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THE LONG-RUN INEFFICIENCY OF BLOCK-RATE PRICING

by

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Flat-rate and increasing block-rate pricing are compared as regulation instruments, in a competitive industry with free entry. Irrigation water charge is a concrete example. Flat-rate pricing leads to a first-best social optimum, while block-rate pricing with marginal cost as the highest block induces over production, too-small firm size, and loss of economic surplus. Moreover, first-best is not implementable by increasing block-rate pricing. This is in contrast to the common belief that block-rate pricing allows for income redistribution while preserving efficiency and is thus superior to flat-rate pricing.

1. Introduction

Increasing block-rate pricing is advocated by many economists (*e.g.*, Wilchens 1991, Yaron 1991, and Zusman 1997) as allowing the separation of efficiency from income transfer. With increasing block-rate pricing users are charged the marginal social costs for marginal quantities but the average water price is lower. On the face of it, such pricing combines the best of all worlds — at the margins resource users face the correct incentive, while the total “amount” which they pay is moderate. This possibility is used to justify the use of block-rate pricing in mitigating the effect of lobbying and political resistance and in cases where subsidization of the farm sector is critical. Indeed, the block-rate pricing regime is applied universally to regulate irrigated agriculture. Particular examples include Californian water utilities and the Israeli water agency (Tsur and Dinar 1997, Kislev and Vaksin 1997, and Yaron 1991).

In this paper we analyze the performance of increasing block-rate pricing considering long-run industry equilibrium under free entry and assess its efficiency relative to flat-rate pricing. Assuming a first-best policy is feasible, we show that, while flat-rate pricing at level of social marginal cost implements social optimum, an increasing block-rate pricing can never achieve it. Basic intuition indicates the following: Consider two types of firms the first of which faces flat-rate pricing while the second faces increasing block-rate pricing. Both, however, face the same marginal price which equals the social marginal cost. Clearly, firms of the second type have lower cost functions and thus lower average cost functions. Consequently, the industry equilibrium of the second type is characterized by: lower product price, more firms, higher production, and higher water utilization than that of flat-rate pricing. Since flat-rate pricing leads to a social optimum, we conclude that block-rate pricing distorts it.

We then take a second-best point of view, and consider circumstances under which a first-best social optimum is impossible. Generally, social concerns which differ from economic surplus may restrict governmental intervention, calling for a second-best optimum.

We analyze two such cases: the preservation of family farms and the supply of agricultural products at a level higher than the socially optimal one. In contrast to the first-best case, when policy is subject to preservation of family farms, we show that block-rate pricing with the highest block at the marginal social cost of water production implements social optimum. However there is no water pricing which implements a social optimum subject to constant level of the agricultural product.

Lobbying and political pressures, commonly aim at the water price itself. To model such situations we introduce a type of reform characterized by constant average water price. Economists often assert that such a reform which increases the marginal price toward the marginal social cost or even higher, is a step in the right direction. Our analysis, however, shows the opposite, the optimal marginal price subject to constant average water price is lower than the social marginal cost of water production. It is worth noting that this finding is consistent with the general second-best theory: with several sources of inefficiency, correcting only some may reduce welfare.

2. Modeling the Market for Irrigation Water

We model two sectors of the economy: 1) the irrigated agricultural sector, which utilizes water for irrigation and 2) the water supplier, which is assumed to be a regulated public utility. In the background of the model there exists a government which regulates the water supply, and consumers who demand the agricultural product. It is worth mentioning that the model is also valid in cases where irrigation imposes negative external effects on current or future generations of consumers .

The Water Utility

Water is produced and delivered by a regulated public-utility with a cost structure represented by the convex and well behaved function $C(W)$, where $W = Nw$ is the total industry water utilization, N is the number of identical farms and w is the per-farm water utilization. The function $C(W)$ subsumes the prices of production factors, which are

required for pumping and delivering water, and by assumption, these prices are given for the irrigation sector. The function C includes any external effects that water utilization in agriculture may impose on other sectors in the economy either in the present or future.

The regulated utility implements a charge function $r(w)$. In general, this function may take many forms. In this paper, however, we limit our attention to the following form:

$$r(w) = p_w(w - \bar{w}) \quad \forall w > \bar{w}, \quad (1)$$

where p_w is the water price per acre-foot and \bar{w} is the quantity given free of charge. In the sequel we consider two distinct cases, in the first $\bar{w} > 0$, the user then faces an *increasing block-rate pricing*. The second case is where $\bar{w} = 0$, equation (1) then reduces to

$$r(w) = p_w w, \quad (2)$$

and the user faces *flat-rate pricing*.

The Irrigated Agricultural Industry

The irrigated agricultural industry consists of N identical farmers who utilize water, w , for irrigation. The farming technology is represented by a concave, differentiable production function $y = f(w, x)$, where y denotes output and x stands for expenditure on other inputs. Both, w , and x are assumed to be normal production factors. The inverse demand function for (irrigated) agricultural products is $\rho(Y)$, where Y is the total industry output, $Y = Ny$.

The sole interest of each farmer is the maximization of his net profit, π , that is each farmer solves the following optimization problem

$$\max_{w, x} \rho f(w, x) - x - r(w). \quad (3)$$

The first-order conditions describing the farmer's behavior with respect to w and x are given by

$$0 \leq \rho f_w \leq r_w \quad \text{and} \quad \rho f_w(w - \bar{w})(\rho f_w - r_w) = 0, \quad (4)$$

and

$$\rho f_x - 1 = 0, \quad (5)$$

where subscripts on f and r denote partial derivatives. In the sequel, we assume that equation (4) reduces to $\rho f_w - r_w = 0$ meaning that all firms operate at the highest block. Equations 4 and 5 can be solved for the farmer's factor-demand schedules $w(\rho, r_w)$ and $x(\rho, r_w)$.

For the analysis below it is useful to consider also the farmer's cost minimization problem:

$$\min_{x, w \geq 0} r(w) + x \quad \text{S.T.} \quad f(w, x) \geq y, \quad (6)$$

with the associated first order conditions:

$$r_w - \lambda f_w = 0, \quad (7)$$

$$1 - \lambda f_x = 0, \quad (8)$$

and

$$f(x) - y = 0 \quad (9)$$

where λ is the Lagrange multiplier.

Note that the above first-order conditions, and thus the conditional factor demand functions $x(r_w, y)$, $w(r_w, y)$ and the Lagrange multiplier $\lambda(r_w, y)$, depend on $r(w)$ only through its derivative, r_w . The cost function for the case of block-rate pricing is given by:

$$c^b(r(w), y) \equiv c^0 + p_w[w(p_w, y) - \bar{w}] + x(p_w, y) + \lambda(p_w, y)(y - f(w, x(p_w, y))), \quad (10)$$

where c^0 is a set-up cost. The cost function can be used to derive the marginal and average cost functions. Employing the Envelope Theorem we get marginal cost equals the Lagrange multiplier:

$$mc^b(p_w, y) = \frac{\partial c^b(r(w), y)}{\partial y} = \lambda(p_w, y), \quad (11)$$

and average cost:

$$ac^b(p_w, \bar{w}, y) = \frac{c^b(p_w, \bar{w}, y)}{y}. \quad (12)$$

The cost, average cost, and marginal cost functions under flat-rate pricing (c^f , mc^f , ac^f , respectively) can be derived as a special case in which $\bar{w} = 0$.

Examination of (10), (11), and (12) leads to the following observation.

Observation 1: *Given effective block-rate and flat-rate pricing with the same p_w , the following holds:*

- i. *The marginal cost of a firm which faces block-rate pricing is identical to that of a firm which faces flat-rate pricing.*
- ii. *The average cost of a firm which faces increasing block-rate pricing is lower than that of a firm which faces flat-rate pricing.*

The competitive industry equilibrium in the long-run with free entry, w^c, x^c, N^c , is given by the solution to the following first-order conditions:

$$\rho(Ny)f_w - r_w = 0, \quad (13)$$

$$\rho(Ny)f_x - 1 = 0, \quad (14)$$

$$\rho(Ny)f(w, x) - x - r(w) - c^0 = 0. \quad (15)$$

The first two conditions are a restatement of the producer's first-order conditions but with endogenous market price for the agricultural product. The last is the familiar zero-profit condition characterizing industry with free entry.

3. Welfare Maximization

The welfare analysis of resource allocation proceeds in two stages. The first assumes a predetermined number of firms and is thus associated with the short-run. The second stage deals with the characterization of the socially optimal number of firms in the industry and is thus relevant for the long-run.

Social Choice in the Short-Run

Social welfare is represented by the total economic surplus, that is,

$$V(w, x, N) = \int_0^{Nf(w, x)} \rho(z) dz - Nx - C(Nw) - Nc^0. \quad (16)$$

As the number of firms is fixed at \bar{N} at this stage, the short-run social optimum is found by maximizing $V(w, x, \bar{N})$ with respect to w and x , yielding the first order condition:

$$\rho(\bar{N}y)f_w - C_W = 0. \quad (17)$$

and

$$\rho(\bar{N}y)f_x - 1 = 0, \quad (18)$$

meaning, that in the short-run social optimum: 1) the value marginal product of water in agriculture should be equal to the social marginal cost of water supply, and 2) the value marginal product of expenditure on other inputs equals one. We now turn to the socially optimal industry size.

Social Choice in the Long-Run

In the long-run, the number of firms in the industry, N , is endogenously determined. The social planner's optimal choice is given by

$$(w^s, x^s, N^s) = \arg \max_{w, x, N} [V(w, x, N)], \quad (19)$$

and an optimum is characterized by the first order conditions:

$$\rho(Ny)f_w - C_W = 0, \quad (20)$$

$$\rho(Ny)f_x - 1 = 0, \quad (21)$$

$$\rho(Ny)f(w, x) - x - C_W w - c^0 = 0. \quad (22)$$

Condition (22) states that the long-run social optimum requires the firm production to take place at a level at which the profit is zero, if water were priced at its marginal cost. Alternatively, conditions (20) and (22) imply that at the optimum

$$\frac{C_W}{f_w} = \frac{x + C_W w + c^0}{f(w, x)}, \quad (23)$$

meaning that each firm operates where its marginal cost equals the average cost from society's point of view ($mc^s = ac^s$).

4. First-Best Regulations

In our analysis, the government may use either of two alternative instruments of intervention: flat-rate or increasing block-rate pricing. The implementation effects of each of the control regimes on the private first-order conditions, the equilibrium production level, water utilization, and number of firms in the industry are examined. We begin with the short-run and then turn to our main findings concerning the inefficiencies of increasing block-rate pricing in the long-run.

Regulation in the Short-Run

To find the optimal policy, the government should maximize social welfare with respect to the policy instrument subject to private behavior as expressed by the farmer's factor demands. In the case of flat-rate pricing, the maximization problem is:

$$\max_{p_w} V(w(p_w), x(p_w), \bar{N}) \quad (24)$$

yielding the first-order condition

$$\begin{aligned} \frac{\partial V}{\partial p_w} &= \frac{\partial V}{\partial w} \frac{\partial w}{\partial p_w} + \frac{\partial V}{\partial x} \frac{\partial x}{\partial p_w} \\ &= N[\rho(Ny)f_w - C_W] \frac{\partial w}{\partial p_w} + N[\rho(Ny)f_x - 1] \frac{\partial x}{\partial p_w} = 0. \end{aligned} \quad (25)$$

The second term on the last line equals zero by the private first-order condition with respect to x (Equation 5). Thus condition (25) reduces to $\rho(Ny)f_w = C_W$, which is the first-order condition for social optimum. Comparing the latter with the private first-order condition with respect to w ($\rho f_w = p_w$) proves that a flat-rate-pricing regime in which $p_w = C_W$ implements social optimum in the short-run.

In the case of increasing block-rate pricing, the government policy is characterized by two parameters: p_w and \bar{w} . In principle, both must be chosen optimally to maximize V . However, in the short-run N is given exogenously and \bar{w} does not affect the farmer's factor demand. Thus, the analysis is identical to the case of flat-rate pricing. That is, setting the highest block-rate to equal the social marginal cost of water production, implements social optimum in the short-run.

Both instruments achieve efficiency in the short-run and only income distribution differs between them. We now turn to the main point of the paper, showing that this separation between efficiency and income distribution is no longer valid in the long-run. That is to say, in the long-run any attempt to subsidise farmers (transfer income) via block-rate pricing, distorts efficiency.

Regulations in the Long-Run

The government now maximizes social welfare subject to the farmer's behavior and free entry. In the case of flat-rate pricing, the maximization problem is:

$$\max_{p_w} V(w(p_w), x(p_w), N(p_w)) \quad (26)$$

yielding the first-order condition

$$\begin{aligned} \frac{\partial V}{\partial p_w} &= \frac{\partial V}{\partial w} \frac{\partial w}{\partial p_w} + \frac{\partial V}{\partial x} \frac{\partial x}{\partial p_w} + \frac{\partial V}{\partial N} \frac{\partial N}{\partial p_w} \\ &= N[\rho(Ny)f_w - C_W] \frac{\partial w}{\partial p_w} + N[\rho(Ny)f_x - 1] \frac{\partial x}{\partial p_w} \\ &\quad + [\rho(Ny)y - x - C_W w - c^0] \frac{\partial N}{\partial p_w} = 0. \end{aligned} \quad (27)$$

Once again, by comparison to the conditions for competitive industry equilibrium, (13) – (15), it is immediately seen that flat-rate pricing regime in which $p_w = C_W$ implements long-run social optimum.

In contrast to flat-rate pricing, strictly increasing block-rate pricing *always* leads to loss of welfare. This result is, formally stated in Proposition 1.

Proposition 1: *Consider a regulation of a competitive industry in the long-run by means of increasing block-rate pricing. Then,*

i. The long-run equilibrium is inefficient,

If, in addition, the government sets the highest block price at the marginal social cost of water production, $p_w = C_W$, the regulated equilibrium is characterized by the following properties:

ii. The equilibrium price of the agricultural product is lower than the socially optimal level.

iii. Total agricultural production is larger than the socially desired levels.

iv Total water utilization is larger than socially desired.

v. The firm production level is smaller than the scale efficient level.

vi. The number of firms is larger than socially desired.

Proof: In the current context, efficiency conditions are the same as the long-run social optimum for which the necessary and sufficient conditions are given by equations (20), (21), and (22). Comparing these to the private first-order conditions under block-rate pricing reveals that for block-rate pricing to achieve social optimum its highest block must be set equal to C_W . But then, unless $\bar{w} = 0$, condition (22) is violated. That is to say, only degenerate block-rate pricing can achieve social optimum.

By Observation 1, the marginal cost functions under flat-rate and block-rate pricing coincide but the average cost under the latter is below that of the former. Consequently, the minimum of the average cost function under strictly increasing block-rate pricing is to

the left of that under flat-rate pricing, implying smaller production on each farm (left-side Figure 1). The market consequence of Observation 1 is a lower equilibrium price, implying too much aggregate production (right-side Figure 1) and water utilization. Finally, since each farm produces less output than under a flat-rate pricing, the number of farms must be greater to accommodate the rise in total output. ■

The implications of the proposition deserve double emphasis. By Proposition 1, *first-best social optimum is not implementable with strictly increasing block-rate pricing. A structure of block pricing that leads to the first-best social optimum, simply does not exist.*

Marginal Reforms

In the previous subsection we analyzed the relative efficiency of the two regulation regimes, i.e. we compared the long-run equilibrium under the two pricing methods. However, governments often reform their policy in stages and, hence, it is of interest to investigate the impact of a marginal reform. The effect of marginal reform is studied via infinitesimal changes in \bar{w} , where as \bar{w} approaches zero the regulation regime changes from increasing block-rate to flat-rate pricing.

To facilitate the analysis we introduce a framework for comparative static analysis of the equilibrium conditions under increasing block-rate pricing. The analysis is based on conditions for long-run competitive equilibrium:

$$\rho(Ny) - mc^b(y) = 0 \tag{28}$$

and

$$\rho(Ny) - ac^b(y) = 0, \tag{29}$$

with y and N as endogenous variables and \bar{w} as an exogenous parameter. We consider a reform that preserves the highest block at the social marginal cost of water production, but increases \bar{w} . Beginning at $\bar{w} = 0$, we then have a gradual change from flat-rate pricing to increasing block rate pricing (with highest block fixed at C_W).

Totally differentiating (28) and (29), we find

$$\begin{bmatrix} N\rho' - \frac{\partial mc}{\partial y} & y\rho' \\ N\rho' & y\rho' \end{bmatrix} \begin{bmatrix} \frac{\partial y}{\partial \bar{w}} \\ \frac{\partial N}{\partial \bar{w}} \end{bmatrix} = \begin{bmatrix} 0 \\ \frac{-p_w}{y} \end{bmatrix}, \quad (30)$$

where ρ' denote the derivative of ρ with respect to y . The solution for the system in (30) is:

$$\frac{\partial y}{\partial \bar{w}} = \frac{-p_w}{y \frac{\partial mc}{\partial y}} < 0, \quad (31)$$

and

$$\frac{\partial N}{\partial \bar{w}} = -\frac{(-p_w)(N\rho' - \frac{\partial mc}{\partial y})}{\frac{\partial mc}{\partial y}\rho'y^2} > 0 \quad (32)$$

which implies

$$\frac{\partial Y}{\partial \bar{w}} = \frac{\partial N}{\partial \bar{w}}y + N\frac{\partial y}{\partial \bar{w}} = \frac{-p_w}{y\rho'} > 0. \quad (33)$$

The following proposition characterizes the impact of such a reform.

Proposition 2: *A marginal regulation reform from increasing block-rate, with the highest block at the social marginal cost, toward flat-rate pricing decreases the number of firms, increases output per firm, decreases total agricultural production, and most importantly, increases total economic surplus.*

Proof: It is only left to show that

$$\frac{\partial V(w, x, N)}{\partial \bar{w}} = \frac{\partial V}{\partial w} \frac{\partial w}{\partial \bar{w}} + \frac{\partial V}{\partial x} \frac{\partial x}{\partial \bar{w}} + \frac{\partial V}{\partial N} \frac{\partial N}{\partial \bar{w}} < 0, \quad (34)$$

for all $\bar{w} > 0$. To see this, note that when $p_w = C_W$ the first two terms on the right of the equality sign vanish by the private first-order conditions. But, $\partial V/\partial N < 0$ since condition (15) is full filled and $r(w) < C_W w$. This and (32) proves the assertion in (34). ■

The implications of Proposition 2 should be emphasized. Given that the highest block is fixed at C_W , the optimal increasing block-rate is a *flat-rate pricing*. This summarizes our finding concerning the absolute efficiency of the two regimes, when the criterion for comparison is total economic surplus. Thus far, the control regimes, were compared as first-best regulations.

5. Final Remarks

The general conclusions that emerge from our analysis are: 1) Applying increasing block-rate pricing reduces net economic surplus. 2) The long-run equilibrium under increasing block-rate pricing, with the highest block fixed at the marginal social-cost, is characterized by too-small and inefficient firm size, too many firms, excess production costs, excess industrial production, over-utilization of resources and external social cost.

In an extended version, we further find: 1) Block-rate pricing with the highest block at the social marginal cost dominates flat-rate pricing as a second-best regulation, subject to a constant number of farms. In this case, the preservation of family farms has a social value of its own and society willingly sacrifices economic surplus to keep farms in the industry. 2) Water pricing alone cannot implement social optimum, subject to a certain level of the agricultural product. 3) Lobbying and political pressure, which force the regulator to keep the average water price at a constant level, result in optimal block-rate pricing with the highest block below the social marginal cost.

A few of our results resemble the conclusions regarding the comparative efficiency of Pigouvian taxes and subsidies in regulating external effects (*e.g.*, Kamien, Schwartz and Dolbear 1966, Polinsky 1979, Fisher 1981, and Cropper and Oates 1992.) However, here, we deal with the regulation of an input market and an increasing block-rate pricing, rather than a subsidy for production and therefore, an entirely different model and analysis are required. Before concluding, we emphasize a few aspects of generality.

In this paper, two blocks were used with the lower at zero. In fact, this does not impose loss of generality relative to many blocks or even more sophisticated forms of nonlinear pricing. The only factor that matters is the size of subsidization relative to first-best flat-rate pricing — the higher the subsidy the worse the distortion.

In many real cases nonlinear pricing is utilized for taxation of the resource users, for example the use of urban water. We then have decreasing instead of increasing blocks. The results and the analysis presented in this paper allow straightforward conclusions for decreasing block-rate pricing as well.

The results in this paper are derived under a partial equilibrium model, as only one sector has been analyzed. Our inefficiency results would remain valid under a general equilibrium model as well, since efficiency requires social optimum in all sectors. Indirect effects on other markets may reduce the inefficiency size.

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Figure 1: Flat-Rate and Block-Rate Equilibriums