conclusions are symmetric to those drawn above for K^{ℓ} on A_{ℓ} .

To prove that $K(\alpha) > 0$ for all $\alpha \in [0, 1]$ it suffices to observe that for all $h \in [0, 2]$

$$K^{\ell}(\alpha=0) = \frac{\gamma^2[3h + 2\gamma(1-h)]}{6v_3} > 0 \quad \text{and} \quad K^u(\alpha=1) = \frac{(2-h)(3-\gamma) + h\gamma}{v_3} > 0.$$

It is obvious that K is differentiable on the interior of the intervals A_{ℓ} , A_m , A_u . Since

$$K_{\alpha}^{\ell}|_{\alpha=\gamma} = K_{\alpha}^m = K_{\alpha}^{\ell}|_{\alpha=1-\gamma} = \frac{2\gamma^2(1-h)}{v_3},$$

K is also differentiable at the points $\alpha = \gamma$ and $\alpha = 1-\gamma$. □

– **Figure 6:** Consumer rent depending on the viewers' distribution and program quality –

Figure 6 illustrates the findings of Lemma 4. The three graphs for $h < 1$, $h = 1$, and $h > 1$ are drawn on top of each other only to economize on space. As spelled out in Lemma 4, the line segment CD has a convex part adjoining $\alpha = 1$ in case that $h < (2 + 2\gamma)/(1 + 2\gamma)$, and the line segment AB has a convex part adjoining $\alpha = 0$ in case that $h > 2\gamma/(1 + 2\gamma)$.

The comparison of figures 6 and 3 shows that the functions of revenue and consumer rent are similar, but also exhibit significant differences. To be more specific, consider first the intermediate interval A_m . Comparing $R^m(\alpha, w) = pw D^m(\alpha, w)$ [with $D^m(\alpha, w)$ from (3b)] and $K^m(\alpha, w)$ from (9) reveals that

$$K^m(\alpha, w) \lesseqgtr R^m(\alpha, w) \Leftrightarrow \frac{\gamma}{2v_3} \lesseqgtr pw \quad \text{and} \quad |K_{\alpha}^m| \lesseqgtr |R_{\alpha}^m| \Leftrightarrow \frac{\gamma}{2v_3} \lesseqgtr pw \quad (h \neq 1).$$

To understand the condition $(\gamma/2v_3) \lesseqgtr pw$ suppose (without loss of generality) that $h = 1$.

Then the triangle ADG in figure 7 measures consumer rent under the assumption, that w is fixed at its "welfare maximizing" level. Assume that the monopolist fixes w at this level. Then her audience is given by $[\alpha_0 - \gamma, \alpha_0 + \gamma]$, i. e. exactly that audience which should turn in on program α_0 under welfare considerations. If her revenue per potential viewer, pw , is equal to γ/v_3 , i. e. $pw = AB$ in figure 7, then her revenue is $ABFG$ which equals ADG , the consumer rent. This illustrates that the difference of consumer rent and revenue depends on the difference between γ/v_3 and pw . Our conclusion carries over to distributions $h \neq 1$ with the qualification that if the revenue from advertising is smaller than consumer rent – which appears to be plausible – then the consumer rent curve is steeper than the revenue curve in the intermediate interval A_m .

We are now in the position to compare the welfare-maximizing and profit-maximizing choices of program quality.

Proposition 3: Suppose that $w \in [0, 1]$ is fixed at its welfare maximizing level and $c_1 \geq 0$, $c_2 = 0$, i.e. the cost function is linear in program quality. Furthermore, let $\gamma/2v_3 > pw$, i. e. consumer rent exceeds revenue from advertising in the intermediate domain A_ℓ and define $H := [R^\ell(\alpha=\gamma) - R^\ell(\alpha=0)]/\gamma = pw[h + 3\gamma(1-h)]$.

(i) Let $h < 1$ and K^ℓ concave on A_ℓ

- (a) If $K_\alpha^m > H$ or $\gamma - 2pwv_3 > \frac{pwv_3}{2\gamma} (\frac{h}{1-h} - \gamma)$, then $\alpha_m^* > \hat{\alpha}_m$ for all $c_1 < K_\alpha^\ell(\alpha=0)$ and $\alpha_m^* = \hat{\alpha}_m = 0$ for $c_1 \geq K_\alpha^\ell(\alpha=0)$. In particular, $\alpha_m^* > 1 - \gamma$ and $\hat{\alpha}_m = 0$ for $c_1 \in (H, K_\alpha^m)$.
- (b) If $K_\alpha^m < H$ or $\gamma - 2pwv_3 < \frac{pwv_3}{2\gamma} (\frac{h}{1-h} - \gamma)$, then $\alpha_m^* > \hat{\alpha}_m = \gamma$ for $c_1 < K_\alpha^m$ and $\alpha_m^* < \hat{\alpha}_m = \gamma$ for $c_1 \in (K_\alpha^m, \min[K_\alpha^\ell(\alpha=0), H])$. If $H < K_\alpha^\ell(\alpha=0)$ or $\gamma - 2pwv_3 < pwv_3 \frac{h - \gamma(1-h)}{h + \gamma(1-h)} \in (-pwv_3, pwv_3)$ then $\alpha_m^* > \hat{\alpha}_m = 0$ for $c_1 \in (H, K_\alpha^\ell(\alpha=0))$ and $\alpha_m^* = \hat{\alpha}_m = 0$ for $c_1 \geq K_\alpha^\ell(\alpha=0)$. In case of $K_\alpha^\ell(\alpha=0) < H$ one has $\hat{\alpha}_m = \gamma > \alpha_m^* = 0$ for $c_1 \in (K_\alpha^\ell(\alpha=0), H)$ and $\alpha_m^* = \hat{\alpha}_m = 0$ for $c_1 \geq H$.

(ii) If $h > 1$, there is $\tilde{c}_1 \in (R_\alpha^\ell(\alpha=0), K_\alpha^\ell(\alpha=0)) \neq \emptyset$ such that $\alpha_m^* \leq \hat{\alpha}_m \Leftrightarrow c_1 \leq \tilde{c}_1$.

Proof. Ad (ia). Since R^ℓ is strictly concave on A_ℓ one clearly has $\hat{\alpha}_m = 0$ for all $c_1 > H$ and $\hat{\alpha}_m = \gamma$ for all $c_1 < H$. It follows from $K_\alpha^m > H$ that if c_1 is raised from zero towards K_α^m , α_m^* decreases but remains greater than $1-\gamma$ whereas $\hat{\alpha}_m$ shrinks from $1-\gamma$ to γ and then towards zero.

Ad (ib). The proof of proposition 3ib is straightforward.

Ad (ii). Recall that $K_\alpha^\ell = \frac{\gamma^2(1-h)}{v_3} + \frac{\gamma h}{v_3} + \frac{2\gamma(1-h) - h}{v_3} \alpha - \frac{1-h}{v_3} \alpha^2$ and

$R_\alpha^\ell = pw[2\gamma(1-h) + h] + 2pw(1-h) \alpha$. Hence $K_\alpha^\ell \geq R_\alpha^\ell$ if and only if $a - b\alpha + \alpha^2 \geq 0$,

where $a := \frac{[h(1-\gamma) + \gamma](\gamma - 2pwv_3) + pwv_3h}{h-1}$ and $b := \frac{h - 2(1-h)(\gamma - pwv_3)}{h-1}$.

By presupposition, $h > 1$ and $\gamma > 2pwv_3$. Hence $a > 0$ and $b > 0$. Consequently $K_\alpha^\ell(\alpha=0) - R_\alpha^\ell(\alpha=0) = a > 0$ and $K_\alpha^\ell(\alpha=\gamma) - R_\alpha^\ell(\alpha=\gamma) = 2\gamma(1-h)(\gamma - 2pwv_3) < 0$. It is easy to show that $a - b\alpha + \alpha^2$ is strictly declining on A_ℓ . Therefore there exists a unique value $\tilde{\alpha}$ in the interior of A_ℓ satisfying $a - b\tilde{\alpha} + \tilde{\alpha}^2 = 0$. Defining $\tilde{c}_1 = K_\alpha^\ell(\tilde{\alpha}) = R_\alpha^\ell(\tilde{\alpha})$ completes

the proof of proposition 3ii. □

– **Figure 8:** Divergences of profit–maximizing and revenue–maximizing program qualities –

Figure 8 demonstrates the displacement effects of monopoly when marginal cost is 'small'. In that figure it is presupposed that $K(\alpha, w) > R(\alpha, w)$ for all α and that the program quality cost is linear (line OE). It is then straightforward that for $h > 1$ the profit–maximizing program quality, $\hat{\alpha}_m$, is greater than the welfare–maximizing quality α_m^* . For $h < 1$ the opposite conclusion holds. Figure 8 illustrates that for sufficiently small marginal cost the allocative bias can be characterized as follows: If the consumer distribution is skewed towards lower or higher program qualities, the monopolist tends to supply a program quality which reflects insufficiently the 'majority' preferences of consumers. In case that consumers want to have high quality programs, the monopolist undersupplies and vice versa. The monopolist is reluctant to supply what the mass of consumers likes most.

As proposition 3 shows the characterization of the comparison between profit maximizing and welfare maximizing program qualities is particularly complex for high marginal costs, i. e. when both maxima are attained on the interval A_ℓ . It is not possible to find an easy and plausible economic interpretation for the way in which the monopolistic quality supply deviates from the welfare maximum depending on the distribution of consumer types (h), consumer preferences (γ) and marginal cost (c_1). Tentatively, the monopolist's program quality is too low which is particularly clear when consumer types cluster at low values of program quality.

5. Concluding Remarks

This paper consists of an exercise in positive and normative price theory in a fairly unconventional market: the product, i.e. the television program proper, is provided costlessly to everybody without exclusion, and revenue stems from a by–product (commercials) that is also free but inferior to the program proper – or even a nuisance – as evaluated by the (potential) viewers. The viewers' preferences vary with respect to program quality, and the supplier has to make her profit–maximizing choice of program quality both because her revenue from advertising firms depends on the number of viewers and because high–quality programs are more costly than low–quality programs.

Shortcutting the intricacies lurking in the welfare assessment of advertising, the paper characterizes both the monopolist's revenue and the consumer rent as a function of program quality. The divergences in shape of these functions determine, for given costs, the program quality bias of monopolistic supply from welfare-maximizing program quality. Particular emphasis is placed on how this bias depends on program quality costs, on the shape and distribution of consumer preferences, the advertising time, and the unit price of advertising. The result is not as straightforward as some activists' conjecture may be, namely that profit-maximizing and advertiser-supported television always comes in lower quality than consumers would like to have. But it is shown that significant biases are to be expected the sign and size of which depend on a variety of parameter constellations. Some of the relevant conditions, e.g. the question whether the viewers's (absolute) willingness to pay is greater or smaller than the amount of money the advertisers pay per viewer, seem to be open to empirical testing.

Particular emphasis has been placed on the microfoundations of both the demand side and the supply side of the market. The formal model captures the influence of advertising (time) and it allows the supplier, in principle at least, to determine endogenously the profit maximizing amount of advertising. Even though the calculations become very messy and inconclusive when advertising is treated as an endogenous variable the model helps to well understand the conceptual role of advertising: An increase in advertising (time) increases revenue because the advertising price per minute and per viewer is fixed. But it also reduces the number of viewers. This suggests that there is an optimal advertising time where both effects just neutralize each other.

A severe restriction of the present approach is that the study of monopoly is already so complex that the analysis cannot easily be extended to the study of oligopoly on the television market – which clearly is the empirically relevant market structure. But as is so often the case in model building, one has to simplify the analysis in some aspects to focus on more complex relationships in other directions if the aim is to keep the model tractable at the same time.

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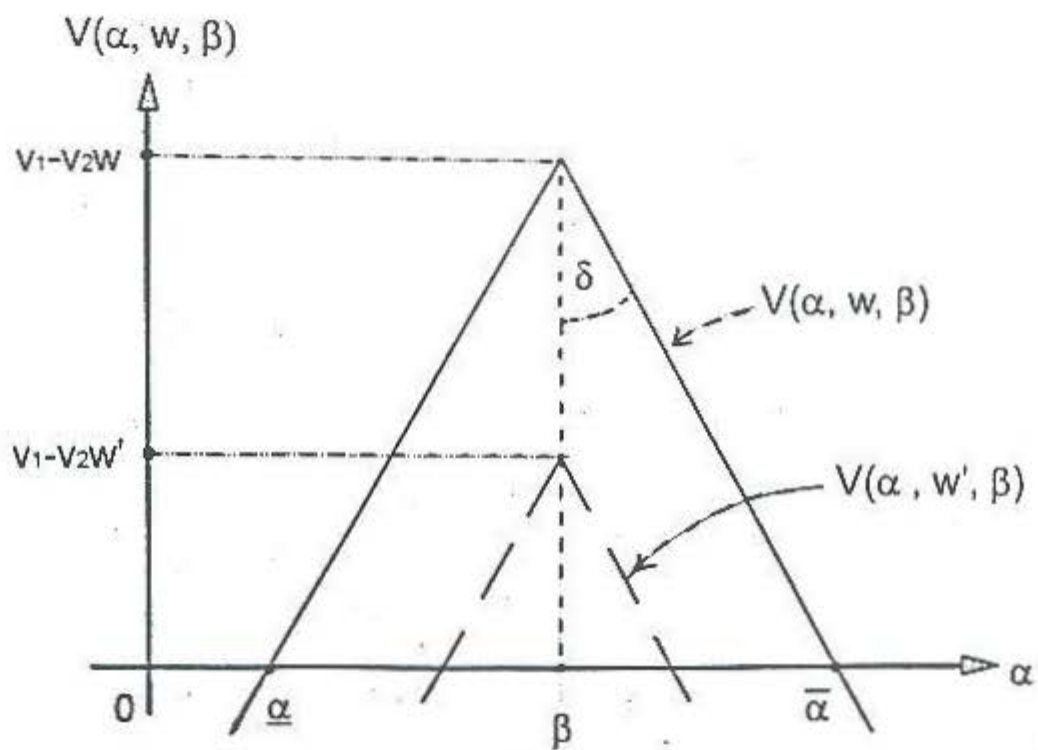


Figure 1: Consumer's preferences of watching TV

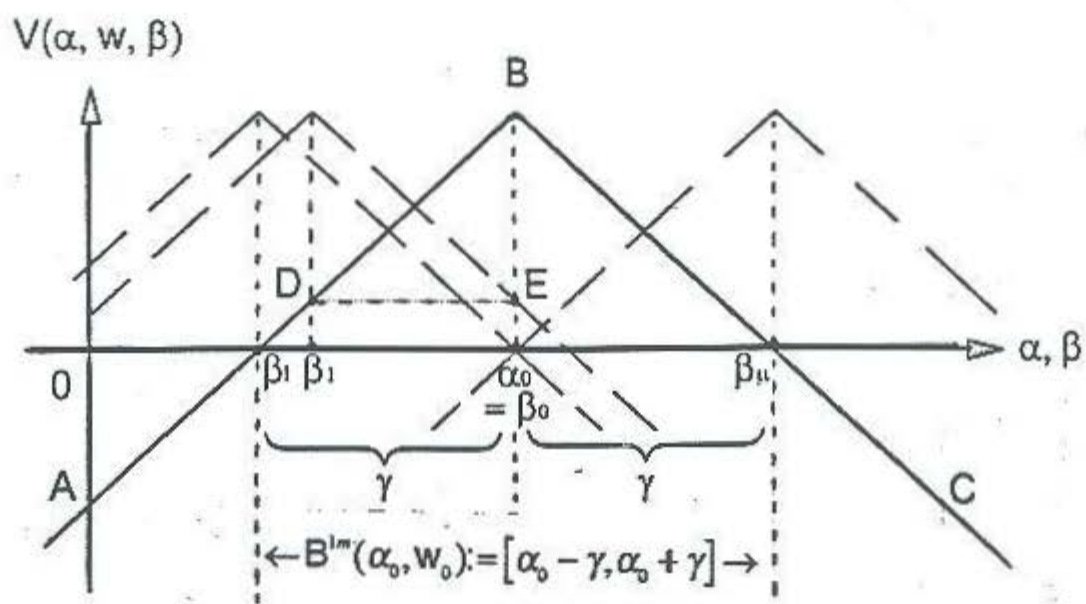


Figure 2: The domain of and the utility distribution for a television program

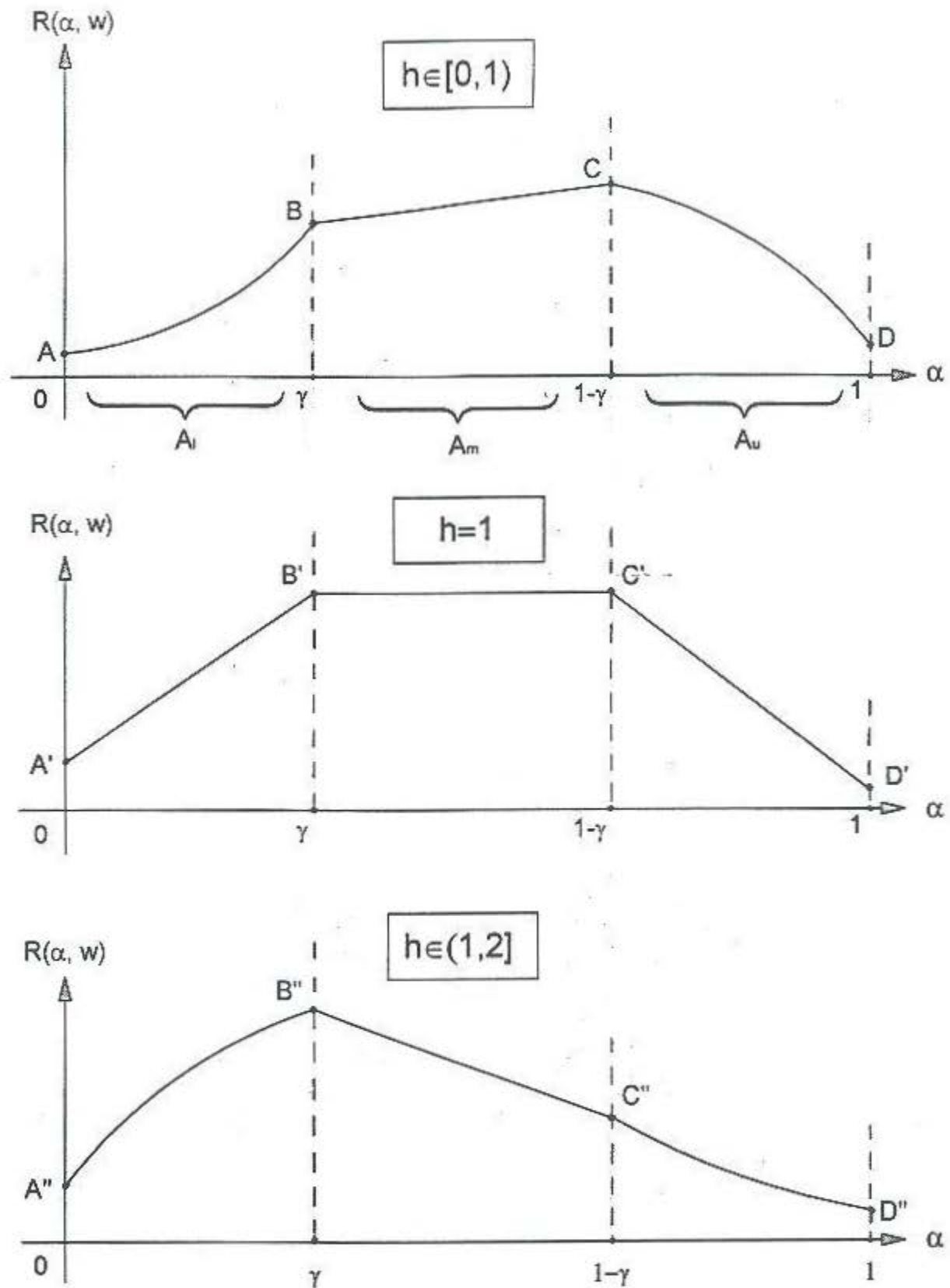


Figure 3: Revenue depending on the viewers' distribution and program quality

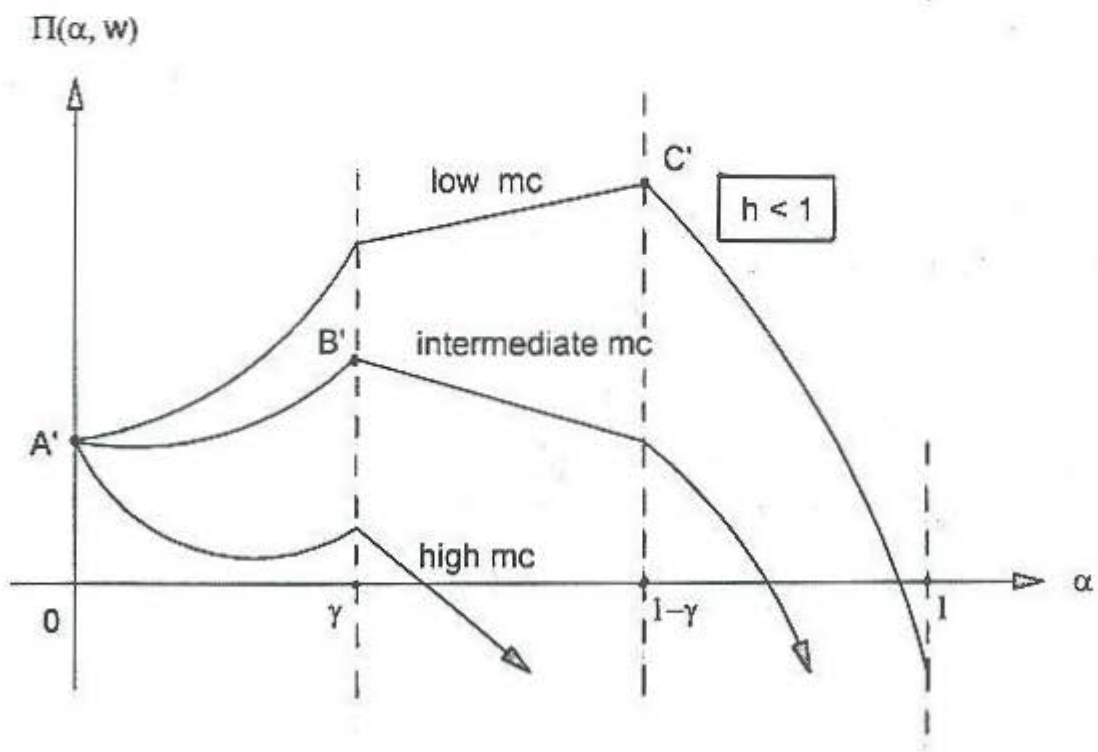
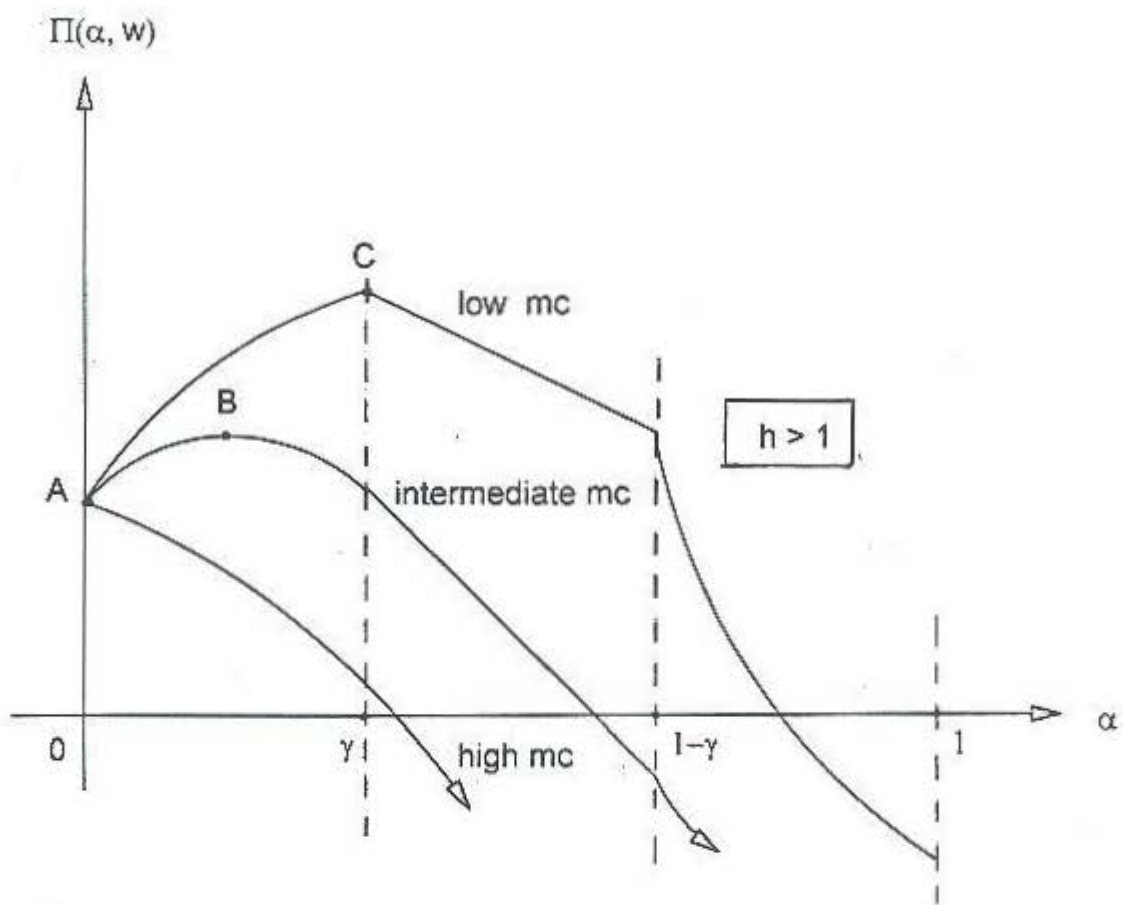


Figure 4: Profit maxima for linear quality costs

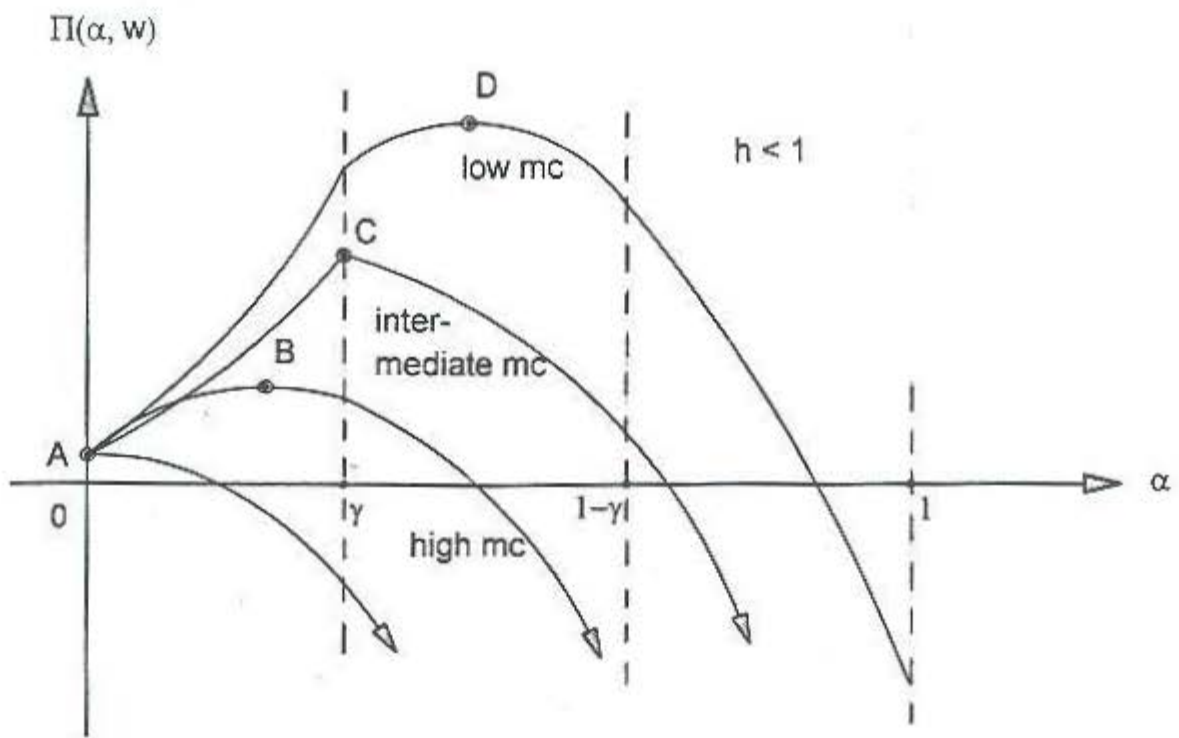


Figure 5: Profit maxima for quadratic quality costs ($h < 1$)

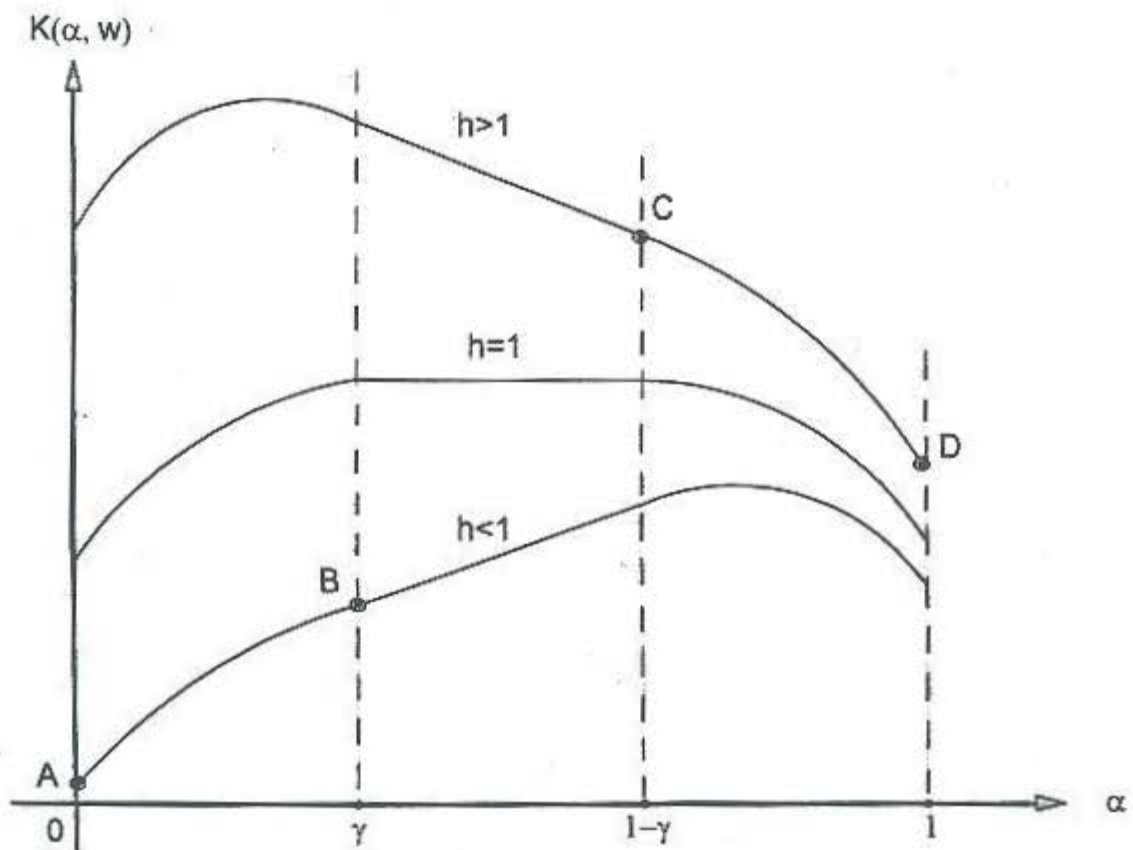


Figure 6: Consumer rent depending on the viewers' distribution and program quality

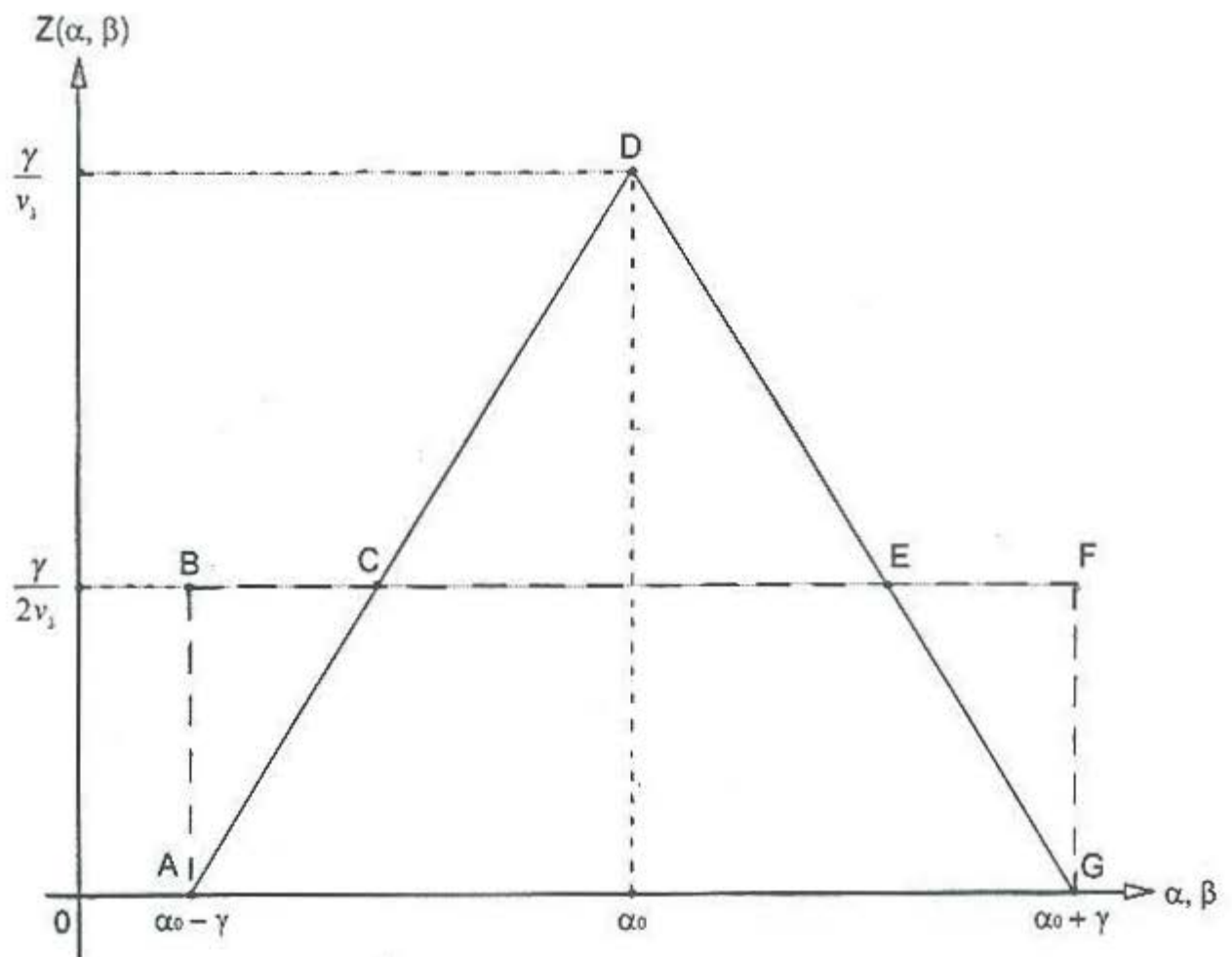


Figure 7: Revenue and consumer rent for $\alpha_0 \in A_m$

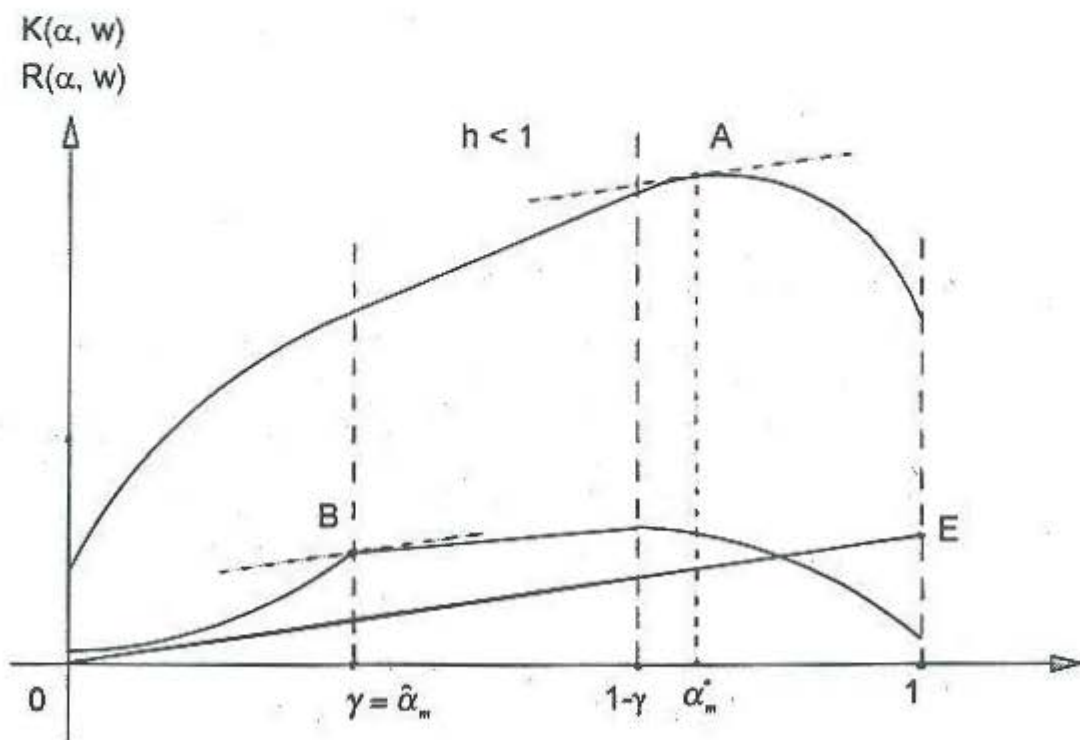
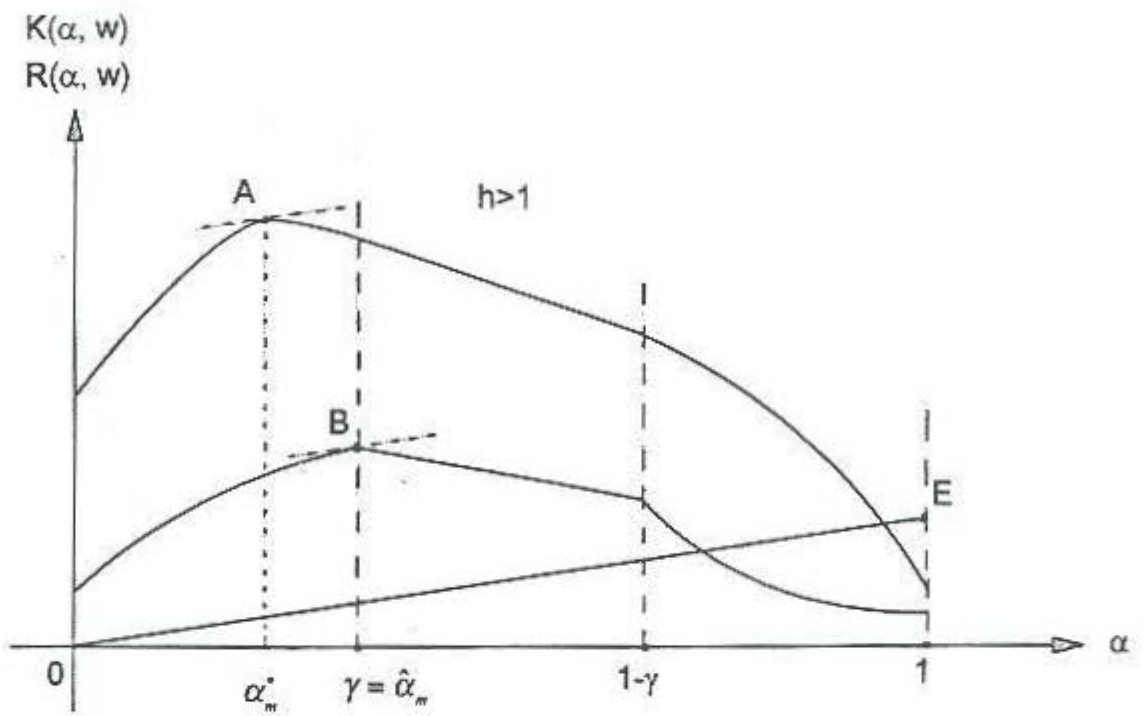


Figure 8: Divergences of profit and welfare maximizing program qualities

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