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# MANAGEMENT, RISK AND COMPETITIVE EQUILIBRIUM

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## 1. Introduction

A farmer can vaccinate his livestock, install auxiliary irrigation systems, apply herbicides and pesticides, and in these ways significantly reduce the variability and uncertainty of the returns to his operation. More subtle, and of no lesser importance, is the ability to reduce risk by day-to-day management and observation. A good poultry grower will recognize a disease before it has spread in the flock and timely cultivation reduces the amount of weeds and their effect on crop yields.

In this paper I suggest a production model in which risk reduction is a function of managerial ability. This ability is not mean-preserving -- better management both reduces the variability of production and increases productivity (for an alternative specification see Pope and Just (1977)). The consequences of this ability to affect risk are analyzed in an industry characterized by a distribution of managerial abilities and perfect competition. Risk neutrality is assumed throughout. It will be shown that better managers will concentrate in the more risky activities -- realizing in this way their comparative advantage -- and that these activities will, as a result, project a relatively low risk image. The analysis is comparative static in nature, but I have in mind an economic selection process as the dynamic mover of the system. Accordingly, the risk considered is the risk associated with economic selection: of failing to cover costs and having to change lines of production. Competition and market forces, by reducing profit margins, increase this risk and tighten the selection stress.

## 2. Production and Skill Distribution

### 2.1 The Production Activity

Consider an agricultural industry producing a single product. All farms are of identical size and assume, for simplicity, that the level of input is the same on all farms. Let $z$ be the dollar value of the constant, identical input vector. Since the analysis is long run in nature, $z$ includes cost of capital services.

Assume that potential, maximal output in physical terms on each farm is $\theta$ units. Production is a random process and actual level of output is $q \leq \theta$. Assume that the probability distribution of the $q$ values is the exponential density function (Figure 1) :

$$(1) \qquad f(q) = \eta e^{-\eta(\theta-q)} \qquad\qquad q \leq \theta$$

The cumulative distribution is

$$(2) \qquad F(q) = \int_{-\infty}^{q} \eta e^{-\eta(\theta-x)}dx = e^{-\eta(\theta-q)}$$

the expected value

$$(3) \qquad E(q) = \theta - 1/\eta$$

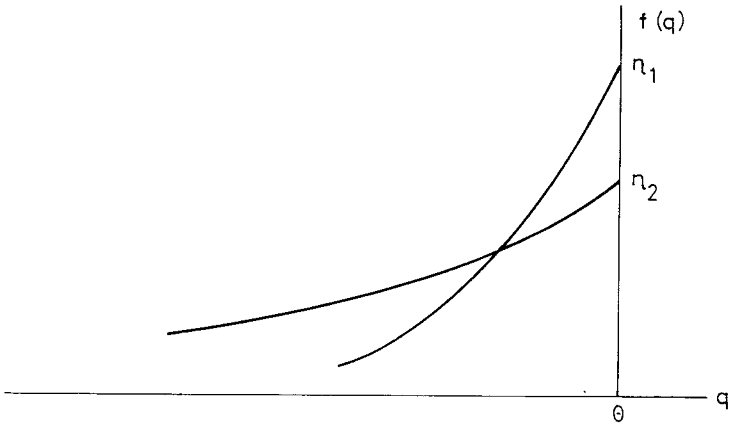


Figure 1: The exponential function $f(q) = \eta e^{-\eta(\theta-q)}$ for two values of $\eta$.

and the variance

(4) $\quad Var(q) = 1/\eta^2$

The parameter $\eta$ is both the mean and the variance parameter.

Farmers differ in management ability. The symbol $m$ stands for the management level and let $0 \leq m \leq 1$. To incorporate management into production, substitute in the distribution of outputs

$$\eta = \lambda m^{\alpha} \qquad\qquad 0 \leq m \leq 1, \; 0 < \alpha$$

Equation (1), for example, will be written as

(1') $\quad f(y) = \lambda m^{\alpha} e^{-\lambda m^{\alpha}(\theta-q)}$

At higher levels of $m$, the mean output, $E(q)$, will be higher and the variance will be lower. The parameter $\alpha$ was introduced to measure the intensity by which management can affect risk and productivity and will assume significance below in comparing lines of production.

With market price $p$ the distribution of the dollar value of output, $y = pq$, is

(5) $\quad g(y) = \dfrac{\lambda m^{\alpha}}{p} e^{-\lambda m^{\alpha}(\theta-y/p)} \qquad\qquad y \leq p\theta$

$$G(y) = e^{-\lambda m^{\alpha}(\theta-y/p)}$$

with mean $p(\theta-1/\lambda m^{\alpha})$ and variance $p^2/\lambda^2 m^{2\alpha}$.

A major measure of risk is the probability of negative profits. Operators for whom this probability is high, may lose often and will be forced to leave the industry. The probability of negative profits is, therefore, termed the <u>selection stress</u>.

Profits are

$$\pi = y - z$$

and the selection stress is

$$\Pr(\pi < 0) = \int_{-\infty}^{z} g(y)dy = G(z) = e^{-\lambda m^{\alpha}(\theta - z/p)}. \tag{6}$$

See Figure 2.

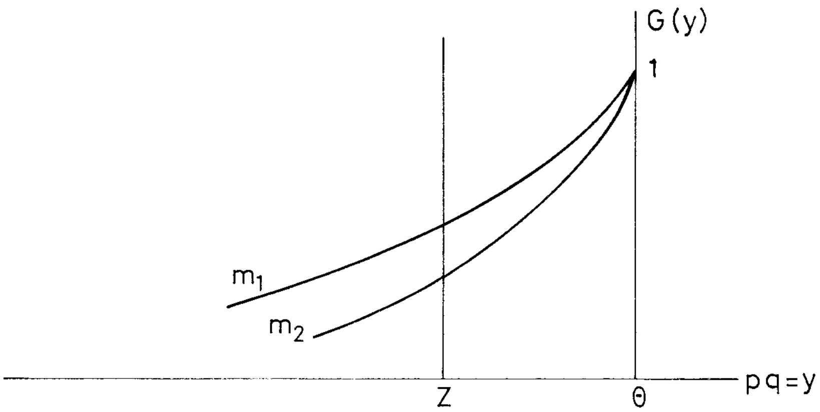


Figure 2: Risk, Pr(y<z), for two levels of management, $m_1 < m_2$.

Since both $\partial var(q)/\partial m$ and $\partial G(z)/\partial m$ are negative, management reduces the variability of outcomes of the production process and, thereby, reduces risk and the selection stress. A better manager faces, therefore, a smaller probability of failure.

2.2 The Industry

The industry is composed of operators of different managerial skills. Let $N(m)$ be the number of operators with management level $m$, and assume the distribution of management abilities to be given by $N(m) = Am^{-\beta}$, $0<\beta<1$. To economize on symbols normalize by setting $A \equiv 1$ and write the distribution as

$$N(m) = m^{-\beta}, \qquad 0<\beta<1,\ 0\le m\le 1. \tag{7}$$

The constraint on $\beta$ reflects the assumption that the proportions of the management groups decrease with management level; see Figure 3.

Assume that the number of operators in the industry is large, so that $N(m)$ can be taken as continuous in $m$. Let $T_{ab}$ stand for the size of the group of operators with management abilities between $m=a$ and $m=b$

$$T_{ab} = \int_a^b N(m)\, dm = \frac{1}{1-\beta}(b^{1-\beta} - a^{1-\beta}) \tag{8}$$

The total number of operators in the industry and outside is

$$\int_0^1 N(m)\, dm = \frac{1}{1-\beta} \tag{9}$$

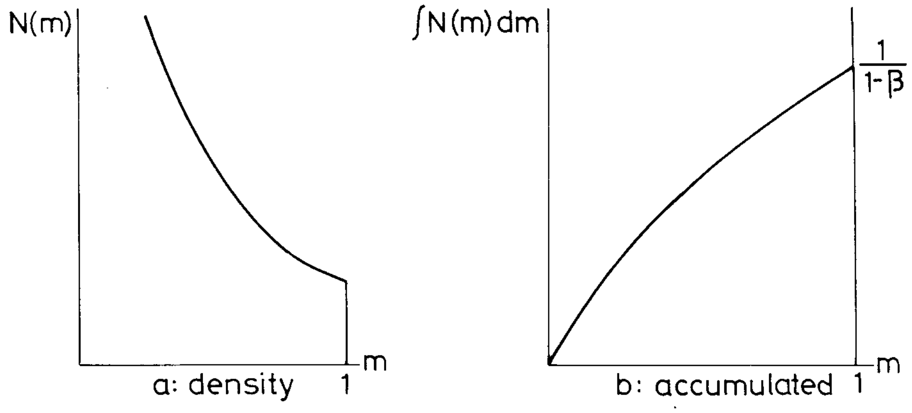


Figure 3: Distribution of Management

However, operators with relatively low levels of abilities cannot cover the cost of their production operations. Low level managers will, therefore, not be found operating in the industry.

Let $q_{.m}$ stand for the expected output of an operator with management level m. Total expected output for a group of firms, between the management levels a and b, is

$$(10)\qquad Q_{ab} = \int_a^b N(m)q_{.m}dm = \int_a^b m^{-\beta}(\theta - \frac{1}{\lambda m^{\alpha}})\ dm$$

Let $\delta \equiv 1-\beta-\alpha$, then for $\beta+\alpha \neq 1$,

$$(10a)\qquad Q_{ab} = T_{ab}\theta - \frac{1}{\lambda}\frac{b^{\delta} - a^{\delta}}{\delta}$$

and for $\beta + \alpha = 1$

$$(10b)\qquad Q_{ab} = T_{ab}\theta + \frac{1}{\lambda}\ (\log b - \log a)$$

Average, per firm, product in the group is

$$(11)\qquad Q_{ab}/T_{ab} \equiv Q..$$

If all operators with management abilities above the level m = a operate in the industry, b in equations (10) and (11) is replaced by 1.

Equation (12) specifies the variance of production in the industry as the sum of within firm and between firm variation.

$$(12)\qquad \sigma^2_{ab} = \int_a^b \frac{N(m)}{T_{ab}} \int_{-\infty}^{\theta} f(q)\ (q-q..)^2\ dq\ dm$$

$$= \frac{1}{T_{ab}} \int_a^b N(m) \left[ \frac{1}{\lambda^2 m^{2\alpha}} + (q_{\cdot m} - q_{\cdot\cdot})^2 \right] dm$$

$$= \frac{1}{T_{ab}} \left[ SW_{ab} + SB_{ab} \right]$$

The symbols $SW_{ab}$ and $SB_{ab}$ stand, respectively, for the within firms and between firms variability components. See Appendix for details.

The interpretation of this variance is the following: if repeated censuses (say, every year) of the group output were taken, and the variance of all the firm level observations around the long-run group average was calculated, its expected value would have been $\sigma^2_{ab}$ as defined in (12). The specification in (12) does not assume independence of output in firms.

If operators in the industry are identical, output in each period can be regarded as a sample from the population of random outcomes whose variance is given by (12). This leads "naturally" to regarding the observed variability of output as a measure of the variance of the probability distribution facing each operator. Such a procedure, may be followed by a new operator contemplating entry or by an outside observer trying to assess uncertainty and risk associated with the industry (Rao, 1971). The same applies to weather related variability, if observations are taken over a period of years. However, even in agriculture, much of livestock, fruits, and vegetable production is quite independent of climatic changes, and still, as every producer is well aware, output variability, risk, and uncertainty are significant in these lines also.

In equation (12) the within firm variance, SW, depends on the management level, the between firm component -- on the degree of concentration of production along the skill axis. Thus, the higher the skill in an industry and the more concentrated its production, the lower the variance of output. A low variance industry may project the impression of a low-risk activity. This is the motivation for the analysis of the next section.

## 3. Comparative Advantage

### 3.1 Two Industries

Assume a production sector, say agriculture, composed of two industries: One producing product 1, and the other producing product 2. Let the demand functions be

(13) $\quad p_i = c_i Q^{-\gamma} \qquad c_i, \gamma > 0, \quad i=1,2$

The management ability to affect the distribution of outcomes of production will now differ from industry to industry; index the parameter $\alpha$, $\alpha_i$ (i=1,2), in (1') and the equations that follow it.

We continue to assume an identical input vector of dollar value z in both industry 1 and 2. The output distributional parameters $\theta$ and $\lambda$ are also identical, $\alpha_1 < \alpha_2$ (Figure 4). Demand may differ according to (13).

Recall the major assertion of the study; namely, that certain characteristics of the industrial organization -- particularly the variability of output and the terms of trade -- will differ in equilibrium configuration from what they otherwise may be. To demonstrate the effect of the market forces, conduct a "thought experiment:" in it, an imaginary configuration, state zero, which will be equilibrium state in all respects but one, will be compared to a final market equilibrium.

To define state zero assume, for simplicity, that market equilibrium can be maintained in each industry separately with identical number and skill distribution of producers. Thus, let the total number of operators with skill level m in the

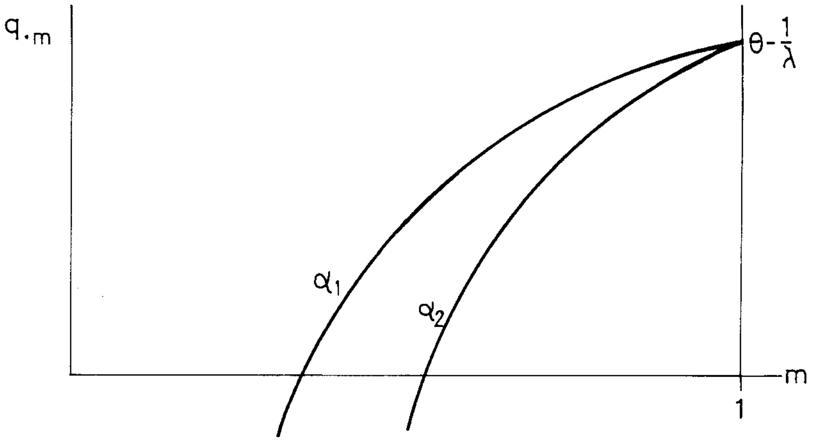


Figure 4: The functions $q_{\cdot m} = \theta - \frac{1}{\lambda m^{\alpha_i}}$ , $\alpha_1 < \alpha_2$

agricultural sector be $2m^{-\beta}$, of which $m^{-\beta}$ operate in each industry. Further, the skill of the marginal manager, the manager for whose firm revenue exactly equals cost, is the same in both industries. Mark this marginal skill level $m_+$, then

$$(14) \qquad p_1E_1(y) = p_2E_2(y) = z, \qquad\qquad m = m_+$$

See Figure 5. Operators with $m < m_+$ will, on the average, lose and will not produce. Total expected output of each product is

$$(15) \qquad Q_i = \int_{m_+}^{1} m^{-\beta} \left(\theta - \frac{1}{\lambda m^{\alpha_i}}\right) dm$$

$$= T_{+1}\theta + \frac{1}{\lambda}\,\frac{1-m_+^{\delta}}{\delta}\ , \quad \delta = 1-\beta-\alpha_i$$

according to (10a), assuming $\alpha+\beta\neq1$. With these quantities, prices, $p_1$ and $p_2$, are determined in the markets according to (13).

Thus state zero is an equilibrium situation in most senses: product markets are in equilibrium, operating producers make profits, the marginal producers (of $m_+$) make zero profit, there are no losers in the industries considered. As will be seen momentarily, the only aspect in which the sector is not in equilibrium is the ordering of producers according to comparative advantage positions. But right now, at state zero, producers are distributed at random (i.e.uniformly) between the two industries.

### 3.2 Equilibrium and Comparative Statics

In state zero product 2 is more profitable than 1 (Figure 5). This is not an equilibrium situation; producers can improve their position by moving from product 1 to 2. Such a movement will reduce $p_2$ and increase $p_1$. In equilibrium it will not pay operators to shift production. Define $\pi_{ki}$ as the profit of operator k in industry i. A producer in i cannot improve his position if for him

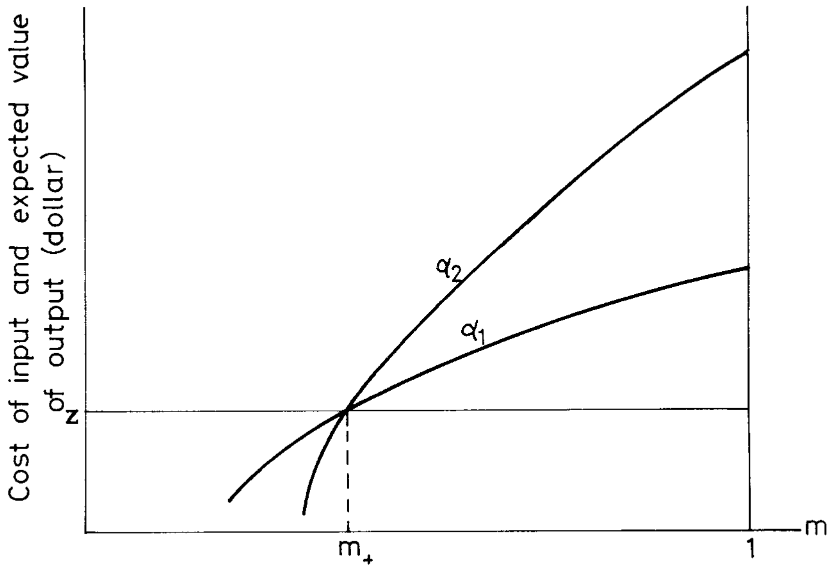


Figure 5: The functions $pq_{\cdot m}$ at state zero

$$E(\pi_{ki}) \geq E(\pi_{kj}) \qquad i, j=1,2$$

The sector is in equilibrium if the inequality holds for all k. An equilibrium is depicted in Figure 6.

In equilibrium, there are two break-even levels of management: at $m_*$

$$(16) \quad p_1E_1(q) = p_2E_2(q) \qquad m = m_*$$

and $m_*$ thus defines the boundary m -- farmers with $m < m_*$ produce product 1; those with $m_* < m$ produce 2. The second break-even point $m_o$ is defined by zero profits

$$(17) \quad p_1E_1(q) = z \qquad m = m_o$$

Producers with $m < m_o$ will not produce product 1; those with management ability on the range $(m_o, m_*^o)$ will operate in industry 1. In Figure 6, $m_o < m_+$ -- the shift to $^o$ equilibrium called into production low management $^o$operators from other industries who could not have survived economically in state zero. The level $m_o$ is defined by

$$(18) \quad z = p_1(\theta - \frac{1}{\lambda m_o^{\alpha_1}}) \qquad m_o = (\lambda(\theta - z/p_1))^{\frac{-1}{\alpha_1}}$$

where $p_1$ is

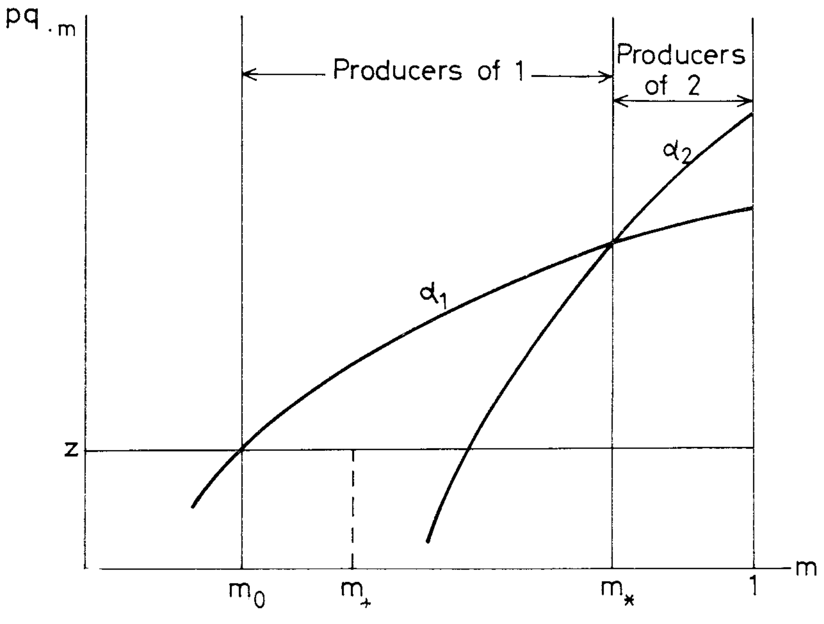


Figure 6: Equilibrium configuration of the agricultural sector

$$(19) \qquad p_1 = c_1 \left( \int_{m_o}^{m_*} 2m^{-\beta} \left(\theta - \frac{1}{\lambda m^{\alpha_1}}\right) dm\right)^{-\gamma} \qquad = c_1 Q_1^{-\gamma}$$

Note the factor 2 in the integrand in (19); it reflects the accumulation of producers from both industries. The same factor will apply similarly in the calculation of $Q_2$. (The integral in (19) assumes that potential producers of $m_o < m < m_+$ are also distributed according to $N(m) = 2m^{-\beta}$.)

By substituting $m_o$ from equation (18) into G(y) in (5) one finds that for $m_o$ the selection stress is $e^{-1} = .37$. The marginal producer will break even on the average, he will lose a third of the time and make profits 2/3 of the time.

In a dynamic environment, with farmers entering into and exiting from lines of activity, the selection stress is interpreted as the probability that a producer, chosen at random, will attempt to enter an industry, lose and fail. Comparing the equilibrium to state zero, we note, that since $p_2$ is lower and $p_1$ is higher the selection stress is, in equilibrium, tighter in industry 2 and looser in industry 1 than in state zero.

The shift from state zero to equilibrium also changed riskiness, as defined in equation (6). It is now more risky for a relatively low m farmer to move from product 1 to 2. In equation (6) for given m and $\alpha$

$$\frac{\partial G(z)}{\partial p} < 0$$

The changes in the terms of trade made industry 1 less risky and industry 2 more risky than in state zero.

The observed variance, as defined in equation (12), also differs in equilibrium from the state zero variance. In industry 2, equilibrium variance is clearly lower than state zero variance -- both within firms and between firms variances are smaller. The reduction in the variance in the value of the output is even larger since $p_2$ is small at equilibrium than in state zero.

It is probable that the observed variance in industry 1 will grow with the shift from state zero to equilibrium -- within firms variance grows and $p_1$ rises-- but since the variance between firms may be smaller, this conclusion cannot be general.

4. A Numerical Example

Consider 2 industries with the following common parameters:

$$\theta = 8$$
$$\lambda = 1$$
$$\gamma = 1$$
$$\beta = 0.5$$
$$z = 4.38$$

The industry-specific parameters are:

| | $\alpha_i$ | $\alpha_i$ |
|---|---|---|
| Industry 1 | 0.8 | 6.78 |
| Industry 2 | 1.2 | 23.31 |

With these specifications $m_+$, the break-even point for both industries at state zero, is 0.2 with prices:

$$p_1 = 1.00$$
$$p_2 = 3.97$$

and $p_1E_1(q) = p_2E_2(q) = z = 4.38$. See the solid lines in Figure 7.

To simplify the calculations, I assumed in this numerical example that $m_+$ will also in equilibrium be the lower bound management level. That is, new operators will not enter the industry even if profits are positive for a range of management level lower than m.

The second equilibrium break-even point is $m_* = 0.3742$. This is the dividing management level between the equilibrium allocation of producers to industries 1 and 2. See the broken lines in Figure 7.

Figure 8 depicts standard deviation of dollar value of output for both industries, $p_i m^{-\alpha_i}$, for state zero (solid lines) and for equilibrium (broken lines).

Table 1 presents a set of selected results of the numerical example. The reading of the table can be exemplified with the average product variable (q..). At state zero the average product per operating farm in industry 1 is 6.13; the same variable assumes the value of 5.19 in equilibrium. Per-farm product is lower in equilibrium; it is only 84 percent of the state zero level. On the other hand, the equilibrium level of industry 2 is 116 percent of the state zero average product of that industry.

The magnitudes reported in Table 1 illustrate well, I trust, the theoretical analysis of the earlier sections of the paper. Since their meaning has mostly been discussed at length, I am leaving the detailed examination and interpretation of the table to the interested reader.

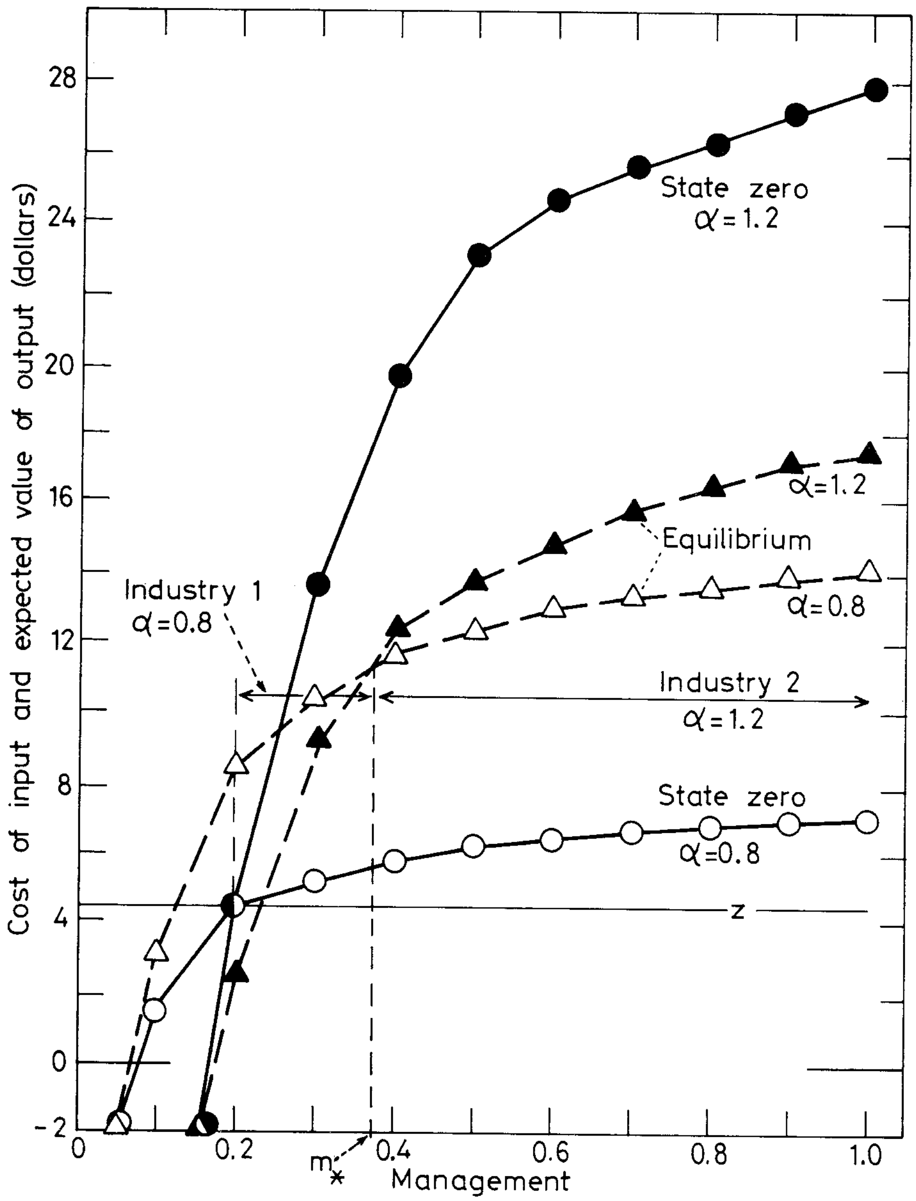


Figure 7: Value of output as a function of management

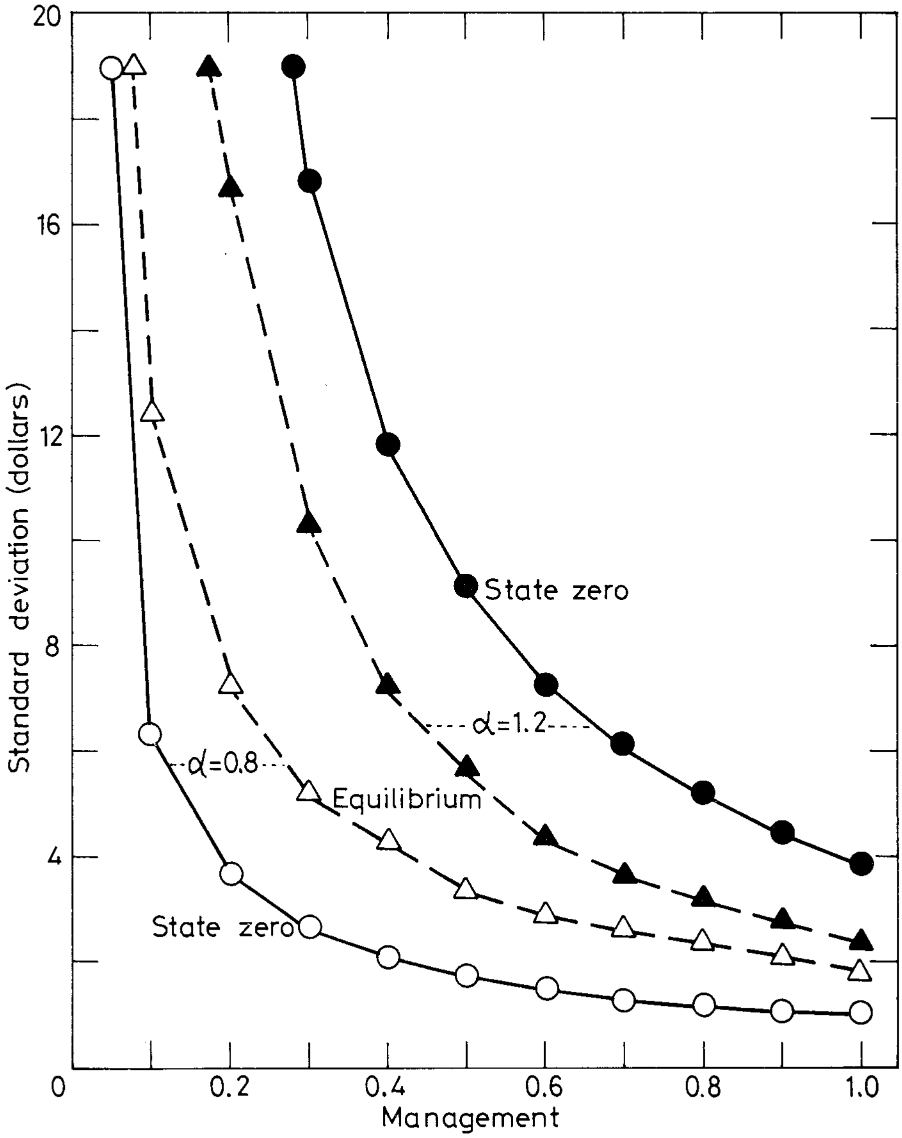


Figure 8: Standard deviation of value of output

Table 1: The numerical example - comparative statics

| | State zero | | Equilibrium | | Equilibrium / state zero | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 1 | 2 | 1 | 2 |
| Market price (p) | 1.00 | 3.97 | 1.98 | 2.43 | 1.98 | 0.61 |
| Industry's output (Q) | 6.78 | 5.87 | 3.41 | 9.60 | 0.50 | 1.64 |
| Average product ($q_{..}$) | 6.13 | 5.31 | 5.19 | 6.18 | 0.84 | 1.16 |
| Number of producers (T) | 1.11 | 1.11 | 0.66 | 1.55 | 0.60 | 1.40 |
| Profits at average output ($\pi = pq_{..} - z$) | 1.75 | 16.71 | 5.87 | 10.63 | 3.63 | 0.64 |
| Variance within firms (SW/T) | 4.01 | 9.66 | 8.08 | 3.71 | 2.02 | 0.38 |
| Variance between firms (SW/T) | 0.51 | 2.40 | 0.17 | 0.39 | 0.33 | 0.16 |
| Industry variance ($\sigma^2$) | 4.52 | 12.06 | 8.25 | 4.10 | 1.83 | 0.34 |
| Industry-wide standard deviation of output ($p\sigma$) | 2.12 | 13.79 | 5.67 | 4.92 | 1.38 | 0.36 |
| Average management[a] ($m_{..}$) | 0.46 | 0.44 | 0.27 | 0.61 | 0.60 | 1.39 |
| Selection Stress | | | | | | |
| Probability of loss at $m_{..}$ | 0.14 | $3.8\times10^{-5}$ | 0.02 | $2.5\times10^{-4}$ | 0.14 | 6.58 |
| Probability of loss at[b] E(m) | 0.22 | 0.16 | 0.09 | 0.19 | 0.41 | 1.19 |

[a] $m_{..}$ defined by $q_{..} = \theta - 1/\lambda m_{..}^{\alpha}$.

[b] $E(m) = \int_0^1 N(m)\, m\, dm = \frac{1-\beta}{2-\beta}$

## 5. Concluding Remarks

Most economic discussions of risk assume a given, subjective or objective, variability in production and returns and analyze the behavior of economic agents in terms of decision theory and readiness to accept risk. An economic unit is assumed to be able to affect its total risk position by selecting portfolios of venture but otherwise it accepts passively whatever riskiness nature offers. Perhaps typically, Arrow's (1971) book deals with risk bearing. Operations research applications have followed the same lines.

The first purpose of this paper was to draw attention to the managerial ability to affect risk and to its economic consequences. But the moral of that story is of wider implications: it means that subjective assessment of the world (subjective probabilities) and capricious preferences (utility) are, in a competitive environment, restricted by technology and market forces. This seems often to have been neglected (for example, by Anderson, Dillon and Hardacker (1977) and by Lin Deal and Moore (1974), but not by Roumasset (1974)). The analysis is also presented as a contribution toward the construction of a theory of economic evolution (Alchian (1950)), which will have though, by its very nature, to be a dynamic theory.

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REFERENCES:

[1] Alchian, A.A., Uncertainty, Evolution, and Economic Theory, Journal of Political Economy,58 (1950) 211-222.

[2] Anderson, Jock R., Dillon, John L. and Hardaker, J. Brian, Agricultural Decision Analysis (Iowa University Press, Ames, 1977).

[3] Arrow, Kenneth J., Essays in the Theory of Risk Bearing (Markham, Chicago, 1971).

[4] Lin, W., Dean, A. and Moore, C.V., An Empirical Test of Utility vs. Profit Maximization in Agricultural Production, American Journal of Agricultural Economics,56 (1974) 497-508.

[5] Pope, Rulon D. and Just, Richard E., Production Function Estimation and Related Risk Consideration, American Journal of Agricultural Economics, 61 (1979) 276-284.

[6] Rao, C.H. Hanumantha, Uncertainty, Entrepreneurship and Sharecropping in India, Journal of Political Economy,79 (1971) 578-595.

[7] Roumasset, James A. Rice and Risk: Decision Making Among Low Income Farmers (North-Holland, Amsterdam, 1974).

APPENDIX: Industry wide variance of production.

(A.1) $$\sigma^2_{ab} = \int_a^b \frac{N(m)}{T_{ab}} \int_{-\infty}^{\theta} f(q)\ (q - q_{..})^2 dy\ dm$$

$$= \int \frac{N(m)}{T_{ab}} \int_{-\infty}^{\theta} f(q)[(q-q_{.m})^2 + (q_{.m}-q_{..})^2 + 2(q-q_{.m})(q_{.m}-q_{..})]\ dq\ dm$$

$$= \frac{1}{T_{ab}} [SW_{ab}+SB_{ab}] + 2\int_a^b \frac{N(m)}{T_{ab}} \int_{-\infty}^{\theta} f(q)[qq_{.m}-qq_{..} - q^2_{.m} + q_{.m}q_{..}]\ dq\ dm$$

$$= \frac{1}{T_{ab}} [SW_{ab} + SB_{ab}]$$

(A.2) $$SW_{ab} = \int_a^b N(m) \int_{-\infty}^{\theta} (q-q_{.m})^2\ dq\ dm$$

$$= \int_a^b m^{-\beta} (\frac{1}{\lambda^2 m^{2\alpha}})\ dm$$

$$= \frac{1}{\lambda^2}\ \frac{b^{\xi} - a^{\xi}}{\xi} \qquad \beta + 2\alpha \neq 1$$

$$= \frac{1}{\lambda^2} (\log b - \log a) \qquad \beta + 2\alpha = 1$$

$$\xi = 1 - \beta - 2\alpha$$

(A.3) $$SB_{ab} = \int_a^b m^{-\beta}\ (y_{.m} - y_{..})^2\ dm$$

Define

$$\delta = 1 - \beta - \alpha$$

$$A \equiv \frac{b^{\delta} - a^{\delta}}{\delta} \qquad \beta + \alpha \neq 1$$

$$\equiv \log b - \log a \qquad \beta + \alpha = 1$$

(A.4) $$SB_{ab} = \frac{1}{\lambda^2} (\frac{b^{\xi} - a^{\xi}}{\xi} - \frac{A^2}{T_{ab}}) \qquad \beta + 2\alpha \neq 1$$

$$= \frac{1}{\lambda^2} (\log b - \log a - \frac{A^2}{T_{ab}}) \qquad \beta + 2\alpha = 1$$

Two cases apply if $\beta$ plus $2\alpha \neq 1$, either $\beta + \alpha \neq 1$ or $\beta + \alpha = 1$.

# International Farm Prices and the Social Cost of Cheap Food Policies: Comment

**Yoav Kislev**

The purpose of this note is to show that the prices which Peterson computed for his recent paper also can be viewed as effective exchange rates. Deviations from the world relative price system in agriculture are usually the result of market intervention, taxes, or subsidies. Such distortions, whether they are the result of domestic or of trade policies, can be viewed as distortions in effective exchange rates. For international comparisons, the exchange rate view is, analytically and conceptually, more general and convenient.

Peterson's wheat equivalent price, $\hat{p}_i$ for the commodity $i$, is defined as

$$\hat{p}_i = p_i(\bar{p}_w/\bar{p}_i), \tag{1}$$

where $p_i$ is the local currency farm price of the commodity $i$; $\bar{p}_i$ and $\bar{p}_w$ are, respectively, the world dollar price of the commodity and wheat. The prices $\hat{p}_i$ are expressed in local currencies and calculated for each commodity in every country (the country index is omitted here).

The aggregate overall average output price for each country is

$$P = \Sigma \hat{p}_i w_i, \tag{2}$$

where the weights are $w_i = (\bar{p}_i q_i)/(\Sigma \bar{p}_i q_i)$, with $q_i$ being the quantity of commodity $i$.

Equation (2) can be rewritten as

$$\begin{aligned} P &= \bar{p}_w \Sigma (p_i/\bar{p}_i) w_i, \\ &= \bar{p}_w E \end{aligned} \tag{2'}$$

The dimension of $E$ is local currency per dollar. Thus, it is the effective farm product exchange rate. $E$ is the value in local currency of the quantity of a composite bundle of domestic farm products that will fetch one dollar on world markets.

Peterson defined the real price as $P/p_f$—output price divided by the country's local price of fertilizers. Comparing countries, we are interested in price differences or ratios of real prices. In such ratios, world prices cancel out, and we can write the real prices as

$$\begin{aligned} R &= (\bar{p}_f/\bar{p}_w)(P/p_f), \\ &= E\,\frac{\bar{p}_f}{p_f}, \end{aligned} \tag{3}$$

where $\bar{p}_f$ is the world dollar price of fertilizers. If one views, with Peterson, cross-country differences in fertilizer prices as representing differences in the average price of production factors, then $p_f/\bar{p}_f$ is the effective exchange rate in the farm input market.

In equation (3), $R$ explicitly reflects the agricultural exchange rate. Differences between countries in their $R$ values are due to effective exchange rate distortions in the product and in the factor markets. Therefore, Peterson's supply equation can be interpreted more generally as a response function to effective exchange rate distortions. These distortions reflect market interventions stemming from both domestic and trade policies.

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### Reference

Peterson, Willis L. "International Farm Prices and the Social Cost of Cheap Food Policies." *Amer. J. Agr. Econ.* 61(1979):12–21.

# Prices versus Quantities: The Political Perspective

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Regulation regimes subject to the influence of interest groups are compared. It is shown that the allocation of the regulated commodity varies with the implemented control and that the advantage of prices (vs. quotas) increases with the elasticity of the demand for or the supply of the commodity and decreases with the number of organized producers in the regulated industry. Control regimes can be ranked for negative, but not positive, externalities. Finally, a control regime leading to a more efficient commodity allocation also entails using fewer resources in rent-seeking activities.

## I. Introduction and Summary

Given that government intervention is subject to lobbying and political pressure, when is regulation by prices the preferred regime and when is quantitative control adequate? The neoclassical answer to the control dilemma is that price and quota regimes are identical in their effect: both yield the same resource allocation and social welfare level. But, as Weitzman (1974) has already shown, the equivalence of the controls does not hold where information is imperfect and monitoring incomplete.[1] We focus on a different issue: the political aspect.

We analyze a single regulated industry, employing a factor with

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[1] For extensions and applications of Weitzman's analysis, see, e.g., Fisher (1981) and Cropper and Oates (1992).

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negative or positive external effects. The political equilibria, and hence the magnitude of the distortions, differ with the external effect and the implemented control. Under quota and when taxes are imposed to reduce negative effects, the employment of the controlled factor will lie between the private profit-maximizing utilization and the social optimum; with subsidies (when the effects are positive), there is a political struggle for higher payments, and equilibrium allocation will be greater than both private, nonintervention, utilization and the social optimum. In this case, resource allocation in the political equilibrium may be worse than free-market factor utilization.

It is further shown—for negative externalities—that the comparative advantage of either of the control regimes depends on a factor involving the share of organized producers in the industry, the value of the demand elasticity for the regulated good, and the tax rate. A price regime yields a more efficient political equilibrium when this factor is less than one. If this is not so, quota is the more efficient instrument. The preferred control cannot be unambiguously characterized when the external effects are positive. Finally, describing the political process as a menu auction with a single industrial lobby, we show that the relatively more efficient regime in terms of resource allocation induces a lower level of rent-seeking expenditures.

## II. Society and Polity

Regulation is called for where external effects exist: in production or consumption, where scale economies lead to a natural monopoly, or in the provision of public goods. The analysis in this paper is confined to regulation of a factor of production with externalities affecting consumers or producers elsewhere in the economy; they do not affect producers in the regulated industry. An example of a negative externality would be an irrigation project lowering the water table of a nearby urban center. An example of a positive effect would be the utilization and disposition of reclaimed sewage. Restricting the discussion to an input does not affect the generality of the conclusions.

The producers using the regulated factor are assumed to behave rationally and disregard externalities associated with their activity. In a free market, the producers tend to overutilize factors of production with negative effects and underutilize factors with positive effects. A social planner, taking into account both the value of production in the controlled industry and its effect on others, can determine socially optimal utilization of the factor. (Income distribution is disregarded in the analysis.)

The government in our analysis is a political entity whose own utility is affected both by social welfare and by political rewards or contributions. The producers and the government (the politicians), being engaged in political give and take, constitute a *polity*, and the ensuing allocation reflects the equilibrium reached in the political struggle. The government willingly accepts rewards and bends its policy but is not powerless. We assume that if a political agreement is not achieved, socially optimal resource allocation is enforced. The producers may also retreat to the social allocation and thus deprive the politicians of the rewards they desire. The social optimum is the threat point of the political game.

The producers either operate individually in the political arena or are organized into lobbies. We analyze the effect of collaboration in the influence groups but do not discuss the structure of the lobbies and modes of collaboration. Also, by our assumption, the individual political contribution is not determined in the political equilibrium; it is left to the lobby to charge its members. Political rewards may come in all shapes and forms: monetary political contributions (or even outright bribes), demonstrations, letter writing, and assistance in campaigns. They may be negative when the producers punish the government or demonstrate against it. Sometimes the political rewards may enhance welfare—the welfare of the receiving politicians or in a wider sense, for instance, when a builder offers a new school in return for a desired permit.

The discussion in the paper is limited to the effect of political contributions on government regulation; the nature of the rewards and their wider implications are not analyzed. As in Grossman and Helpman (1994), only "linear," money-like rewards are considered, and the political influence technology is restricted to exhibiting constant returns to scale. This assumption simplifies the analysis considerably by permitting recursive calculation of the variables making the political equilibrium. The use of the controlled factor is set in the first stage, and the political rewards—the distribution of the political surplus—are determined in the second stage. An important advantage of the linear model is that factor allocation is the same for a variety of political economies. The political contributions, on the other hand, are model-specific. We remark on possible generalizations in the concluding section of the paper (Sec. VIII).

The political process we consider is embedded in a "constitution" by which the control regime may be either a quota or a price regime. The constitution is accepted as predetermined, it is not debatable, and we do not consider here the political process leading to its establishment.[2]

Our main concern is to compare a quota with a price regime. Under quota, the producers must comply with administrative regulations. With price control, they either pay a tax or receive a subsidy and freely choose the quantity of the factor they use. Focusing on the efficiency of the controls, we eliminate income differences by introducing revenue-neutral policy shifts; that is, lump-sum payments are seen as balancing taxes or subsidies. For example, when the change is made from a quota to a tax, the government pays upfront the value of the taxes that will be applied in the political equilibrium. A shift to a subsidy regime entails a compensating lump-sum tax. Similarly, a move from a tax to a quota control is associated with a lump-sum payment to the government. The compensation is not debatable, and the producers cannot expect to affect it, even if the magnitude of the tax or subsidy is modified in the political negotiations that follow once the control regime has been in place and the compensation scheme implemented.[3]

Compensations of this nature are observed in reality. The government of Israel, for example, is at the present time "purchasing" production quotas in agriculture in an attempt to gain political acceptance of steps toward the elimination of planning and administrative intervention in farming.

## III. Recent Theories of Political Economy

Political processes affecting public intervention in the economy have been the subject of intensive literature. Examples include Zusman (1976) in agricultural planning; Rodrik (1986), Hillman (1989), and Grossman and Helpman (1994) in the context of international trade; and Scarpa (1994), who studies the consequences of political influence by a public utility. These studies analyze political equilibria for particular control regimes. In contrast, we attempt to compare the performance of alternative politically influenced regimes.

The political process may be viewed in many ways. Following the

[2] A similar approach is taken by both Rodrik (1986) and Grossman and Helpman (1994), who view the evolution of the political process as proceeding in two stages. In an analysis of the political choice of regimes, Buchanan and Tullock (1975) concluded that politicians will, generally, prefer quantitative controls. These authors, however, ignore the possibility that rent-seeking activities will modify the level of controls once they are implemented.

[3] Lump-sum compensating payments eliminate income effects of control regimes and facilitate an analysis of net allocation effects. Sometimes, however, a crucial consideration in the choice of a control is revenue raising and cost covering. These considerations are disregarded in the present analysis.

Peltzman (1976) tradition, Hillman (1989) sees the government as setting policies to maximize a political support function that trades welfare of voters with divergent interests. In Zusman (1976) and Scarpa (1994), the political process is a Nash (1950) bargaining game, with politicians and lobbies negotiating policy parameters and political contributions. Grossman and Helpman (1994) describe the political process as a menu auction.

Although these models differ, they share a common property: The equilibrium reached is politically efficient and is located on the polity's contract curve. Moreover, as we show shortly, in the case of linear political rewards, the allocation of the controlled factor is independent of the magnitude of the political contributions, and all the models above predict identical allocations (Hillman does not specify rewards explicitly). We make use of this property in the next four sections of the paper.

## IV. The Model

Net income of a producer in the regulated industry is

$$y^i = \pi^i(q^i) - c^i - tq^i + R^i, \tag{1}$$

where $q^i$ marks the $i$th producer's utilization level of the regulated factor and the magnitude $t$ marks the tax imposed by the government (for a subsidy $t < 0$). The compensation payment is $R$, and it is equal to the equilibrium level of $tq$. The variable $c^i$ indicates political contribution. The function $\pi^i(q^i)$ is the $i$th producer's profit in the production activity; it is concave and subsumes the prices of goods other than the regulated good. It also subsumes the private market price, $p$, of the regulated factor, but taxes or subsidies are not included in $\pi$. The industry supplying $q$ is competitive and is characterized by constant returns to scale with a perfectly elastic supply. There are $N$ producers in the regulated industry, and total factor utilization and political rewards are given, respectively, by

$$Q = \sum_{i=1}^{N} q^i, \quad C = \sum_{i=1}^{N} c^i. \tag{2}$$

If only $K$ producers participate in the industry's lobby ($K \leq N$), $c^i$ may be zero for some values of $i$.

The second sector, the government, is viewed as maximizing the sum

$$W = V(\mathbf{q}) + \alpha C, \tag{3}$$

where $V(\mathbf{q})$ is social welfare defined over the vector $\mathbf{q} = q^1, \ldots, q^N$, and the constant $\alpha > 0$ represents the preference of the government for political bribes relative to public welfare. It can also be seen as standing for the political power of the influence group in the industry. Lobbies in different industries may have different $\alpha$ values.

The welfare function, $V$, is given by

$$V(\mathbf{q}) = \sum_{i=1}^{N} \pi^i(q^i) + \sum_{j=1}^{M} \mu^j(Q), \tag{4}$$

where $\mu^j(Q)$ is the money-metric utility function of the $j$th person who is affected by the external effects of the regulated factor. The function $\mu$ increases with $Q$ for positive externalities and decreases for negative effects. Utility is also defined over the vector of prices of consumption goods, but under the assumption of a small economy with all goods traded, prices are constant and are not represented explicitly in the function.

It is assumed that $\mu^j$ is concave in $Q$ and hence in each $q^i$. Similarly, since $V$ is the sum of concave functions (in each $q^i$), it is a concave function itself. All functions are second-order differentiable, and interior solutions are assumed throughout.[4] It is also assumed that enforcement of the regulation instrument is costless.

Because of externalities, optimal levels of $q^i$ from the points of view of the producer, $q_i^{pr}$, and the society, $q_i^s$, do not agree. That is,

$$q_i^{pr} = \underset{q_i}{\operatorname{argmax}}[\pi(q)] \neq q_i^s = \underset{q_i}{\operatorname{argmax}}[V(\mathbf{q})]. \tag{5}$$

This, of course, creates the conflict that induces rent seeking and political rewards.

As indicated, producers in an industry may operate in the political arena individually or in the industrial lobby. We assume that a lobby maximizes total income of the members in the group:

$$Y = \sum_{k=1}^{K} y^k. \tag{6}$$

The formulation is general: an industry may have just a single producer ($N = K = 1$); this may be a monopsonist in the use of the regulated factor, perhaps a public utility. Alternatively, some or all

[4] Among other things, interior solutions mean that all producers use positive quantities of $q$ at any of the prices considered.

producers in an industry may form an influence group and lobby for their interests.[5]

One difference between the regimes affects behavior in a crucial way. Taxes are uniform, and in an industry with many producers, both those who lobby to modify the policy and those who do not face the same tax. We show that an industry with a comparatively large share of free riders is politically weaker, but, as indicated, we do not analyze the internal structure of the lobby groups and the forces that keep them together.

Under a quantity control, on the other hand, a producer who does not engage in political activity will be assigned the social quota (with negative externalities, nonparticipants may even get zero quotas to balance overutilization by the political activists). There is, therefore, no free riding in the political equilibrium of a quota regime: all producers participate and are members of the industrial lobby.[6]

## V. Equilibrium Utilization of the Regulated Factor

In the first stage of the recursive calculation of the political equilibrium, we set the allocation of the regulated factor. This first stage is described here. The contributions by the $K$ politically active producers are determined in the second stage, which is presented in Section VII.

Let $\gamma$ mark a common label for the allocation parameters in the two alternative regimes considered in the paper: a quota system in which $\gamma = \mathbf{q} = q^1, \ldots, q^N$; and indirect control, a price regime with a per unit tax or subsidy, $\gamma = t$. Exogenous to the political equilibrium are the production technology, prices, private and social preferences, and the constitution specifying the instrument of regulation.

An efficient agreement between the government and the producers, located on the polity's contract curve, can be characterized by the necessary conditions for an internal solution to the following constrained maximization problem:

$$\begin{gathered} \gamma^{po}, \mathbf{c}^{po} = \underset{\gamma, \mathbf{c}}{\operatorname{argmax}}\ W(\gamma, \mathbf{c}) \\ \text{subject to} \quad Y(\gamma, \mathbf{c}) \geq \overline{Y}. \end{gathered} \tag{7}$$

[5] With linear political rewards, the analysis is not modified by the number of lobby groups in the industry. For simplicity and brevity, the discussion is conducted in terms of a single lobby.

[6] Similar considerations underlie Rodrik's (1986) analysis of trade with either a uniform tariff or firm-specific subsidies.

In equation (7), $\overline{Y}$, defined as in (6), is the reservation utility, the alternative income of the lobby members in the event that an agreement is not reached, and **c** is the vector of political rewards. We commence with a quota control.

### *A. A Quota Control*

The government sets quotas, **q**, the magnitudes of which are subject to political pressure. In this case, $y^i = \pi^i(q^i) - c^i$, and a politically efficient agreement concerning **q** satisfies (7) and is characterized by the following $N$ first-order conditions (derivatives are marked as subscripts):

$$\pi^i_q(1 + \alpha) = -\sum_{j=1}^{M} \mu^j_Q(Q), \quad i \in \{1, \ldots, N\}. \tag{8}$$

*Remarks.*—(*a*) The political rewards, $c^i$, do not appear in the necessary conditions for the determination of the quotas. This verifies our earlier assertion on the recursive nature of the solution of the political equilibrium. (*b*) The utilization of the regulated factor likewise does not depend on the compensation, $R$. (*c*) Equations (8) will be the same whether the producers in the industry are unionized in a single lobby or in several groups or whether they operate individually. Political organization does not affect the equilibrium reached. These three features arise from the linear nature of the political reward system. The equilibrium would have been different with nonlinear rewards: if the political action was subject to economies or diseconomies of scale.

A useful result that emerges from condition (8) is that, as the right-hand side, $\sum_{j=1}^{M} \mu^j_Q(Q)$, is identical for all $i$, $\pi^i_q = \pi^j_q = \pi_q$ for all $i, j \in \{1, \ldots, N\}$ (similarly, $V_{q^i} = V_{q^j} = V_q$ for all $i, j \in \{1, \ldots, N\}$). In words, the value of the marginal profit (VMP) of the regulated factor is the same for all producers. The political game distorts the level of aggregate factor utilization, but allocation among producers is efficient. This is a reflection of producers with a higher VMP pressing harder for quotas.[7] When resources are administratively allocated, the political process replaces the market in securing between-firm efficiency.

Because of the signs of the derivatives $\mu^j_Q$, equation (8) implies that for negative (positive) externalities $\pi^i_q > (<) \ 0$. In addition, equations (8) can now be rewritten as

[7] The argument that producers with a higher VMP press harder relies on a "truthful" property, namely, that producers struggle more—offer higher rewards—for more valuable political favors. We comment further on this property in Sec. VII.

TABLE 1

PROPERTIES OF THE POLITICAL EQUILIBRIUM

| | Marginal Contribution of $q$ | | |
|---|---|---|---|
| | Social | Private | Quantity |
| | | Negative Externalities | |
| Quota/tax | $V_q < 0$ | $\pi_q > 0$ | $Q^s < Q^{po} < Q^{pr}$ |
| | | Positive Externalities | |
| Quota | $V_q > 0$ | $\pi_q < 0$ | $Q^{pr} < Q^{po} < Q^s$ |
| Subsidy | $V_q < 0$ | $\pi_q < 0$ | $Q^{pr} < Q^s < Q^{po}$ |

$$V_q = -\alpha\pi_q, \tag{8'}$$

which implies that for negative (positive) externalities $V_{q^i} < (>)\ 0$ for all $i \in \{1, \ldots, N\}$. Since all VMPs are equal, all the $q^i$ values move together, and it follows unambiguously from the sign of $V_q$ that for negative (positive) externalities, $q_i^{po} > (<)\ q_i^s$ for all $i \in \{1, \ldots, N\}$. Thus, under quota, the political equilibrium is a "compromise": With negative externalities, factor utilization exceeds the social optimum (where $V_q = 0$) but is lower than free-market use (characterized by $\pi_q = 0$). With positive externalities, utilization at the political equilibrium is smaller than socially optimal and larger than the private profit-maximizing quantity. These findings are summarized in the first two rows of table 1.

The political equilibrium is depicted graphically for a single producer and negative externalities in figure 1. The graphs $W_1$, $W_2$ and $y_1$, $y_2$ are the government's and the producer's indifference curves; their slopes are $-V_q/\alpha$ and $\pi_q^i$, respectively. (For the government, the curve is drawn with all other producers at the equilibrium configuration.) Because of differences in political payments, $W_2 > W_1$ and $y_2 > y_1$. Each indifference curve of the government has a minimum at $q = q^s$, the socially desired level, and the point $q = q^s$, $c = 0$ is the disagreement threat point. The equilibrium quota is $q^{po}$, and the segment $[a, b]$, between indifference curves passing through the origin, marks the core of the political game.

## B. *Indirect Control*

A pure price control is either a tax or a subsidy. In this case, $y^i = \pi^i(q^i) - tq^i - c^i$ ($R$ is omitted), and the producer is free to utilize any quantity of the factor. The private first-order condition charac-

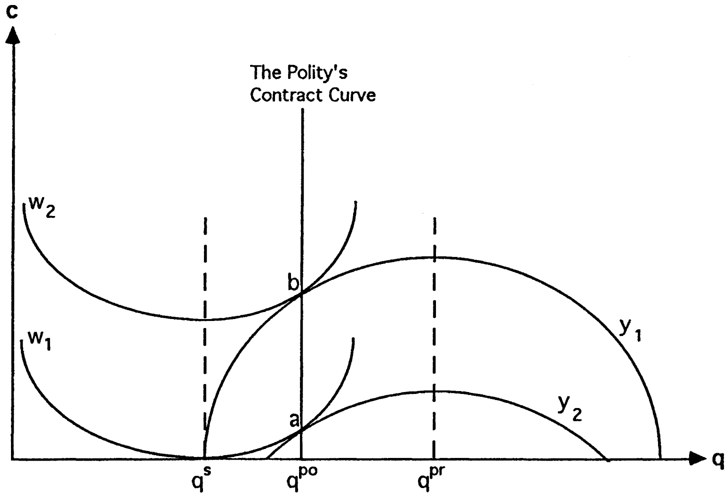


FIG. 1.—Construction of political equilibrium: negative externalities

terizing the producer's choice of $q^i$ is then

$$\pi^i_q = t, \tag{9}$$

which implies

$$\frac{\partial q^i}{\partial t} = \frac{1}{\pi^i_{qq}}. \tag{9'}$$

By (9), for $t \neq 0$, $q^{po} < (>)\ q^{pr}$ for negative (positive) effects.

Solving (7) with respect to $t$ and **c**, using equation (9), yields the condition that characterizes the political equilibrium under a price regime:

$$\sum_{i=1}^{N} V_{q^i} \frac{\partial q^i}{\partial t} = \alpha Q^K, \tag{10}$$

where $Q^K$ is the aggregate factor utilization by the members of the industrial lobby. The marginal effect of a tax on the whole industry is balanced against its effect on the active group whose utility is reserved on the political contract curve. The remarks following equation (8) on the independence of allocation apply here too. Also, producers in an industry controlled by prices may operate in several groups; their contributions will be aggregated by the receiving politicians in the government, and their effect will be a function of the sum. In this situation, $K$ stands for the total number of participants in all groups.

It follows from $\pi_q^i = t$, for all $i \in \{1, \ldots, N\}$, that

$$V_{q^i} = \pi_q^i + \sum_{j=1}^{m} \mu_Q^j = V_q \quad \forall\ i \in \{1, \ldots, N\}$$

and that (10) can be written as

$$V_q = \alpha Q^K \frac{\partial t}{\partial Q}. \tag{11}$$

By concavity of $\pi^i$, $\pi_{qq}^i < 0$; then by (9′), $\partial t/\partial Q < 0$, implying that $V_q < 0$ regardless of the sign of $\pi_q$. Thus, under a price control, the producers overutilize (socially) the regulated factor both when the external effects are negative and when they are positive. With negative externalities, the political pressure is to reduce the tax. With positive effects, it is to increase the subsidy up to and above the social optimum (table 1). Consequently, while under a quota regime the political equilibrium is always a compromise (between the free-market allocation and the social optimum), in the presence of political power and with positive external effects, a price regime may yield an allocation that is *socially worse than the free-market utilization of the regulated factor.* In the presence of political pressure, the intervention of an otherwise benevolent government may detrimentally impair resource allocation.

That taxes and subsidies differ in their effects on resource allocation modifies—for a political economy—the Coase (1960) and Weitzman (1974) conclusion that property rights do not affect the nature of the solution to an externality problem. If the producer owns the right to pollute the air, to take an example from these references, **q** will stand for the resources going into pollution prevention, and their use will have positive externalities and will be subsidized. If the public, represented by the government, owns these rights, the polluters will be taxed. With political pressure, resource allocations will differ. In the first case the equilibrium will be characterized by overinvestment in pollution prevention; in the second it will be suboptimal.

Another useful way to write equation (11) is

$$V_q = \alpha \frac{\sigma}{s\eta} \pi_q, \tag{12}$$

where $s = t/(p + t)$; $\eta$ is the factor demand elasticity, defined at the price the producer actually pays, $p + t$; and $\sigma = Q^K/Q$ is the share of the regulated factor utilized by the producers in the lobby group.[8] The formulation of (12) is utilized in the analysis to follow. Expressing $V_q$ in its extended form, we can rewrite equation (12) as

$$\sum_{j=1}^{M} \mu_Q^j = \pi_q \left( \frac{\alpha\sigma}{s\eta} - 1 \right), \tag{13}$$

which implies that, for positive externalities and a price regime, internal tangency solutions are confined to the region in which $\alpha\sigma/s\eta < 1$.

## VI. Comparative Efficiency of Factor Utilization

We are ready now to turn to the question of *prices or quantities*. To examine this, we make the following definition: a control yields a *more efficient utilization* of the regulated factor than the alternative regime if and only if it yields a higher level of social welfare, $V(\mathbf{q})$.

### A. *A Formal Proposition*

With negative externalities, both under quota and in a tax regime, the quantity of the regulated factor lies between the privately desired level and the social optimum. This "closeness" of the equilibria enables an analysis of the comparative performance of the alternative regimes. Such an analysis is impossible for a positive externality because of the distance between equilibria in which, under a quota, $q^i$, $i \in \{1, \ldots, N\}$, are lower than the social optimum and with a subsidy are above the optimum. These considerations are reflected in the following proposition, which summarizes the principal findings of the paper.

PROPOSITION 1. Suppose that the government is regulating the utilization of a factor by either a price or quota control. The factor is used by many producers. With quotas, all producers are represented in the political process; with prices, not all producers are necessarily members of the industrial lobby. Then (i) with a negative externality, a price (quota) regime yields a more efficient factor utilization if and only if $|\sigma/\eta s| < (>)\ 1$ (the inequality is evaluated at the price regime equilibrium); (ii) with a positive externality, a price regime yields a larger factor utilization than under quota; efficiency comparison is, however, inconclusive; (iii) under both types of externalities, the efficiency of a price relative to a quota control increases

[8] With a subsidy ($t < 0$), $s$ can be either negative or positive. When $|t| < p$, $s < 0$; when $|t| > p$, $s > 0$. In the latter case, calculated $\eta > 0$; in both cases, $s\eta > 0$. For completion, we set $s\eta = 1$ for $|t| = p$.

with the elasticity of the demand for the regulated factor and decreases with the share of organized producers in total production; and (iv) the efficiency of both controls increases with the ethical norms of the politicians, $1/\alpha$.

*Proof.* To prove part i, denote $\epsilon = |\sigma/\eta s|$. For $\epsilon = 1$, resource allocation under quota is identical to allocation in a tax regime. To compare the controls, consider a shift in a given industry from a quota to a tax. Since the move occurs between equilibria, the compensation ($R$) is implemented and the only difference in the first-order condition occurs in the value of $\epsilon$. Examining (8′) and (12), one realizes that, for $\epsilon < 1$, $V_q$ in (12) is smaller in absolute value than in (8′); a tax regime is then comparatively more efficient. The inequality is reversed for $\epsilon > 1$, as required for the proof. Part ii is proved by noting that because of the differences in $V_q$ values in table 1, comparative advantage cannot be determined. Parts iii and iv are proved by examination of (12). Q.E.D.

We now discuss interpretations and elaborations.

### B. *Demand Elasticity*

The intuition behind the role played by demand elasticity in comparing efficiency of the regimes in part i of proposition 1 can be explained conveniently for $\sigma = 1$, $p = 0$, and $s = 1$; that is, the industry consists of a single producer or of an all-embracing lobby, there is no charge for the factor $q$ under a quota regime, and the tax is the entire unit price under a price regime. For this situation, $q_0$ in figure 2 is an initial quantity, either determined by a quota or reached by the producer when the tax was set to $t_0$.

Consider the rent-seeking effort that increases the quantity to $q_1$. Depending on the control, the change may be achieved by either increasing the quota itself or reducing the tax to $t_1$. The corresponding gain to the producer is

$$\text{price regime:}\quad A + B,$$

$$\text{quota regime:}\quad B + C,$$

$$\text{difference:}\quad A - C.$$

With unitary elasticity, $A = C$ and the difference vanishes, the regimes are equivalent at the margin. The returns to marginal political efforts of equal quantitative effects are identical. Alternatively, if the factor demand is elastic, $A < C$, the returns under a price regime are smaller than under quota. Consequently, under a price regime the political struggle is less intensive and the equilibrium is closer to the social optimum. Similarly, for part iii, the more elastic the

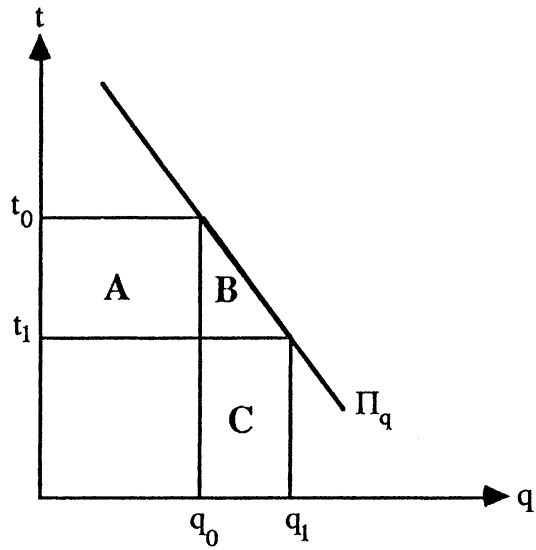


FIG. 2.—Gains from political influence: prices vs. quantities

demand function passing through $(q_0, t_0)$, the smaller the area $A + B$ and the less intensive the political struggle. In figure 1, more elastic demand is expressed in smaller slopes of the producer's indifference curves and a move of the political equilibrium quantity to the left.

These findings may seem to contradict the established Ramsey-Boiteux tradition (Atkinson and Stiglitz 1980) of optimal taxation by which the more elastic the demand (or supply), the more socially harmful an intervention in prices. The apparent contradiction is resolved by recognizing that when taxes are levied to raise revenue, optimal rates minimize their effect on resource allocation; here the sole purpose of taxes is to modify the use of resources.

### C. *Organization of Producers*

With a single producer, $\sigma = 1$ and the difference between the control regimes is reflected only in the size of the product $s\eta$. As we saw earlier, under quota, all producers are politically active and the degree of their organization does not affect the equilibrium reached. Similarly, if in a tax regime all producers are organized in a lobby and operate in unison, $\sigma = 1$ and the number of producers or their organizations does not affect equilibrium. But a price regime is conducive to free-riding.

The explanation of the importance of cooperation in determining the political equilibrium of an industry is simple, and the situation is familiar to observers of administrative controls. With a quota, every producer tries to increase his or her own utilization of the controlled factor as does a lobby arguing for its members. The political activists present convincing arguments aplenty. For the government, it is comparatively easy to yield to the pressure of a particular individual or lobby; the quantitative effect is relatively small. Alternatively, in a price regime with a uniform tax rate, the government stands firmer: a concession to one producer or group is a concession to the whole industry. Consequently, the greater the amount of free-riding in a price regime, the stronger the comparative social advantage of this control.

According to conventional thinking, heterogeneity of the production units argues in favor of price control, since prices, being uniform, economize on information; with heterogeneous producers, efficiency calls for unequal, individually tailored quotas. This argument was qualified by Weitzman (1974), who noted that for iterative planning there is no significant information difference between a price and a quota regime. In a political environment, between-firm allocation is efficient, and heterogeneity in production affects equilibrium allocation only to the extent that it may lead to a looser organization and to a larger number of free riders.

### *D. A Caveat*

The intuitive interpretations, and indeed proposition 1 and particularly its part i, should be accepted with care. The proposition is defined for the conditions of a political equilibrium. The equilibrium ratio $s$ is endogenously determined, and the elasticity of the factor demand is also, in general, an endogenous magnitude. These variables are components of a political equilibrium. The proposition, as indicated, *characterizes* the equilibrium. If in equilibrium (with negative externalities) $|\sigma/\eta s| < 1$, price control dominates. It may, however, happen that even for an elastic demand and a comparatively small lobby, the equilibrium value of $s$ will be so small that $|\sigma/\eta s| > 1$, and then a quota regime will be more efficient. The situation is simpler for an inelastic demand and $\sigma = 1$; it is then assured that $|1/\eta s| > 1$, and a quota control clearly dominates.

## VII. Political Contributions

While the characterization of the allocation parameters in the first stage of the calculation of equilibrium was based solely on the common property of political efficiency, the contributions depend on the specific political process. The analysis in the paper is confined to Grossman and Helpman's (1994) model, which employs the procedure of a menu auction. As before, the analysis is conducted under the assumption that all organized producers are members of a single industrial lobby and that under a price regime some producers may not participate in the political game. As indicated earlier, with our structural assumption of constant political cost and effect, only the aggregate reward, $C$, is determined in the political equilibrium; the individual $c^i$ values are set by the lobby. The model conceptualizes the political process as a two-stage noncooperative auction game. In the first stage, lobbies, which may have opposing interests, offer political contributions for changes in policy parameters. In the second stage, the government chooses parameters that maximize its utility, which is, as in equation (3), a weighted sum of social welfare and political rewards. The perfect Nash equilibrium of this game is not unique, but "truthful" strategies lead to unique Nash equilibria that are coalition proof and focal.[9] With a single lobby, which is the situation we analyze, the government obtains only its reservation utility, and all surplus in the polity is received by the producers.

The government reservation utility is given by $V(q_1^s, \ldots, q_N^s)$. Accordingly,

$$C = V(q_1^s, \ldots, q_N^s) - V(q_1^{po}, \ldots, q_N^{po}). \tag{14}$$

In figure 1, the payment to the government is represented by the distance, on the contract curve, from the $q$ axis to the point $a$. The political contributions grow with the deviation of equilibrium allocation of the regulated factor from the social optimum.

Using equations (14), we make the following conclusion.

PROPOSITION 2. Consider the setup of proposition 1 with negative externalities, and suppose that the political process follows the procedure of a menu auction. Then a quota (price) regime induces a larger level of political contributions if and only if $|\sigma/\eta s| < (>)\ 1$.

If the political process follows the procedure of a menu auction, then proposition 2 and part i of proposition 1 complete the main answers to the question of *prices or quantities:* ($a$) the comparative advantage of either of the regimes can be determined unambiguously for negative externalities; ($b$) with negative externalities, the condition for price regimes to be more efficient both in yielding resource allocation closer to the social optimum and in saving on

[9] Marginally and when contribution schedules are differentiable, all politically efficient equilibria are truthful: at points of tangency in fig. 1, producers under quota offer $\partial c/\partial q = \pi_q$; in a tax regime, they offer $\partial c/\partial t = q$. In both cases the marginal contribution is equal to the true value of an additional unit of the negotiated control.

political pressure and rewards is that $|\sigma/\eta s| < 1$; and ($c$) with positive externalities, the comparative efficiency of either of the regimes cannot be determined in general terms.

## VIII. Concluding Remarks

Government intervention invites political pressure, and a political environment affects the efficiency of the instruments of public regulation. Our principal findings were that conditions for preference of a tax or a quota regime can be identified for negative externalities, but not for positive effects, and that a regime with more efficient factor allocation will also have lower levels of political activity. Moreover, the comparative advantages of the control regime—always in terms of factor allocation and in many cases also in terms of political contributions—are the same for markedly different modes of political activity.[10]

Simplifying and clarifying, we chose to restrict the discussion to linear political influence structure. But the cost of political activity can increase, for example, when it becomes more and more difficult to mobilize demonstrators and other activists, and it can decrease when a large lobby is more effective than the sum of its members. Likewise, the marginal political influence may decrease with the amount of the political contributions or with the intensity of the demonstrations. Incorporating decreasing or increasing cost and influence, we have found elsewhere (not as yet reported) that allocation and contributions are determined simultaneously; more interesting for the purpose of the present analysis, the major findings of the paper are left intact and are not affected by the adoption of the simplifying assumptions. The robustness of the conclusions in the face of changes in structural assumptions and in the political mechanism augments our confidence in the generality of our findings.

The analysis can be expanded in several directions. An immediate extension would be to apply it to the external effects caused by a product and not a factor. Another would be to examine the finding that the conclusions are the same whether the industry has one lobby group or several. In a nonlinear structure, lobbies may compete, and one may be stronger than the others. A further possibility envisages that consumers and socially conscientious individuals—not only producers—may organize in influence groups and counterbalance, at least partly, the political pressure of the industrial lobbies. One may

[10] In a working paper version of this article (Finkelshtain and Kislev 1995), we considered also the Harsanyi-Zusman model of cooperative bargaining (Zusman 1976) and reached similar conclusions.

also consider the imposition of mixed control combining a binding quantity control with some level of taxes. In a preliminary analysis in this direction, we found that an optimal policy combination can be identified and that it is not always true that an increased reliance on prices, in a mixed regime, improves allocation efficiency. We hope to examine these and other possibilities in the future.

## References

Atkinson, Anthony B., and Stiglitz, Joseph E. *Lectures on Public Economics.* New York: McGraw-Hill, 1980.

Buchanan, James M., and Tullock, Gordon. "Polluters' Profits and Political Response: Direct Controls versus Taxes." *A.E.R.* 65 (March 1975): 139–47.

Coase, Ronald H. "The Problem of Social Cost." *J. Law and Econ.* 3 (October 1960): 1–44.

Cropper, Maureen L., and Oates, Wallace E. "Environmental Economics: A Survey." *J. Econ. Literature* 30 (June 1992): 675–740.

Finkelshtain, Israel, and Kislev, Yoav. "Prices *vs.* Quantities: The Political Perspective." Manuscript. Rehovot: Hebrew Univ., Dept. Agricultural Econ. and Management, 1995.

Fisher, Anthony C. *Resource and Environmental Economics.* Cambridge: Cambridge Univ. Press, 1981.

Grossman, Gene M., and Helpman, Elhanan. "Protection for Sale." *A.E.R.* 84 (September 1994): 833–50.

Hillman, Arye L. *The Political Economy of Protection.* Chur, Switz.: Harwood, 1989.

Nash, John F., Jr. "The Bargaining Problem." *Econometrica* 18 (April 1950): 155–62.

Peltzman, Sam. "Toward a More General Theory of Regulation." *J. Law and Econ.* 19 (August 1976): 211–40.

Rodrik, Dani. "Tariffs, Subsidies, and Welfare with Endogenous Policy." *J. Internat. Econ.* 21 (November 1986): 285–99.

Scarpa, Carlo. "Regulation as a Bargaining Process: Negotiation over Price and Cost-Reducing Investments." *Oxford Econ. Papers* 46 (July 1994): 357–65.

Weitzman, Martin L. "Prices *vs.* Quantities." *Rev. Econ. Studies* 41 (October 1974): 477–91.

Zusman, Pinhas. "The Incorporation and Measurement of Social Power in Economic Models." *Internat. Econ. Rev.* 17 (June 1976): 447–62.

# 12 Economic Regulation and Political Influence[1]

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## 1 INTRODUCTION

The purpose of this chapter is to discuss the effect of political pressure on economic regulation. In particular, we compare indirect regulation by prices to direct, administrative control of quantities. This is Martin Weitzman's (1974) comparison. However, while Weitzman contrasts controls where information is incomplete, we analyze the consequences of political influence. As a concrete example, we consider an industry employing a factor with external effects – negative or positive. (Drawing water from a shared source may create negative externalities and using reclaimed sewage for irrigation may have positive effects.) The government is attempting to regulate utilization of the factor and the producers react, trying to modify the implemented policy. The ensuing political equilibrium varies with the nature of the externalities and means of control.

The regulation regime may be either an administrative regime with quantity controls (enforcement is costless), or a price regime. Under the latter, taxes are imposed when the externalities are negative and subsidies are used, to encourage utilization of the regulated factor, when the effects are positive. By assumption, the regulation regime is determined 'constitutionally' and is not subject to the political debate (a similar assumption is made explicitly by Rodrik, 1986, in an analysis which resembles ours in several ways). The major question posed is: given political influence, when is regulation by prices the preferred regime and when is direct, quantity control more adequate? In this chapter we describe the problem and survey the findings. A rigorous mathematical analysis is presented elsewhere (Finkelshtain and Kislev, 1995).

## 2 THE SETTING

An industry with $N$ homogeneous producers is employing a single variable factor with external effects on the rest of the economy. The producers maximize profits and disregard the externalities they create. A planner, taking into account both the value of production in the industry and its effect on others, can determine socially optimal utilization of the externalities-inducing factor.

The role of the social planner is undertaken by the government, with one modification: politicians are sensitive to political pressure, to rent-seeking efforts. We model the pressure as contributions or rewards paid by the producers to the politicians. In this framework, rent-seeking lowers social welfare but creates a political surplus which is shared by the politicians and the producers. The magnitude of the political contributions determines the division of the surplus: the higher the rewards, the larger the share of the politicians and the smaller the share of the producers. The rewards may take many forms: monetary campaign contributions, outright bribes, demonstrations, strikes, letter-writing, and personal services. The political rewards may enhance welfare, the welfare of the politicians or even public welfare as when a constructor builds a school in return for a lucrative permit. Concentrating on political influence, we disregard the particular nature of the rewards and their wider implications.

One assumed characteristic of the producers–government polity which has significant implications for the analysis is linearity: the political rewards are in money or money-like contributions, they are of constant cost and effect. We do not consider the possibility that the cost of collecting political contributions is rising or that their effect may show diminishing returns.

The policy regimes – taxes, subsidies or quotas – have different and opposing income and budgetary effects. Concentrating on allocation, we put the alternative regimes on the same footing by introducing a lump-sum compensation payment which, by assumption, is introduced with the imposition of a regime. For example, the implementation of a tax regime is accompanied by a compensation equal to the computed equilibrium value of the tax and distributed to the producers as a side-payment; when the control shifts to a subsidy regime, the producers are asked to pay the lump-sum. Being a lump-sum payment, the compensation does not affect allocation – either the magnitude of the political rewards or employment of the variable factor. Such payments, which are here introduced as an analytical device, are observed in practice. For example, the government of Israel is now considering a reform in the country's water economy. Prices will rise to replace administrative allocation, farmers will be compensated. The compensation will be a function of the water quota a farmer has held, independent of future water utilization.

By construction, taxes and subsidies are uniform while quotas may be individually tailored. Consequently, free-riding can be expected in a price regime. Accordingly, we assume that only $K$ of the $N$ producers participate in the industry's lobby if prices are the instrument of control. The number $K$ is taken as exogenous; that is, the size of the lobby is accepted in the analysis as given. Under an administrative control, on the other hand, the government may assign each firm its social optimum employment of the regulated factor, producers can then be expected to lobby individually to modify personal quotas. Moreover, as firms are identical, if it pays one firm to invest in political activity, it is worthwhile for every other firm. Therefore, in a quota regime, full participation of all $N$ producers is part of the definition of a political equilibrium (to be further characterized below); is not an assumption of the analysis. Still, to emphasize the possibility of individual political activity, we keep the firm index $i$ in the presentation.

Formally, let net product, or profits – before taxes or subsidies – in the production activity of the $i$th producer be written as

$$\pi^i(q^i) = \rho f^i(q^i) - pq^i \tag{1}$$

In (1), $q$ marks the regulated factor; $q^i$ is the $i$th producer's utilization level of this factor; $\rho$ is the price of the industry's product; $f^i(q^i)$ is the production function with $q$ the only variable input; and $p$ is the private market price of the variable factor. By assumption, $\rho$ and $p$ are constant and so also prices of other, non-variable inputs are constant. It is also assumed that the function $\pi^i(q^i)$ is concave in $q^i$

Maximizing profits, the producers maximize $y$ in

$$y^i = \pi^i(q^i) - c^i - tq^i + R^i \tag{2}$$

The variable $t$ marks the tax; for a subsidy $t < 0$ and when the control is a quota, $t = 0$. The variable $c$ indicates political contributions. The compensation payment is $R$, equal to the equilibrium magnitude of $-tq$. With $N$ producers in the industry, total income, factor utilization and political rewards are given, respectively, by

$$Y = \sum_{i=1}^{N} y^i,\ Q = \sum_{i=1}^{N} q^i,\ \text{and } C = \sum_{i=1}^{N} c^i \tag{3}$$

If, under a price regime, $K < N$, $c^i$ may be zero for some values of $i$.

The second sector, the government, is viewed as maximizing the weighted sum

$$W = V(\mathbf{q}) + \alpha C \tag{4}$$

where $V(\mathbf{q})$ is social welfare defined over the vector $\mathbf{q} = q^1, \ldots , q^N$. The constant $\alpha > 0$ represents the preference of the government for political bribes relative to public welfare; it can also be seen as standing for the political power of the influence group in the industry. Lobbies in different industries may have different $\alpha$ values.

Welfare is taken to be the sum of net product and external effects. Accordingly, the function $V$ is written as

$$V(\mathbf{q}) = \sum_{i=1}^{N} p^{i}(q^{i}) + \sum_{j=1}^{M} m^{j}(Q) \tag{5}$$

where $\mu^j(Q)$ is the money-metric utility function of the $j$th consumer who is influenced by the external effects of the regulated factor. The function $\mu$ increases with $Q$ for positive externalities and decreases for negative effects. Utility is also defined over the vector of prices of consumption goods; but, assuming a small economy with all goods traded, prices are constant and they are not represented explicitly in the function. It is assumed that $\mu^j$ is concave in $Q$, and hence in each $q^i$. Similarly, since $V$ is the sum of concave functions (in each $q^i$), it is a concave function itself. All functions are second-order differentiable and interior solutions are assumed throughout.

Note that $c$ and $C$ enter linearly in (2) and (4). This reflects the linear nature of costs and effects in the political process and will simplify significantly the analysis below.

## 3 POLITICAL EQUILIBRIUM

As indicated, politicians in the government are willing to accept political contributions in return for economic favours. In our model the politicians are willing to lower taxes, raise subsidies or modify quotas. By the 'political process', we mean the particular interaction between the politicians and the interest groups attempting to influence them. The threat point of both sides to the political give and take is the social allocation with no rewards. This is the situation either side may retreat to if it is not satisfied with the outcome of the political process. The government can, by assumption, force social optimum; the producers may also decide to accept the social allocation and in so doing deprive the politicians of the rewards they desire.

A political process leads to a political equilibrium. The equilibrium in our model is characterized by a set of rewards and controls. Thus, under a price regime, the equilibrium is defined by a pair of values $C$ and $t$; under quota, the equilibrium is characterized by $C$ and a vector $\mathbf{q}$. The political equilibrium is process-specific. Several models of political processes have been suggested in the literature (example are Zusman, 1976; Rodrik, 1986; Hillman, 1989; Grossman and Helpman, 1994; Scarpa, 1994). We consider below two game theoretic models, a cooperative bargaining and a political auction. The political equilibrium of the bargaining model, for example, will be the Nash (1950) solution to a cooperative game.

Though often differing in many ways, most processes considered in the literature – including the games employed in the chapter – share a rather natural common property: they are politically efficient. Their equilibria lie on the contract curve where the indifference curves of the sides to the political process are at points of tangency. It will be convenient to rely on efficiency in the presentation below.

In principle, equilibrium political contributions and controls are determined simultaneously; but when, as we assume, the contributions are linear in cost and effect – the equilibrium configuration can be calculated recursively: the controls are set regardless of the level of the contributions (provided that no side chooses the threat point). These are identical levels of controls for all processes maintaining linearity and political efficiency; the particular model specifying the political process can then be seen as affecting only the division of the political surplus between the parties, between the producers and the politicians.[2] We therefore separate the presentation and start with the employment of the regulated factor and postpone the specification of the games and the determination of the political payments to Section 6.

## 4 FACTOR UTILIZATION

Relying on the linearity of the political process and its consequences, the derivation of the conditions specifying levels of controls and factor utilization is based in this section solely on efficiency of the political equilibrium; that is, on the equality of the marginal rate of substitution between the control and the political contribution for the producers with the corresponding rate for the politicians.[3] The equilibrium is indicated by tangency of social and private indifference curves in the $q$, $c$ plane, depicted in Figure 12.1 for negative externalities. The indifference curves in the figure are for a single producer and society, where for society it is assumed that all other producers are at equilibrium utilization of the factor $q$.

A private indifference curve is the graph of points of identical income; it is derived from (2) by changing $c$ and $q$, keeping $y$ constant. Accordingly, the curves are marked $y_1$ and $y_2$. As drawn, $y_1 < y_2$ as for each value of $q$, the political payment on $y_1$ is higher than on $y_2$. Similarly, the social indifference curves are constant $W$ graphs (4), marked $W_1$ and $W_2$, with $W_1 < W_2$.

Three levels of utilization are marked on the diagram: $q^w$ for social optimum, this is the utilization maximizing $V(\mathbf{q})$ in (5); $q^p$ for political

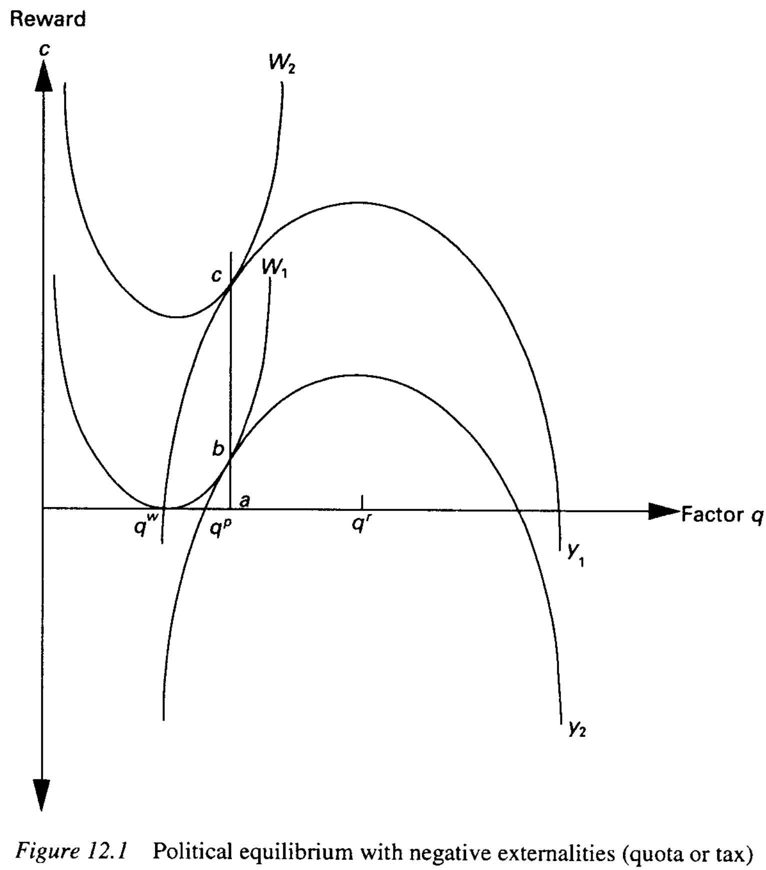


*Figure 12.1* Political equilibrium with negative externalities (quota or tax)

equilibrium, and $q^r$ for private, non-intervention, profit-maximizing level. The contract curve is the line extending from $q^p$; it being vertical reflects the property that the quantity of the regulated factor is the same for any level of the political reward. As Figure 12.1 indicates, when the externalities are negative, the political equilibrium employment of the regulated factor is a compromise between the social optimum and the no-intervention, private profit-maximizing employment of the factor. For negative externalities, the graphical configuration is the same for either a tax regime or a quota control and the political utilization is a compromise for both regimes (not necessarily the same quantity $q^p$). The situation will be different with positive externalities; but before considering positive effects, it is useful to view the equilibrium reached in terms of marginal magnitudes in panel a of Figure 12.2. In this diagram, $\pi_q$ marks private marginal profits,[4] while $V_q$ marks marginal social welfare (both termed marginal utility in the diagram). The political equilibrium for negative externalities is again seen to be a compromise in which private marginal profit is positive and social marginal welfare is negative.

The indifference curves $Y_1$ and $W_1$ in Figure 12.1 pass through the threat point $q^w$; the segment *bc* on the contract curve is the core of the political game. The segment *ab* indicates the amount the politicians have to receive to be kept on their reservation utility. It is the minimum political payment for the politicians to participate, to move from the socially optimal allocation to the political equilibrium.

Panels b and c in Figure 12.2 depict political equilibrium for positive externalities. Under a quota regime, equilibrium allocation is a compromise – as it is for negative effects – between the social and the private allocations. Under a price regime, on the other hand, the producers need not be forced to increase production; with subsidies they do it willingly and they further augment the price effect by pressing for even higher subsidies. As a result, the political equilibrium is not a compromise. In Figure 12.2, panel c, $q^p$ is to the right of both $q^r$ and $q^w$. Consequently, when externalities are positive and the control instrument is a subsidy, the political equilibrium may be socially inferior to the profit-maximizing allocation of a free market without government intervention.

## 5 PRICES OR QUANTITIES

The central question of this chapter is: when are prices the adequate instrument and when is a quantity control better? A control is preferable if it is relatively more efficient, it will therefore be useful to clarify the different

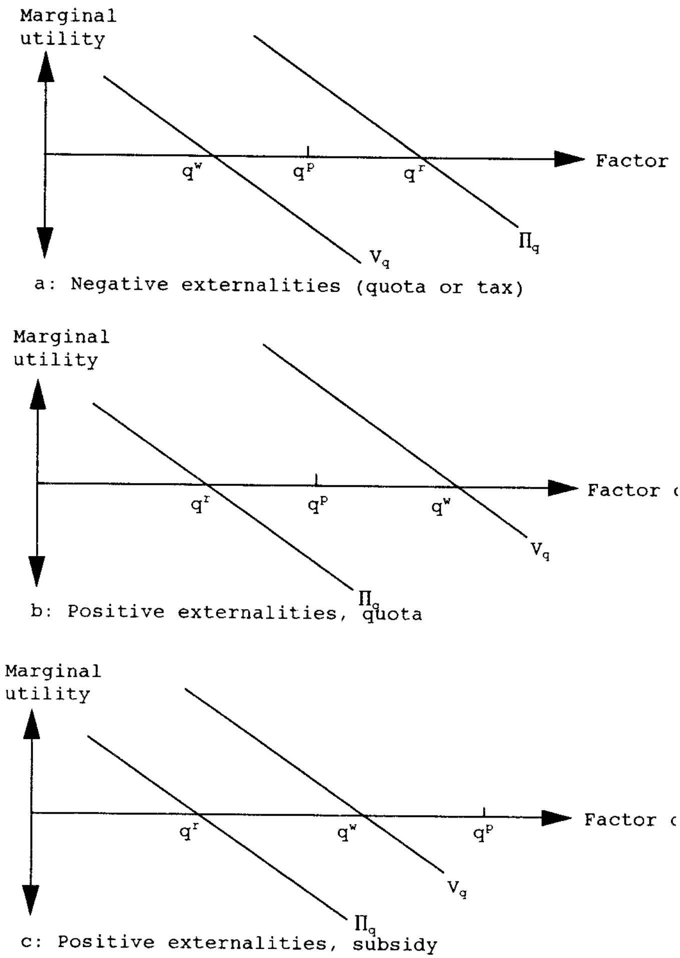


*Figure 12.2* Marginal welfare and marginal profits

dimensions of efficiency in the analysis. Political efficiency was defined in Section 4 as Pareto-efficiency of the polity: the producers and the politicians are on their contract curve. Allocative efficiency as used below for a political equilibrium is measured by the distance of the employment of the factor $q$ from social optimum utilization. The closer the employment, the more efficient the equilibrium. *S*-efficiency (for rent-*S*eeking) is defined by the size of the political reward: the smaller the reward, the more efficient the political equilibrium.

Since the political equilibrium may be computed recursively in two stages and it is, by construction, politically efficient, the two other dimensions of efficiency – allocative and *S*-efficiency – can also be examined separately. We start with allocative efficiency. Our findings are summarized in Proposition 1, in which the following symbols are used:

$\sigma = \dfrac{Q(K)}{Q(N)}$ the share of production by firms in the lobby under a price regime
$\eta$ = the elasticity of the demand for the factor $q$
$s = t/(p+t)$ the ratio of the tax to the producer price of $q$

**Proposition 1**

Consider political equilibria calculated for price regimes (either a tax or a subsidy) then,

(i) With negative externalities, a price control yields a more efficient allocation if and only if in equilibrium $|\frac{\sigma}{\eta s}| < 1$. A quantity control is more efficient when the inequality is reversed. The controls are equally efficient when $|\frac{\sigma}{\eta s}| = 1$.
(ii) Under both types of control, the efficiency of prices relative to quotas increases with the elasticity of the demand for the factor and decreases with the share of the producers organised in the industrial lobby.
(iii) Efficiency of both controls decreases with the political power of the producers, $\alpha$.
(iv) With positive externalities, a price control yields higher utilization of the factor $q$ than a quota regime. Efficiency comparison is inconclusive.

As indicated, a formal proof is given in Finkelshtain and Kislev (1995). We limit the present discussion to a few clarifying remarks and some interpretations and elaborations.

## 5.1 Remarks

The comparative advantage of a regime can be clearly identified only for negative externalities. When the external effects are positive, the equilibrium utilisations for the alternative regimes – quota and subsidy – are always 'far apart', one being a compromise and the other located to the right of the no-intervention profit-maximizing quantity (Figure 12.2). It is therefore impossible to find analytically conditions under which the regimes are equally efficient and conditions which characterize comparative efficiency of either of the controls. Given the necessary data for any particular situation, one can, of course, calculate the political equilibrium utilization for both regimes and compare their welfare implications.

Item (iii) in Proposition 1 could be expected intuitively: the more powerful the producers, the more they succeed in moving the political equilibrium closer to profit-maximizing allocation and further away from the social optimum.

Item (iv) is again a reflection of the differences in Panels b and c in Figure 12.2.

## 5.2 Demand Elasticity

The intuition behind the role played by the elasticity of the demand for the regulated factor in comparing allocative efficiency of the regimes in part (i) of Proposition 1 can be explained conveniently for the special case where $\sigma = 1$, $p = 0$, $s = 1$; that is, the industry consists of a single producer or of an all-embracing lobby, the factor can be acquired freely up to the designated amount under a quota regime, and the tax is the entire unit price under a price regime. For this situation, let $q_0$ in Figure 12.3 be an initial quantity, either determined by a quota or reached by the producers when the tax was set to $t_0$. Consider the rent-seeking effort that increases the quantity to $q_1$. Depending on the control, the change may be achieved by either an increase in the quota itself or by reducing the tax to $t_1$. The corresponding gain to the producers is

| | |
|---|---|
| Price regime | $A + B$ |
| Quota regime | $B + C$ |
| Difference | $A - C$ |

With unitary elasticity, $A = C$ and the difference vanishes, the regimes are equivalent at the margin. The returns to marginal political efforts of an equal quantitative effect are identical. Alternatively, if the factor demand is elastic, $A < C$, the returns under a price regime are smaller than under quota. Consequently, under a price regime, and with elastic demand, the political struggle will be relatively less intensive, and the equilibrium will be closer to the social optimum. Similarly, for Part (ii): the more elastic the demand function passing through $(q_0, t_0)$ the smaller the area $A + B$, and the less intensive the political struggle. In Figure 12.1, more elastic demand means smaller slopes of the producer's

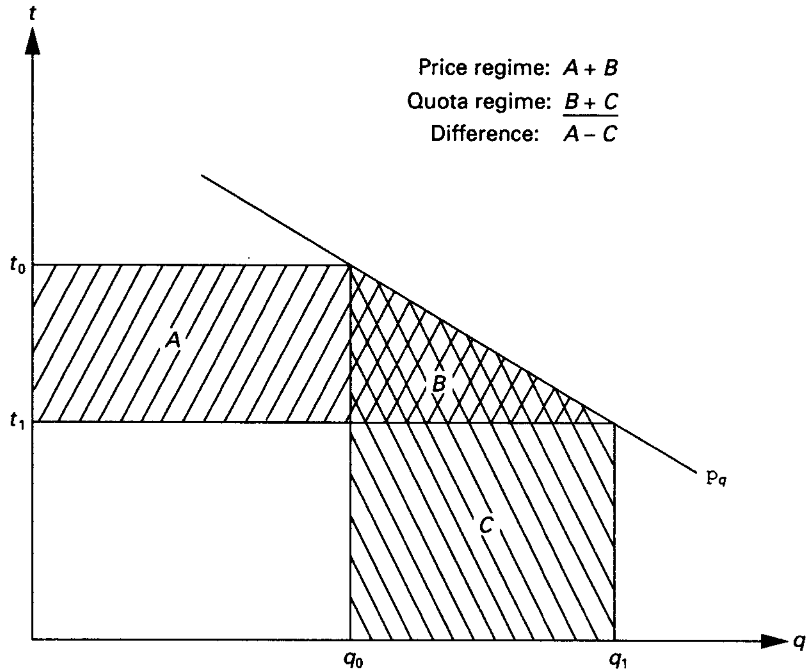


*Figure 12.3* Gain from political influence – prices v. quantities

indifference curves and a move of the political equilibrium employment to the left.

These findings may seem to contradict the established Ramsey–Boiteux tradition (Atkinson and Stiglitz, 1980) of optimal taxation by which the more elastic the demand (or supply) the more socially harmful an intervention in prices. The apparent contradiction is resolved by recognizing that when taxes are levied to raise revenue, optimal rates minimize the effect of the tax on resource allocation, while here the sole purpose of taxes is to modify use of resources so as to reduce the harming effects of the negative externalities.

## 5.3 Organization of Producers

With a single producer, $\sigma = 1$ and the difference between the control regimes is reflected only in the size of the product $s\eta$. It has been explained already that under quota all producers are politically active and the extent of their organization does not enter the analysis of the political equilibrium. Similarly, if in a tax regime all producers are organized in a lobby and operate in unison, $\sigma = 1$ and the number of producers or their organization does not affect equilibrium. But a price regime is conducive to free-riding.

The explanation for the importance of cooperation in determining the political equilibrium of an industry is simple and the situation is familiar to observers of administrative controls. With a quota, every producer is trying to increase his or her utilization of the controlled factor and so does a lobby arguing for its members. The political activists present convincing arguments aplenty. For the government it is relatively easy to yield to the pressure of a particular individual or lobby; the quantitative effect is relatively small. In a price regime with a uniform tax rate, on the other hand, the government is standing firmer – a concession to one producer or group is a concession to the whole industry. Consequently, the greater the amount of free-riding in a price regime, the stronger the comparative social advantage of this control. Similar considerations underlie Rodrik's (1986) analysis of trade regimes, though he views subsidies as firm-specific.

By conventional wisdom, heterogeneity of the production units argues in favour of price control as prices, being uniform, economize on information while, with heterogeneous producers, efficiency calls for unequal, individually-tailored quotas. This argument was qualified by Weitzman (1974), who noted that for iterative planning there is no significant information difference between a price and a quota regime. In a political environment, heterogeneity in production further affects equilibrium allocation as a more heterogeneous industry may tend to be more loosely organized and have a larger number of free-riders.

## 5.4 A Caveat

The intuitive interpretations, and indeed Proposition 1 and particularly its Part (i), should be accepted with care. The proposition is defined for the conditions of a political equilibrium. The equilibrium ratio $s$ is endogenously determined; the elasticity of the factor demand is also in general an endogenous magnitude. These variables are components of a political equilibrium. The proposition, as indicated, *characterizes* the equilibrium: if in equilibrium for a price regime (with negative externalities) $|\frac{\sigma}{\eta s}| < 1$, price control dominates. It may however happen that even for an elastic demand and a comparatively small lobby, the equilibrium value of $s$ will be so small that $|\frac{\sigma}{\eta s}| > 1$, and then a quota regime will be more efficient. The situation is simpler for an inelastic demand and $\sigma = 1$; it is then assured that $|\frac{1}{\eta s}| > 1$ and a quota control clearly dominates.

## 6 POLITICAL CONTRIBUTIONS

The derivation of the conditions specifying the allocation parameters – quotas, taxes, or subsidies – was based in the first stage of the calculation of equilibrium solely on the common property of political efficiency. The political contributions, and with them the division of the surplus between the producers and the politicians, depend on the particular characteristics of the political process. We have examined two alternative game formulations: the Harsanyi–Zusman model of cooperative bargaining (Zusman, 1976; Zusman and Amiad, 1977), the equilibrium of which is the Nash (1950) solution to the bargaining game, and Grossman and Helpman's (1994) model which employs the procedure of First Price Menu Auction. As before, the analysis is conducted under the assumption that all producers are members of a single industrial lobby and that in a price regime, some producers may not participate in the political activity. The analysis, for either model, determines the total industrial political contribution; the individual contributions by the producers in the industry are left to the lobby to set.

The two political games differ in the nature of their solution – in the equilibrium level of contributions. By the First Price Menu Auction, with a single lobby, as is the case analyzed here, the industry receives all the political surplus and the politicians are left on their reservation utility. In Figure 12.1, the politicians are given the segment *ab*. A Nash solution divides the surplus and the equilibrium corresponding to that solution will be located on the segment *bc* in Figure 12.1.

As with political allocation, equilibrium political rewards cannot be characterized unambiguously for positive externalities, the conclusions are limited to negative effects. The main findings of the analysis are summarized in Proposition 2 in which the control regimes are compared in terms of $S$-efficiency and a regime is relatively more efficient if it leads to smaller political contributions than the alternative control.

**Proposition 2**

With negative externalities,

(i) Both for a Nash solution of a cooperative bargaining game and for a First Price Menu Auction: if, in equilibrium under a tax control, $|\frac{\sigma}{\eta s}| < 1$, a quota regime induces a larger political contribution and a price regime is the more efficient control.

(ii) For a Nash solution, if $|\frac{\sigma}{\eta s}| > 1$, and $\sigma < 1$, a quota regime may yield a larger or smaller political contribution. The relative size of the political contribution in a First Price Menu Auction is not affected by the magnitude of $\alpha$.

The inequality condition in Proposition 2, part (i), is the same condition as for allocative superiority of a price regime in Proposition 1. The explanation being that with comparatively high allocative efficiency, $q^p$ is relatively close to $q^w$ and the compensation needed to keep the politicians on their reservation utility (the segment *ab* in Figure 12.1) is low. Hence the more efficient the allocation in the political equilibrium, the smaller the political contribution if the political process follows the procedure of the First Price Menu Auction. Also, the political surplus to be divided between the politicians and the producers is small when allocative efficiency is high, and so also the absolute contribution to the politicians is relatively small – whatever their share by the Nash solution to the bargaining game.

Part (ii) in Proposition 2 is a consequence of the fact that a small lobby, relative to the size of the industry, will often raise small amounts of political contributions. Hence, even if the sign condition indicates superiority of the quota regime (in terms of $S$-efficiency), it may still happen, in a particular case, that a price regime induces smaller contributions.

## 7 SUMMARY AND EXTENSIONS

The principal findings of the analysis are:

(a) The comparative advantage of one of the regimes can be characterized only for negative externalities. Then, if $|\frac{\sigma}{\eta_S}| < 1$, a price regime induces socially preferred allocation and relatively less intensive rent-seeking efforts.

(b) The political equilibria for negative or positive effects are not symmetric. With negative externalities, the producers struggle to increase quotas under administrative control and they attempt to reduce the tax when regulation relies on prices. The political influence – under both control regimes – results in increased employment of the regulated factor, compared to the social optimum utilization. With positive externalities, on the other hand, depending on the control regime, the producers attempt to reduce quotas or to increase the subsidy. The results are different, higher subsidies increase production.

(c) Consequently, when the effects are positive, subsidization with political influence may reduce welfare compared to a free market no-intervention situation.

(d) Political modification of a uniform price instrument – a tax or a subsidy – is a public good. Therefore, it can be expected that free-riding will erode the political power of the interest group in a price regime.

The conclusions of the analysis are not confined to the simplified framework of the chapter, of external effects associated with the use of a factor of production. They can be extended in several directions. For example, the conclusions apply, with obvious modifications, to external effects caused by a product or a service. Likewise, the analysis is not necessarily limited to externalities, it applies to any case of administrative intervention: of a national government, a municipality, or even the management of a corporation. Political activity is present in any organization in which groups can gather around common interests.

The political rewards are seen here as income transfers from the producers to the politicians. The analysis can be elaborated. Preliminary work we did indicated that the conclusions of the analysis do not change if the formulation of the model covers explicit utilization of real resources in rent seeking. Further, the analysis was made simple by assuming constant costs and effects in the political process. Experiments with increasing costs or decreasing effects yielded similar conclusions. These findings strengthened our confidence in the main lessons of the analysis presented in the chapter.

It is natural to expect political activity to be found only in industries with a specific fixed factor or where entry is limited, as free entry and open access to all factors may erode the achievements of the costly political struggle. We have therefore confined the analysis to an industry with a given number of producers. Still, one sometime observes intense political activity where entry is not successfully limited; several farm industries can be taken as examples. We hope to report in the future on an extension in this direction.

## Notes

1. We received useful comments and productive suggestions from Arye Hillman, Yair Mundlak, Martin Paldam, Norbert Wunner and Pinhas Zusman.
2. The rewards, $C$ and $c^i$, do not appear in the first-order conditions of the Nash solution determining either $t$ or $\mathbf{q}$, while the controls do appear in the equation determining the rewards.
3. The conditions characterizing efficient equilibrium are derived by maximizing $W$ in (4), with respect to the rewards and the controls (either $t$ or $\mathbf{q}$), subject to an arbitrary pre-assigned value of $Y$, total income in the industry.
4. Remember that $\pi(q^i)$ stands for profits before taxes or subsidies.

## References

Atkinson, A. B. and J. E. Stiglitz (1980) *Lectures on Public Economics* (New York: McGraw-Hill).

Coase, R. H. (1960) 'The Problem of Social Cost', *Journal of Law and Economics*, vol. 3, no. 1, pp. 1–44.

Finkelshtain, I. and Y. Kislev (1995) 'Prices vs Quantities: The Political Perspective', *Working Paper*, 9508, The Center for Agricultural Economic Research, Rehovot, Israel.

Grossman, G. M. and E. Helpman (1994) 'Protection for Sale', *American Economic Review*, vol. 84, no. 4, pp. 833–50.

Hillman, A. L. (1989) *The Political Economy of Protection* (Chur: Harwood).

Nash, J., Jr (1950) 'The Bargaining Problem', *Econometrica*, vol. 18, no. 1, pp. 155–62.

Rodrik, D. (1986) 'Tariffs, Subsidies, and Welfare with Endogenous Policy', *Journal of International Economics*, vol. 21, pp. 285–99.

Scarpa, C. (1994) 'Regulation as a Bargaining Process: Negotiation Over Price and Cost Reducing Investments', *Oxford Economic Papers*, vol. 46, no. 3, pp. 357–65.

Weitzman, M. L. (1974) 'Prices vs Quantities', *Review of Economic Studies*, vol. 41, no. 4, pp. 477–91.

Zusman, P. (1976) 'The Incorporation and Measurement of Social Power in Economic Models', *International Economic Review*, vol. 17, no. 2, 447–62.

Zusman, P. and A. Amiad (1977) 'A Quantitative Investigation of a Political Economy – The Israeli Dairy Program', *American Journal of Agricultural Economics*, vol. 59, no. 1, pp. 88–98.

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# Taxes and subsidies in a polluting and politically powerful industry

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In memory of Professor D. Gale Johnson

**Abstract**

This paper analyzes the effect of political pressure on taxes and subsidies in a polluting industry. Two innovations are offered: (a) The model of the analysis is simple; it is based on profit maximization, the participation constraint, and that politicians are willingly influenced. No additional structure is assumed. (b) It is shown that the conventional conclusion that, as pollution controls, taxes and subsidies are equivalent, does not hold in the presence of political pressure—both in short-run and in the long-run. In addition, production is generally not efficient in a political equilibrium and costs are not minimized.


*JEL classification:* D78; H23

*Keywords:* Pigovian taxes; Subsidies; Lobbies; Political equilibrium

A great believer in free markets, D. Gale Johnson devoted his long professional career to the study of the effect of public policies on prices, production and welfare in agriculture. World Agriculture in Disarray (1991) is still a must reading for anyone interested in farm policies and their intended and unintended effects on farmers, consumers, and taxpayers—in industrial as well in developing countries. We hope that the analysis of policy formation in the presence of politically powerful groups, offered in this paper, contributes to the clarification of issues that were in the center of Professor Johnson's interest.

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## 1. Introduction and summary

In this paper we examine regulations implemented to reduce pollution in a competitive but politically powerful industry. Agriculture can serve as an immediate example. The paper has three messages. The first two deal with contents: (a) the symmetry of the effects of taxes and subsidies breaks down, even in the short-run, in the presence of political pressure; (b) production is inefficient (it is not at minimum AC) both in the short- and long-run. The third message concerns method: an analysis of the political economy can rely solely on general assumptions of individual rationality; in particular, on what game theorists term the participation constraint. It is not necessary to formulate a detailed model with stronger assumptions in order to reach our conclusions.[1]

It is an established finding of analysis, relying on marginal economic principles, that a socially optimal level of pollution can be achieved by either a tax per unit of discharge or a subsidy per unit of reduced emission (for a survey and references, see Cropper & Oats, 1992). The symmetry of the two control instruments was, however, criticized on several grounds, the most common being the marked difference in their long-run effects.

A series of studies focused on endogenous (long-run) entry (e.g., Kamien, Schwartz, & Dolbear, 1966; Kohn, 1985; Polinsky, 1979). The general conclusion that emerged was that a tax regime is more efficient than a subsidy, since it yields fewer active firms, smaller pollution levels and lower production costs. Moreover, several studies have shown that, with subsidies and in the long-run, pollution may be greater than its free market, non-intervention level. Fisher (1981) pointed out incentives of strategic behavior: firms could increase pollution in anticipation of future subsidies.

Although the main criticism of the symmetric effects of taxes and subsidies focused on the long-run, some authors questioned its short-run validity. For example, Just and Zilberman (1979) showed that, with uncertain externalities, subsidies decrease risk of pollution, while under a tax regime, pollution reduction depends on additional restrictions on the structure of risk preference. Differences in income and profits were the principal sources of asymmetry in the effects of the alternative regimes in the last study as well as in those quoted earlier.

More often than not, government intervention, even if well intended, induces lobbying and political pressure. Interest groups organize in order to modify policies: either to fend-off threats or to exploit opportunities. This paper shows that—even with full information, no strategic behavior, and predetermined industry size—the political equilibrium with taxes and subsidies is asymmetric. In the short-run, a tax regime leads to over-production of the polluting good, while with subsidies, too little is produced.

Our analysis of the political economy shows, further, that asymmetry of controls also prevails in the long-run. Taxation reduces output and pollution, while subsidization increases them. Except for one special case, production is not efficient under both regimes: with taxes, firms produce more than the cost minimizing quantity, while with subsidies, they produce less than this amount. The upshot is that, contrary to the professional

[1] Elsewhere (Finkelshtain & Kislev, 1997) we demonstrate asymmetry in a general equilibrium analysis conducted in a more structured model.

conventional wisdom, in the presence of political pressure, a tax regime may be inferior both to a non-intervention, free market equilibrium and to a subsidy regime.

## 2. The economy and the environment

There are $N$ identical polluting firms in a competitive industry. The producers disregard negative externalities associated with their activities. We study the consequences of regulation in this industry in the short-run, when $N$ is given, and in the long-run, when $N$ is endogenous and determined as part of the political-economic equilibrium. Several simplifying assumptions are adopted: (1) the analysis is of partial equilibrium, focusing on the industry and its regulation; (2) firms are identical; (3) pollution is proportional to output, $q$, with a proportionality coefficient $e$; (4) the polluting sector, assumed to be small and competitive in the input market, faces constant input prices; (5) the cost function, $c(q)$, increases and the long-run average cost is U-shaped; (6) all functions are second-order differentiable and interior solutions are assumed throughout.

Social welfare is measured as total economic surplus

$$V(Q,N) = \int_0^Q p(z)\mathrm{d}z - Nc\left(\frac{Q}{N}\right) - eQ, \tag{1}$$

where $p(\ )$ is the decreasing inverse demand function for the product, defined over total industry output, $Q = Nq$.

## 3. The political economy

The government, aiming at pollution control, chooses a regulation instrument, either a tax or a subsidy. Once an instrument was chosen, producers endeavor to affect the ensuing policy but, by assumption, the choice itself is not subject to political debate and influence.

### 3.1. The polity

Each producer in the regulated industry contributes the sum $r$ (dollars per year) as a political reward. The rewards may take the form of aid in campaigns, demonstrations, letter writing, or even outright bribes. We assume that the producers understand the significance of the political activity; free riding is not practiced. The politicians, accepting the rewards, are ready to modify regulation policies. Accordingly, the politicians are seen as maximizing $W$ in

$$W = W(V,R), \tag{2}$$

where $V$ is defined in (1) and $R = \sum r = Nr$ is the sum of the political contributions in the regulated industry.

By (2), the politicians are interested only in the total sum, $R$, contributed by the industry; its distribution among the producers makes no difference. However, as indicated, we assume that firms are identical and each producer contributes the same $r$. One special case deserves attention: sometimes industries, collecting political contributions, impose levies in proportion to output, $r = \rho q$. It will be shown in the following that this proportionality modifies one of the conditions of the long-run political equilibrium.[2]

Long-run equilibrium in a competitive industry is characterized by zero profits. However, at any point in time, firms own tangible and intangible productive assets the returns to which they maximize. As part of their activities, producers are ready to contribute to political causes—whether they realize or do not realize the long-run zero profit destiny of the industry.

The producers in the industry attempt to maximize profits while the politicians (the government) strive to maximize their own welfare *W*. The parties are seen as striking a deal, trading regulation reforms against political rewards. The details of the deal are not specified, but it is assumed that the social optimum [the set of policies maximizing (1)] is the threat-point of the political game: if the producers do not keep their part of the bargain, the government is powerful enough to force a tax or subsidy maximizing social welfare. The producers may also threaten to accept the welfare-maximizing instrument and deprive the politicians of the desired reward *R*.

### 3.2. Rational participation

Two groups of models have been applied to the study of policy formation in the presence of political activity. The first employs explicit game formulation; examples are Zusman (1976) using a Nash (1950) cooperative bargaining game and Grossman and Helpman (1994) who model the political process as a non-cooperative auction game. Fredrikson (1997) applies Grossman and Helpman's model to study pollution taxes in an open economy. Peltzman (1976) and Hillman (1989) belong to the second group. In their work, the government is viewed as setting policy parameters in order to maximize a political support function that trades the welfare of voters with divergent interests.

Individual rationality is an integral part of all game-theoretic models, both cooperative and non-cooperative. Actors will not take part in a game unless their reservation utility is maintained. This axiomatic prerequisite, that the utility of joining a game must be at least as great as the opportunity foregone, is incorporated in formal models as the participation constraint. A similar rationality assumption can also be attributed to models in the second group of studies, although generally individual behavior is not part of their explicit formulation.

In the analysis to follow, individuals or firms may form lobbies and invest financial or other resources to influence political decisions. Apart from profit maximization, the only behavioral assumption is that the producers are politically active only if the participation constraint is satisfied; a more detailed behavioral structure is not assumed. Consequently, the conclusions do not rely on any particular form of the political process. Simplicity and generality are convenient and powerful attributes of a theoretical analysis but, needless to say, they limit the scope of the issues considered. We shall comment on limitations in the conclusion of the paper.

[2] We are indebted to Ayal Kimhi for this insight.

## 4. Short-run equilibrium

This section is devoted to a description of short-run industrial equilibrium, where the number of firms is given, $\bar{N}$. Denote the profit of the typical firm by $\pi = pq - c(q)$, and mark by a superscript *pr* free market, non-intervention variables. Accordingly, in the absence of intervention, the profit maximizing output of a single firm is

$$q^{pr} = \arg\max_{q \geq 0}[pq - c(q)], \tag{3}$$

yielding the short-run equilibrium condition:

$$p^{pr}(\bar{N}q^{pr}) - c'(q^{pr}) = 0. \tag{4}$$

With pollution, the equilibrium defined by (3) and (4), though profit maximizing, is socially not optimal. We turn therefore to welfare maximization and continue with the incorporation of political pressure and the demonstration of the asymmetric effects of the control instruments.

### 4.1. Welfare maximization

In the short-run, socially optimal, welfare maximizing output, $Q^{\mathrm{w}}$, is

$$Q^{\mathrm{w}} = \arg\max_{Q \geq 0}[V(Q, \bar{N})], \tag{5}$$

with the first-order condition:

$$p(Q^{\mathrm{w}}) = c'\left(\frac{Q^{\mathrm{w}}}{\bar{N}}\right) + e. \tag{6}$$

Production by (6) is lower than by (4); namely, for the industry $Q^{\mathrm{w}} \leq Q^{pr} = \bar{N}q^{pr}$ and at the firm $q^{\mathrm{w}} \leq q^{pr}$. This motivates government intervention.

The government may use either of two alternative instruments of intervention. First, it may levy a per-unit tax, $t$, on production; namely, a firm producing under a tax regime $q^t$ units of output, pays taxes to the amount $tq^t$. Second, the government may subsidize a reduction in the production of each firm below some predetermined level, $\bar{q}$. In this case, the typical firm is paid a subsidy of $s(\bar{q} - q^s)$.[3]

The implementation of the control regimes modifies the private first-order conditions and it becomes

$$p(\bar{N}q^t) - c'(q^t) = t \text{ and } p(\bar{N}q^s) - c'(q^s) = s. \tag{7}$$

In the absence of political pressure, the government takes into consideration condition (7) and sets per unit tax or subsidy to maximize $V$. The first-order conditions for the choice of $t$ and $s$ are, respectively,

$$\frac{\partial V}{\partial t} = \bar{N}(p(\bar{N}q^t) - c'(q^t) - e)\frac{\partial q^t}{\partial t} = 0, \tag{8}$$

[3] If $\bar{q}$ is too small, firms may give up the subsidy rather than lose income. We shall therefore assume, for simplicity, that $\bar{q}$ is set at minimum AC.

and

$$\frac{\partial V}{\partial s} = \bar{N}(p(\bar{N}q^s) - c'(q^s) - e)\frac{\partial q^s}{\partial s} = 0. \tag{9}$$

Since $\partial q^t/\partial t < 0$ and $\partial q^s/\partial s < 0$, the expressions $(p - c'(q^t) - e)$ and $(p - c'(q^s) - e)$ must vanish and, comparing with (7), it is seen that the control measures are set at $t = s = e$, yielding $q^t = q^s = q^{\mathrm{w}}$. At these levels of production, pollution will be socially optimal in the short-run—with a given number of producers—although production may be inefficient: if, before the imposition of the control, firms were at minimum AC, they produce with government intervention at lower $q$ levels.

### 4.2. Asymmetry of political effects

Proposition 1 characterizes short-run political equilibrium.

**Proposition 1**. *Consider the regulation of a polluting and politically powerful industry with a predetermined number of firms. Then*:

(i) *Under a tax regime*, $0 < t < e$ *and*, *therefore*, *equilibrium production and pollution exceed the socially optimal levels but fall short of the free market*, *non-intervention levels*;

(ii) *Under a subsidy regime*, $0 \leq e < s$ *and*, *therefore, equilibrium production and pollution fall short of both the free market*, *non-intervention levels and the social optimum*.

**Proof**. In a political equilibrium, under a tax regime, satisfaction of the participation constraint implies

$$p^t q^t - c(q^t) - tq^t - r > p^t \hat{q} - c(\hat{q}^t) - e\hat{q}^t, \tag{10}$$

where $\hat{q}^t = c'^{-1}(p^t - e)$ and the right hand side of (10) is the threat-point of the political game. Note that $\hat{q}$ maximizes profits when the market price is $p^t$ and the tax is $e$ and, also, at the threat-point the reward $r = 0$. By (10), the perceived net profit at the threat-point should not exceed profits at the political equilibrium.[4] The calculation, at the threat-point, of profits for the price prevailing when the instrument $t$ is implemented, is a reflection of the myopic outlook of the producers who do not comprehend fully the market equilibrium that will prevail if their threat ever materializes.[5]From $\hat{q}^t$ being profit maximizing, it follows that

$$p^t q^t - c(q^t) - eq^t < p^t \hat{q}^t - c(\hat{q}^t) - e\hat{q}^t. \tag{11}$$

[4] Formally, (10) could be written as a weak inequality; however, if equality prevails, the participation constraint is barely satisfied but producers still have to invest in lobbying activity. In most cases, they will prefer the threat point, $t = e$ and $r = 0$. We therefore wrote (10) as a strict inequality.

[5] Note that if the producers do comprehend the equilibrium condition, then they understand that the realization of the treat-point ($t = e$) will raise prices above $p^t$. However, the inequality in (10) will remain valid.

Combining Eqs. (10) and (11) we find $(e-t)q^t - r > 0$ and, as $r \geq 0$, and $t \geq 0$, $0 \leq t < e$, as proposed. With $t$ between 0 and $e$, $Q^w < Q^t \leq Q^{pr}$. Similarly for subsidies, the participation condition is

$$p^s q^s - c(q^s) + s(\bar{q} - q^s) - r > p^s \hat{q}^s - c(\hat{q}^s) + e(\bar{q} - q^s), \tag{12}$$

here $\hat{q}^s = c'^{-1}(p^s - e)$. Now, replacing the right hand side of (12) by $p^s q^s - c(q^s) + e(\bar{q} - q^s)$ it is seen that $(s-e)(\bar{q} - q^s) - r > 0$. Since $(\bar{q} - q^s) \geq 0$, it follows that $s > e \geq 0$, as proposed.

By Proposition 1, under a tax control, the political equilibrium is a compromise, with production between free market and the socially desired level. A subsidy regime, on the other hand, induces too little production and ''too little'' pollution. The intuitive explanation is simple. Under taxes, the political pressure is to reduce the tax; while with subsidies, it is to increase the subsidy, up to and above the social optimum. (Political pressure may eliminate a tax altogether or even turn it into a subsidy. We are not considering these possibilities here.)

A Pigovian tax, being a compromise, even if modified by interest groups, is welfare enhancing. Not always so under a subsidy; with political pressure, a subsidy—being too high—may reduce welfare relative to non-intervention equilibrium. The situation is even more ambiguous, since both taxes and subsidies are not optimal and they operate in opposite directions, welfare loss under a subsidy regime may be smaller than under a tax.

## 5. The long-run

In the long-run, the number of firms in the industry, $N$, as well as the tax or the subsidy, are endogenously determined, affecting both pollution and intra-firm production efficiency. As indicated in the Section 1 of the paper, it has already been established that, in the long-run, pollution reducing subsidies cannot improve welfare. For completion, we repeat this finding and then show what equilibrium is reached if the government—despite the theoretical admonitions—opts for subsidies and the regulated industry is politically powerful.

### 5.1. Welfare maximization in the long-run

Optimal, welfare maximizing, industrial output and number of firms are

$$(Q^w, N^w) = \arg\max_{Q,N \geq 0} [V(Q, N)], \tag{13}$$

maintaining the first-order conditions:

$$p(Nq) = c'(q) + e, \tag{14}$$

$$\frac{c(q)}{q} = c'(q). \tag{15}$$

Eq. (15) is the familiar long-run condition of minimum average cost. The competitive non-intervention equilibrium is characterized by (15) and $p(Q) = c'(q)$, which leads to over-production of the polluting good. The government may then levy a tax or offer a subsidy. The conditions of the ensuing long-run equilibrium at the firm level are now presented in pairs, for taxes and subsidies,

$$p = c'(q^t) + t \qquad p = c'(q^s) + s, \tag{16}$$

$$p = \frac{c(q^t)}{q^t} + t \qquad p = \frac{c(q^s) - s\bar{q}}{q^s} + s, \tag{17}$$

from which we get

$$\frac{c(q^t)}{q^t} = c'(q^t) \qquad \frac{c(q^s) - s\bar{q}}{q^s} = c'(q^s). \tag{18}$$

A comparative static analysis of the effect of a tax and a subsidy on output and the number of firms is detailed in the Appendix A. It yields the following signed derivatives

$$\frac{\mathrm{d}q}{\mathrm{d}t} = 0, \qquad \frac{\mathrm{d}q}{\mathrm{d}s} < 0, \tag{19}$$

$$\frac{\mathrm{d}N}{\mathrm{d}t} < 0, \qquad \frac{\mathrm{d}N}{\mathrm{d}s} > 0, \tag{20}$$

and

$$\frac{\mathrm{d}Q}{\mathrm{d}t} < 0, \qquad \frac{\mathrm{d}Q}{\mathrm{d}s} > 0. \tag{21}$$

As Eqs. (19)–(21) exhibit, with subsidies and in the long-run, firm production is less than non-intervention output, the number of firms is greater and total production of the industry also increases. Thus, efficiency is impaired and pollution increases. A rational government will not choose subsidy as a pollution-regulating instrument (an optimum subsidy cannot be found mathematically). Under a tax regime, as the signs indicate, intervention does not impair intra-firm efficiency and it reduces total output and pollution.

Fig. 1 depicts average and marginal cost. AC and MC are for a free market situation. $\mathrm{AC}^e$ and $\mathrm{MC}^e$ in the tax panel are the graphs of the cost functions when a tax $t = e$ is imposed. Production stays at $q^0$ (min AC). Parallel graphs are not shown in the subsidy panel since, as indicated, equating $s = e$ does not set an optimum subsidy for the long-run. The graphs $\mathrm{MC}^t$ and $\mathrm{MC}^s$ and the corresponding average cost curves represent political equilibrium and are introduced in the following.

We show now that under a tax regime, the optimal policy is, as in the short-run, to set $t = e$. Maximizing (13), the first-order condition can be written as

$$V_Q \frac{\partial Q}{\partial t} + V_N \frac{\partial N}{\partial t} = 0. \tag{22}$$

Inserting the comparative static derivatives from the Appendix A and recalling (15), one gets

$$V_Q \frac{1}{p'} + V_N \frac{1}{qp'} = \frac{1}{p'} \left\{ p(Q) - c'\left(\frac{Q}{N}\right) - e - \frac{1}{q}\left[c\left(\frac{Q}{N}\right) + qc'\left(\frac{Q}{N}\right)\right] \right\} = 0 \Rightarrow p = c' + e. \tag{23}$$

That is, $t = e$ maximizes welfare. We turn now to the political equilibria.

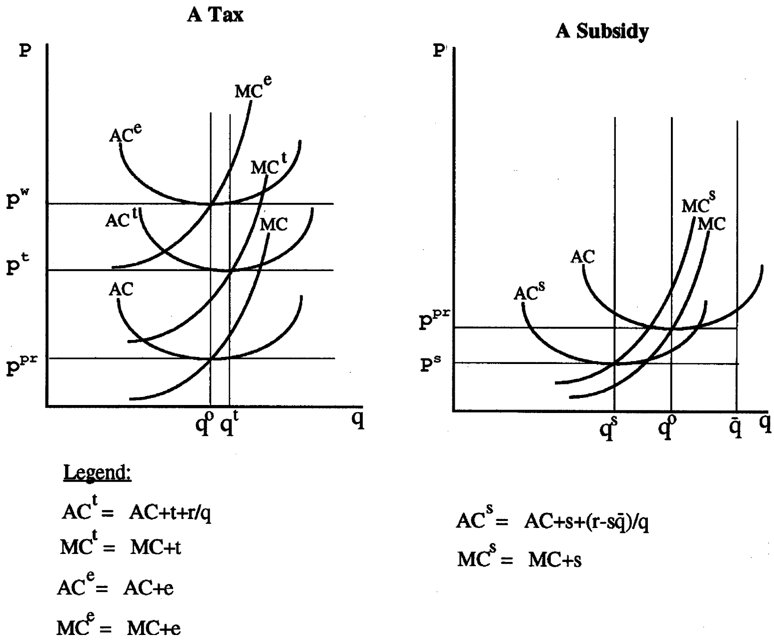


Fig. 1. Long-run equilibrium.

### 5.2. *Asymmetry of political equilibria in the long-run*

Proposition 2 characterizes the long-run political equilibrium for both a tax and a subsidy regime. Before presenting the proposition, we introduce the notations:

$$Q^{\mathrm{w}} = N \arg\min_{q} \left[\frac{c(q) + eq}{q}\right], \tag{24}$$

$$q^0 = \arg\min_{q} \left[\frac{c(q)}{q}\right]. \tag{25}$$

to mark the socially optimal and efficient, long-run output of the regulated industry and the firms in the industry.

**Proposition 2**. *Consider the regulation of a polluting and politically powerful industry. The political long-run equilibrium is characterized by*:

(i) *Under a tax regime, production and pollution form a compromise between the corresponding socially optimal and the free market, non-intervention level; that is,* $Q^{\mathrm{w}} < Q^t < Q^{pr}$.

(ii) *Under a subsidy regime, production and pollution exceed the free market, non-intervention level; namely,* $Q^s > Q^{pr} > Q^{\mathrm{w}}$.

(iii) *Except for the special case of proportional contributions* ($r = \rho q$), *under both regimes, cost of production is not minimized. With taxes,* $q^t > q^0$, *under a subsidy regime,* $q^s < q^0$.

(iv) *When* $r = \rho q$, *then under a tax regime*, $q$ *is optimal*, $q^t = q^0$.
(v) *Under a tax (subsidy) regime*, *the per-unit tax (subsidy) is smaller (larger) than the per-unit pollution coefficient*, $t < e\,(s > e)$.

**Proof**. To prove that $Q^t < Q^{pr}$, we show that $p^t > p^{pr}$. From the long-run and zero profit condition, we have

$$p^t = \min_q \frac{c(q) + r + tq}{q} \tag{26}$$

and

$$p^{pr} = \min_q \frac{c(q)}{q} \tag{27}$$

Recall now that at the threat-point $t = e$ and $r = 0$, in a political equilibrium, $t < e$, $r > 0$ (the last inequality may be termed the participation constraint of the politicians). In both cases $r + tq > 0$, yielding $p^t > p^{pr}$; as required.

To prove that $Q^t > Q^{\mathrm{w}}$, we show that $p^t < p^{\mathrm{w}} = p(Q^{\mathrm{w}})$. Write

$$p^{\mathrm{w}} = \min_q \frac{c(q) + eq}{q} = \frac{c(q^{\mathrm{w}}) + eq^{\mathrm{w}}}{q^{\mathrm{w}}}, \tag{28}$$

where $q^{\mathrm{w}}$ minimizes $(c(q) + e)/q$. Turn now to the participation constraint. By (26), the left-hand-side of (10) is zero and, therefore, the right-hand-side is negative. So also, if $\hat{q}$ is replaced by $q^{\mathrm{w}}, p^t q^{\mathrm{w}} - c(q^{\mathrm{w}}) - eq^{\mathrm{w}} < 0$. Rewriting,

$$p^t < \frac{c(q^{\mathrm{w}}) + eq^{\mathrm{w}}}{q^{\mathrm{w}}} = p^{\mathrm{w}}. \tag{29}$$

This completes the proof of (i).

To prove (ii), we show that $p^s < p^{pr}$. Write

$$\begin{aligned} p^s &= \min_q \left[\frac{c(q) - s(\bar{q} - q) + r}{q}\right] \leq \min_q \left[\frac{c(q)}{q}\right] + \min_q \left[\frac{r - s(\bar{q} - q)}{q}\right] \\ &= p^{pr} + \min_q \left[\frac{r - s(\bar{q} - q)}{q}\right]. \end{aligned} \tag{30}$$

It was shown following (12) that$s(\bar{q} - q^s) - r > e(\bar{q} - q^s) > 0$. Hence

$$\min_q \left[\frac{r - s(\bar{q} - q)}{q}\right] < 0. \tag{31}$$

Substituting into (30), the proof of (ii) is completed.

To prove (iii) for a tax regime where $r$ is not proportional to output, note in Fig. 1, the marginal cost that the firm faces, $\mathrm{MC}^t$, is higher than MC; that is for every $q$, $\mathrm{MC}^t = \mathrm{MC} + t$. The difference in average cost is larger, $\mathrm{AC}^t = \mathrm{AC} + t + r/q$. Consequently, production is to the right of min AC.

Under a subsidy, $\mathrm{MC}^s = \mathrm{MC} - s$; $\mathrm{MC}^s$ is lower than MC. For average cost, $\mathrm{AC}^s = \mathrm{AC} + [r - s(\bar{q} - q)]/q = \mathrm{AC} - s + (r - s\bar{q})/q$. We have already seen that $r - s(\bar{q} - q)] < 0$.

Hence $AC^s$ is also lower that AC, but the difference is larger than for marginal cost. Production, in Fig. 1, is to the left of min AC.For (iv), note that if $r = \rho q$, in Fig. 1, $AC^t = AC + t + \rho$ and also $MC^t = MC + t + \rho$. Hence average and marginal cost rise equally and $q^t = q^0$.

Finally, (v) was proved to hold for the short-run and similarly, it can be shown to hold for the long-run.

Several aspects of the proposition deserve attention. First, in the presence of political pressure, government intervention, in an economy with external effects, may reduce welfare. This is true both for a tax and a subsidy regime. Second, unlike intervention in a non-political world, production under a tax regime is inefficient, taxes may reduce welfare, and may even be dominated by a subsidy control. Third, as in a non-political world, in the long-run, a subsidy regime always increases pollution and production costs and reduces welfare in comparison with free market equilibrium.

## 6. Concluding remarks

It was shown in the paper that political pressure affects the efficiency of regulation and production, both in the short-run and the long-run. Considering the reality of political influence, the only surviving conclusions of the normative, politically free analysis is that taxes improve welfare in the short-run and subsidies reduce it in the long-run. Neither control assures socially optimal production and pollution when producers are politically active and politicians are willingly influenced. Moreover, the alternative controls, taxes or subsidies, can only be ranked if specific behavioral functions and magnitudes are known. Relying on the elementary assumption, that the participation constraint is satisfied in the political equilibrium, we could complete the qualitative analysis and show the directions by which political pressure modifies welfare enhancing policies. Nevertheless, weak assumptions limit the scope of the analysis. As an example, the analysis in the paper could not determine the magnitude of the political contributions in equilibrium, not even the relative magnitude of the contributions associated with taxes compared with the rewards agreed upon under subsidies. More detailed and explicit formulation is required to answer such questions. Similarly, a complete analysis of the effect of the sometime suggested policy that taxes be imposed only on incremental production, on output above a certain preset threshold, could not be conducted with the structural assumptions in this paper. These shortcomings are the costs of simplicity, generality and robustness.

## Appendix A. Comparative statics

Rewrite (16) and (17)

$$p(Nq^t) - c'(q^t) = t \qquad p(Nq^s) - c'(q^s) = s \tag{A.1}$$

$$p(Nq^t) - \frac{c(q^t)}{q^t} = t \qquad p(Nq^s) - \frac{c(q^s)}{q^s} = s\left(1 - \frac{\bar{q}}{q^s}\right). \tag{A.2}$$

In the analysis, the variables $q$, $N$ and $Q$ are taken as endogenous while $t$ and $s$ are considered exogenous parameter. For the tax and subsidy cases, and $t = s = 0$, where Eq. (15) holds:

$$\begin{bmatrix} Np' - c'' & qp' \\ Np' & qp' \end{bmatrix} \begin{bmatrix} \dfrac{dq}{dt} \\ \dfrac{dN}{dt} \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \end{bmatrix} \tag{A.3}$$

$$\begin{bmatrix} Np' - c'' & qp' \\ Np' & qp' \end{bmatrix} \begin{bmatrix} \dfrac{dq}{ds} \\ \dfrac{dN}{ds} \end{bmatrix} = \begin{bmatrix} 1 \\ 1 - \dfrac{\bar{q}}{q^s} \end{bmatrix} \tag{A.4}$$

Employing Cramer's rule, condition (A.3) and (A.4) yield:

$$\frac{dq}{dt} = 0, \qquad \frac{dq}{ds} = -\frac{\bar{q}}{qc''} < 0, \tag{A.5}$$

$$\frac{dN}{dt} = \frac{1}{qp'} < 0, \qquad \frac{dN}{ds} = \frac{1}{q^2}\left(\frac{N\bar{q}}{c''} - \frac{\bar{q} - q}{p'}\right) > 0, \tag{A.6}$$

and

$$\frac{dQ}{dt} = \frac{1}{p'} < 0, \qquad \frac{dQ}{ds} = \frac{q - \bar{q}}{qp'} > 0. \tag{A.7}$$

## References

Cropper, M. L., & Oates, W. E. (1992). Environmental economics: a survey. *Journal of Economic Literature*, *30*, 675–740.

Finkelshtain, I., & Kislev, Y. (1997). *Political lobbying and asymmetry of Pigovian taxes and subsidies*. (Working Paper 9703). Rehovot, Israel: The Center for Agricultural Economic Research.

Fisher, A. C. (1981). *Resource and environmental economics*. Cambridge: Cambridge University Press.

Fredrikson, P. G. (1997). The political economy of pollution taxes in a small open economy. *Journal of Environmental Economics and Management*, *33*, 44–58.

Grossman, G. M., & Helpman, E. (1994). Protection for sale. *The American Economic Review*, *84*, 833–850.

Hillman, A. L. (1989). *The political economy of protection*. Switzerland: Harwood.

Johnson, D. G. (1991). *World agriculture in disarray* (2nd ed.). Macmillan.

Just, R. E., & Zilberman, D. (1979). Asymmetry of taxes and subsidies in regulating stochastic mishaps. *Quarterly Journal of economics*, *93*, 139–148.

Kamien, M. I., Schwartz, N. L., & Dolbear, F. T. (1966). Asymmetry between bribes and charges. *Water Resources Research*, *2*, 147–157.

Kohn, R. E. (1985). A general equilibrium analysis of the optimal number of firms in a polluting industry. *Canadian Journal of Economics*, *18*, 347–354.

Nash, J. (1950). The bargaining problem. *Econometrica*, *18*, 155–162.

Peltzman, S. (1976). Toward a more general theory of regulation. *Journal of Law and Economics*, *19*, 211–240.

Polinsky, M. A. (1979). Note on the symmetry of taxes and subsidies in pollution control. *Canadian Journal of Economics*, *12*, 75–83.

Zusman, P. (1976). The incorporation and measurement of social power in economic models. *International Economic Review*, *17*, 477–562.

# A Two-Pronged Control of Natural Resources: Prices and Quantities with Lobbying

by

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# A Two-Pronged Control of Natural Resources: Prices and Quantities with Lobbying


## ABSTRACT

This study offers a political-economic model of an industry regulated by an integrated system of both direct and market-based policies. The model is incorporated into a normative theoretical analysis and serves as a basis for structural econometric estimations. Exploiting disaggregated data on agriculture and irrigation in Israel in the mid-1980s, when water was regulated by both quotas and prices, the model's political and technological parameters are structurally estimated and used to assess the relative efficiencies of quotas, prices, and an integrated regulation regime.


## I. Introduction

Recent decades have seen population and income growth and alongside them, over-utilization of natural resources and aggravated environmental problems in many parts of the world. These developments — often augmented by awareness of the need to cover costs — are increasingly leading policymakers to reinforce the traditional arsenal of quantity instruments with market-based policies such as user and polluter charges (OECD 2010). As a result, the prevailing regulations in many countries are mixtures of direct and market-based instruments. Examples include the 1990 Clean Air Act in the U.S. that involves polluting standards and charges (EPA 2001) and the regulation of environmental externalities in many countries by means of both quotas and user taxes (EPA 2004). An additional important case is irrigation water—70% of freshwater used around the world—that in many locales is managed by a combination of charges and quotas; examples can be found in Australia, California, China, Iran, Israel, Peru, and Spain (Molle 2009).

Government intervention, whatever its nature, most often encounters political lobbying and pressure and, beginning with the seminal work of Buchanan and Tullock (1975) on taxes and quotas, there has been a long succession of studies of environmental and resource regulation under political lobbying. More recently, Fredriksson (1997) compared taxes with subsidies in pollution control; Finkelshtain and Kislev (1997) examined the relative robustness to political influence of quantity versus price regulations; Finkelshtain and Kislev (2004) analyzed alternative subsidy and tax regimes facing politically powerful interest groups; Yu (2005) studied environmental protection and direct and indirect political influence; and Roelfsema (2007) investigated strategic delegation of environmental policymaking. However, to the best of our knowledge, political equilibrium under a mixed policy regime of direct and indirect controls is an as-yet unexplored topic. This is the subject of the present study, wherein we offer a political-economic model of an industry regulated by an integrated system of both direct and market-based policies.

Political influence has also been studied empirically. A noticeable earlier effort was the pioneering work of Zusman and Amiad (1977) who analyzed agricultural support policies. More recent estimates of structural political parameters have been based on application of the *Protection for Sale* theory of Grossman and Helpman (1994) to trade policies. A common feature of the estimations in the trade context was that policymakers were found valuing social welfare highly relative to political contributions. This finding is puzzling, particularly in light of reports on extensive investments in lobbying. Many extensions of the model were suggested in attempts to reconcile the apparent contradiction of broad support for lobbying and political contributions on the one hand, and irresponsive governments on the other. However, as Gawande and Magee (2010) demonstrated, despite these efforts, the puzzle has not been solved.

In their own attempt to solve the puzzle, Gawande and Magee distinguish between cooperative lobbying, wherein all firms take part in the political activity; and non-cooperative lobbying, wherein some firms lobby and contribute politically while others are free-riders. Inter-industrial differences in protection may be explained by variations in the level of free-riding. In this paper, we study water regulation in Israel and show that free-riding in lobbying may play an important role in explaining the differences in effectiveness of firms’ specific controls (quotas) in contrast to uniform regulation (economy-wide tax or price). Accounting for these differences, we found that policymakers in Israel valued highly the interests of the agricultural lobby.

When an industry is regulated by a system of two integrated controls, the intensities of lobbying associated with any of the economic instruments are mutually interdependent. For instance, lobbying for higher quotas will not be observed where both taxes and quotas are comparatively high and the quotas are not effectively constraining. In another situation, with a combination of a low tax and small quotas, the tax will be irrelevant. Borrowing from the terminology of information economics, we term these specific cases, respectively, *pooling price* and *pooling quota* equilibrium. When both controls are effective, a *separating equilibrium* emerges wherein the population is divided into two interest groups, each bounded by a different instrument and acting accordingly in the political arena. In the proposed terminology, the situation in Israeli agriculture forms a separating equilibrium.

The political process we are studying is embedded in a predetermined "constitution," wherein the control regime may be quotas, a price, or an integrated regime. By its choice of the control regime, and the initial quotas, the government determines which type of equilibrium will emerge in the economy. Thus, an interesting policy question is: Which of the above equilibria is more efficient? This question is examined empirically in the paper via simulations of the various equilibria, based on estimated technological and political parameters. An important finding of the paper, at least for the conditions prevailing in Israel, is that pooling price equilibrium, inducing more free-riding than the alternative regimes, is welfare dominating.

The next section of the paper presents a political-economic model of a mixed regime in a sector with heterogeneous producers. We then develop the necessary conditions for the existence of the three cases: pooling price, pooling quota, and separating equilibrium. These conditions are employed in Section III to construct a structural empirical model used to estimate the technological and political parameters of the model. Section IV presents simulations of alternative equilibria, and Section V is a concluding comment.

## II. Theory

Consider an agricultural sector in a small, open economy. Water suppliers allocate water to farmers using both prices and quotas as dictated by a government regulator. The quotas are individual and non-transferable.[1] Technologies and markets are ever changing; the regulation instruments are therefore examined periodically and modified as needed. This modification and the resetting of prices and the quotas is the subject of the political process modeled below.

Farming conditions are heterogeneous and farmers vary in their abilities. Let $\gamma$, with the distribution function $z(\gamma)$, represent the farming unit's technological level, and for convenience, treat this variable as continuous. The profit per farm is given by $\pi(w,\gamma)-pw$, where $w$ is the farm's water use and $p$ is an administratively determined agricultural water price. The function $\pi(w,\gamma)$ subsumes the prices of all variable outputs and inputs, excluding $p$, and is assumed continuous, increasing, twice differentiable, and strictly concave in $w$. The derivative of $\pi(w,\gamma)$ with respect to water consumption, $\pi_w(w,\gamma)$, is the water's value of marginal product (VMP), which we assume is increasing in $\gamma$. The inverse of this function, $D(p,\gamma)=\pi_w^{-1}(p,\gamma)$, is the farm's water demand. The slope of the demand function is $D_p=1/\pi_{ww}$. In the section on comparative statics, it will be assumed that $D_{p\gamma}=0$.

The allocation of water quotas, $q$, to the farms (all of them) is represented by the distribution function $k(q)$. The farm's water consumption is then given by $w(p,\gamma)=\min(D(p,\gamma),q)$. The price $p$ and the distribution of quotas $k(q)$ are the instruments used by the government to control water consumption in agriculture. These controls are set through a political process wherein politicians may bend policies in favor of interest groups who, in return, provide political rewards. We omit the explicit formulation of the political game and instead rely on Peltzman (1976), Zusman (1976), Hillman (1982), Grossman and Helpman (1994), Damania, Fredriksson, and List (2003), and others who have shown that policies constituting

[1] The quotas are here a regulation instrument; there are no private property rights in the utilization of water.

equilibrium in a political system with rewards can be viewed as maximizing the following governmental objective function.

$$G = S\left(p, k\left(q\right)\right) + \beta U\left(p, k\left(q\right)\right) \tag{1}$$

In (1), $S\left(p, k\left(q\right)\right)$ and $U\left(p, k\left(q\right)\right)$ are social welfare and the organized interest groups' profits respectively, and $\beta, 0 \le \beta$ is the extra weight attached by the politicians to the welfare of politically organized groups [in the political models, suggested by Zusman (1976) and Grossman and Helpman (1994), $\beta$ is the weight attached to political rewards]. In our context, $\beta$ may also reflect weight attached by decision-makers to social objectives such as food security, viability of family farms, and the development of rural areas.

Consistently with the practice in Israel, we visualize prices as modified and set before the rainy season, while the quotas are announced only after the winter rains have been observed. We are therefore considering a two-stage political game, wherein quotas are set subsequent to price determination. Political activities differ as per the stage of the game. Lowering the price is in the entire farming sector's interest, and hence is in the nature of a public good. Partial participation in the political struggle for price cuts can therefore be expected. In contrast, since quotas are farm-specific assets, free-riding in lobbying for higher quotas is less probable; however, only farmers whose quotas are binding can be expected to negotiate quota raises. The separation into the two interest groups — the entire sector, and the operators constrained by the quotas — yields the political separating equilibrium.

Given the price of water, whether a farm is constrained by the quota depends both on its technological level and the size of its specific water allotment. We wish to order the farms and consequently divide them into two groups so that water use in one group is dictated by the price, while those in the second group utilize their allotments fully. Formally, let $q^0$ denote the farm's historical, pre-modification quota (the unit index is omitted) and $k^0\left(q^0\right)$, the associated continuous distribution function with the support $\left[q^l, q^h\right]$. Define $\nu \equiv \pi_w\left(q^0, \gamma\right)$, $\nu \in \left[\nu^l, \nu^h\right]$, as the VMP of water measured at the historical quota. The joint distribution of $z\left(\gamma\right)$ and $k^0\left(q^0\right)$ induces the continuous distribution function $f(\nu)$ on the support $\left[\nu^l, \nu^h\right]$. Given $p$ and $f(\nu)$, the water consumption of the farms with $\nu^l \leq \nu \leq p$ is dictated by the price, while those with $p < \nu \leq \nu^h$ consume water quantities equal to their quotas. In other words, for the historical regulation parameters,

$$w(p,\nu) = \begin{cases} D(p,\nu) = \pi_w^{-1}(p,\nu), & \nu \in \left[\nu^l, p\right] \\ q(\nu), & \nu \in \left(p, \nu^h\right] \end{cases}$$

where $q(\nu)$ is the quota associated with $\nu$. The controls are examined and modified annually. Our interest is in the emerging political equilibrium price $p^*$ and quota allocation rule $q^*(\nu)$. The economic value of a quota is a decreasing function of the price paid for water; hence, the higher the price, the less intense the political struggle for quotas (this assertion is proven formally in subsection II.C). The politicians may take this effect into account when setting the price in the first stage of the political game (this conjecture is tested in the empirical sections). Accordingly, the game is solved recursively, starting with the second stage.

### A. *The Second Stage: Allocating Quotas*

Using the above notations and definitions, total water consumption in the economy is given by:

$$W\left(p, f(\nu)\right) = \int_{\nu^l}^{\nu^h} w(p,\nu) f(\nu) d\nu = \int_{\nu^l}^{p} D(p,\nu) f(\nu) d\nu + \int_{p}^{\nu^h} q(\nu) f(\nu) d\nu \qquad (2)$$

Given $p^*$ and $f(\nu)$, quotas are reallocated to farmers whose quotas are binding, i.e., having $\nu \in \left(p^*, \nu^h\right]$. Denoting by $c$ the constant per-unit water supply cost, and recalling (1), the equilibrium quota allocation is solved as an optimal control problem with the objective

$$\begin{aligned} &\max_{q(\nu)} G\left(q(\nu)\right) = \int_{p^*}^{\nu^h} \left[\pi\left(q(\nu),\nu\right)(1+\beta) - \beta p^* q(\nu)\right] f(\nu) d\nu - cW\left(p, f(\nu)\right) \\ &s.t.\ \ \dot{W} = q(\nu) f(\nu) \end{aligned} \qquad (3)$$

The solution of (3) yields the equilibrium rule with respect to $q(\nu)$:

$$\frac{c+\beta p^*}{1+\beta} = \pi_w\left(q^*(\nu),\nu\right)\Big|_{\nu\in\left(p^*,\nu^h\right]} \equiv \pi_w^h \tag{4}$$

Or, writing explicitly, the inversion of (4) yields

$$q^*(p,\nu)\Big|_{\nu\in\left(p^*,\nu^h\right]} = \pi_w^{-1}\left(p^*,c,\beta,\nu\right) \tag{4'}$$

Eq. (4') will be used in the empirical analysis below. As $\pi_w^h > 0$ in Eq. (4) is a constant with respect to $\nu$, the political process yields efficient intra-group water use equating the VMPs of all farms with $\nu\in\left(p^*,\nu^h\right]$. However, it will be shown below that as long as $\beta > 0$, $c > \pi_w^h > p^*$; this inequality implies a welfare loss. Finally, we note that in the special case of $p^* = 0$, Eq. (4) becomes

$$\frac{c}{1+\beta} = \pi_w\left(q^*(\nu),\nu\right)\forall\ \nu\in\left[\nu^l,\nu^h\right], \tag{4''}$$

characterizing a pooling quota equilibrium.

Note that the lower bound of the integral in (3) is the equilibrium price reached in the first stage of the political game. Farmers with $\pi_w\left(q^0(\nu),\nu\right) > p^*$ are bound by their historical quotas (they belong to the group $\nu\in\left(p^*,\nu^h\right]$) and they all participate in lobbying activity in the second stage. Since, as shown above, $\pi_w^h > p^*$, they will all belong to the same group in the equilibrium reached after the second stage.

*B. The First Stage: Setting the Price*

Again rewriting (1), the equilibrium price $p^*$ is the solution to the following problem:

$$\begin{aligned}\max_p\ G(p) = &\int_{\nu^l}^{\nu^h}\pi\left(w(p,\nu),\nu\right)f(\nu)d\nu - cW\left(p,f(\nu)\right)\\ &+\beta\theta\int_{\nu^l}^{\nu^h}\left[\pi\left(w(p,\nu),\nu\right)-pw(p,\nu)\right]f(\nu)d\nu\end{aligned} \tag{5}$$

In (5), $0\le\theta\le 1$ represents the portion of the farming population supporting the lobby in its struggle for price reduction. The necessary condition for the maximum in (5) is:

$$\int_{\nu^l}^{\nu^h} \left(\pi_w(p,\nu) - c\right) w_p f(\nu)\, d\nu = \beta\theta \left[ W\left(p, f(\nu)\right) - \int_{\nu^l}^{\nu^h} \left(\pi_w(p,\nu) - p\right) w_p f(\nu)\, d\nu \right] \qquad (6)$$

where $w_p = \dfrac{\partial D(p,\nu)}{\partial p}$ $\forall\, \nu \in \left[\nu^l, p\right]$ and $w_p = \dfrac{\partial q^*(\nu)}{\partial p}$ $\forall\, \nu \in \left(p, \nu^h\right]$.

The left-hand side of (6) is the price change's marginal effect on social welfare. It is the sum, over all farms, of the per-unit deadweight loss. On the right-hand side, the terms in the square brackets are the price change's marginal effect on farmers' welfare. In equilibrium, the former equals $\beta\theta$ times the latter. Since $\pi_w(p,\nu) \geq p$ and $w_p < 0\ \forall\, \nu \in \left[\nu^l, \nu^h\right]$, the right-hand side of (6) is positive, and it follows that

$$\int_{\nu^l}^{\nu^h} (p - c) w_p f(\nu)\, d\nu > \int_{\nu^l}^{\nu^h} \left(\pi_w(p,\nu) - c\right) w_p f(\nu)\, d\nu > 0 \quad \Rightarrow \quad c > p\,.$$

That is, the equilibrium price is lower than marginal cost. Moreover, substituting $c > p$ in (4), it follows that $c > \pi_w^h > p^*$. Hence (a) water's VMP is below marginal cost; welfare loss is indicated for both groups of farms; and (b) water is allocated inefficiently between the group with binding quotas and the other farms. In analogy to the quota case, Eq. (6) with *p* binding for all farmers characterizes a pooling price equilibrium. In this case, Eq. (6) is rewritten as:

$$p^* = c + \beta\theta W\left(p, f(\nu)\right) \Big/ \int_{\nu^l}^{\nu^h} \frac{\partial D(p,\nu)}{\partial p} f(\nu)\, d\nu \qquad (6')$$

Note that the pooling equilibria, Eqs. (4'') and (6'), may emerge, either if the "constitution" dictates a single-control regime, or in the case of a mixed regime with no solution, $\nu^l < p^* < \nu^h$, to Eq. (6).

### *C. Comparative Statics*

The regulation instruments' sequential setting implies that the comparative statics exercises should also be performed in two stages. The effect of an exogenous change on the price is analyzed in the first stage. The direct effect of the exogenous change and the indirect effect (through the price) on the quotas are examined in the second stage. Table 1 summarizes the results; the proofs are presented in Appendix A.

The effects on the price of marginal shifts in political parameters $\beta$ and $\theta$ and of the supply cost *c* can be recognized intuitively; i.e., the larger the power or representation of the farming sector in the political arena, the lower the price, whereas higher supply costs increase the price. The impacts on the quotas are also expected; i.e., allotments increase with $\beta$ and $\theta$ and shrink with *c*. Note that $\theta$, the parameter measuring participation in the political struggle, has no direct effect on the quotas; its indirect impact is lowering the price and thereby increasing the quotas.

Technological improvements and alternative schemes of quotas' historical allocations are modeled as variations in the distribution functions $z(\gamma)$ and $k^0(q^0)$, both of which affect the $f(\nu)$ distribution. In particular, technological improvement or a rise in the agricultural terms of trade are modeled as a first-order stochastic dominant (FSD) shift of $z(\gamma \mid q^0)$, the conditional distribution of $\gamma$, given $q^0$. Recalling our assumption that the demand function's slope is invariant to changes in $\gamma$, such a change leads to a price reduction and indirectly increases the quotas and total water usage and hence enlarges the deadweight losses (the last effect is not reported explicitly in the table). Intuitively, for a given *p*, technological improvement (or an improvement in terms of trade) increases the number of farmers with binding quotas ($N^h$) and shifts the entire farmers' population towards larger water consumption. These effects lead to an increase in the farmers' marginal gain from a price decrease, the right-hand side of Eq. (6), and hence augments the pressure on the price. Moreover, the increase in $N^h$ reduces the social gain from price increase. This follows from two reasons. First, for the farmers with binding quotas, water consumption is less responsive to a price hike. Secondly, the per cubic meter dead weight losses of the "high" *v* group is smaller than that of "low" *v* group farmers. This means that technological improvement makes it "cheaper" for the politicians to discount the water price. Therefore, the equilibrium is restored at a lower price, higher quotas, and higher level of the marginal deadweight loss; i.e., the left-hand side of Eq. (6).

*Ceteris paribus*, an economy with higher initial quotas will have a higher equilibrium price, and paradoxically, smaller quotas and less water use. The explanation is that when historical quotas are comparatively high, more farmers who would otherwise be in the "high" *v* group find themselves in the "low" range. This means an increase in the share of the water controlled by the price and more farmers with larger per-unit dead weight loss, which increases government resistance to pressure on the price. While the change has no direct effect on the equilibrium quotas, the indirect effect through the price reduces quotas' allocation, aggregate water use and the deadweight losses.

In Section IV, the above comparative statics effects are quantified for the Israeli case in simulations based on the estimated parameters. In addition, the comparative statics results suggest several testable implications of the model, such as an increase in the administrative water price in periods of declining terms of trade. Below, we indicate that the Israeli data are consistent with this prediction of the model.

## III. Empirical Analysis

All water sources in Israel are publicly owned, and their use is regulated by the state. In the period covered by our analysis, the regulator was the Water Commissioner, but other government agencies and politicians were deeply involved in the decisions on prices and quantity allocation (Zusman 1997; Mizrahi 2004; Kislev 2006; and Margoninsky 2006). Our data set covers prices and quotas for cooperative and communal villages (*moshavim* and *kibbutzim* respectively) that received their water from the national company, Mekorot, the provider of most of the water in the country. The village, not the individual farmer, is the consuming unit in the sample, receiving water up to its specific quota and paying for the quantity used.

The data in the study cover the period 1985-88, when prices were linear and region-specific (today farmers pay increasing block rate prices, and the same tariff structure applies nationwide). The prices' variation across regions and over time allows econometric estimates. Strictly speaking, this means that lobbying is conducted in each region separately; however, since regional prices were correlated, political activity at the nationwide level was also observed. During the study period, the agricultural sector utilized less water than allowed by the aggregate quota; while some farmers were constrained by their quantitative allocations, others did not fully use the water they were allotted (a separating equilibrium, in the proposed terminology). The empirical analysis is conducted at two levels: The parameters of demand function and the quota allocation rules, including the magnitude $\beta$, are estimated at the village level, while price setting is estimated at the regional level. Obtaining the size of the parameter $\theta$ is based on these estimations' output.

*A. The Demand Function and the Quota-Allocation Rule*

The challenge of the econometric analysis is to "explain" two observed magnitudes: per-village water use, and its quota. Recall that (a) water use is determined either by price or by quota; and (b) quotas are endogenously set in the political process. Consequently, our task is to estimate two structural equations: water demand, and the quota-setting function.

For convenience, write water's VMP for village *i* and year *t* as the linear function

$$\pi_{w\,it} = \omega_{it} + \psi w_{it} \tag{7}$$

In (7), $w_{it}$ and $\omega_{it}$ are respectively, the village-year-specific water consumption and the function's intercept, and $\psi$ is its slope, assumed identical for all *i* and *t*. The derived water demand function is $D(p_{it}, \mathbf{z}_{it}) = \boldsymbol{\mu}\mathbf{z}_{it} + \delta_1 p_{it}$, where $p_{it}$ is the price (villages in the same region may have identical prices), $\mathbf{z}_{it}$ is a vector of village-year-specific variables, $\boldsymbol{\mu}$ is the vector of corresponding coefficients, and $\delta_1 \equiv \psi^{-1}$. Let $q_{it}$ be the village annual water quota. By substituting the linear VMP specification into Eq. (4'), $\pi_{w\,it}\big|_{w_{it}=q_{it}} = \omega_{it} + \psi q_{it}$, and rearranging, we get a linear political equilibrium quota allocation rule: $Q(p_{it}, \mathbf{x}_{it}) = \boldsymbol{\xi}\mathbf{x}_{it} + \delta_2 p_{it}$, where $\mathbf{x}_{it}$ is a vector of village-year-specific variables, $\boldsymbol{\xi}$ is the associated vector of coefficients, and $\delta_2 \equiv \psi^{-1}\beta/(1+\beta)$. The political parameter $\beta$ is identifiable through $\beta/(1+\beta) = \delta_2/\delta_1$.

Following Burtless and Hausman (1978) and Mofitt (1986), we add to the structural equations three random components. The first is heterogeneity across villages and along time, not explained by $p_{it}$ and $\mathbf{z}_{it}$; it is represented by the random variable $\alpha_{it}$, which stands for managerial skills and other factors not observed by the modeler, yet known to the farmers and therefore affecting their individual demand for water. Two additional sources of randomness are those associated with measurement errors and optimization mistakes that may emerge in both the farmer's decision on water usage and the allocation of quotas by the government, which are represented respectively by the terms $\varepsilon_{it}$ and $u_{it}$. A linear additive formulation is adopted, with two interrelated equations of water demand and quota allocation:

$$w_{it} = \begin{cases} D(p_{it}, \mathbf{z}_{it}) + \alpha_{it} + \varepsilon_{it} & \text{if} \quad D(p_{it}, \mathbf{z}_{it}) + \alpha_{it} \le q_{it} \\ q_{it} + \varepsilon_{it} & \text{if} \quad D(p_{it}, \mathbf{z}_{it}) + \alpha_{it} > q_{it} \end{cases} \tag{8}$$

$$q_{it} = \begin{cases} q_{it-1} + u_{it} & \text{if} \quad D(p_{it}, \mathbf{z}_{it}) + \alpha_{it} \le q_{it-1} \\ Q(p_{it}, \mathbf{x}_{it}) + u_{it} & \text{if} \quad D(p_{it}, \mathbf{z}_{it}) + \alpha_{it} > q_{it-1} \end{cases} \tag{9}$$

By Eq. (8), wherever the quantity demanded at the given price is less than the quota, consumption equals the demand function $D(p_{it}, \mathbf{z}_{it}) + \alpha_{it}$ plus a stochastic error term. If water demand exceeds the quota, then the observed water consumption equals the quota $q_{it}$ plus the stochastic error term. The quota's endogenous setting is formulated in Eq. (9): If the historical quota $q_{it-1}$ exceeds demand, and is therefore unbinding, then, $q_{it} = q_{it-1}$ plus an error term. An effective historical quota, on the other hand, would lead to bargaining and to a political equilibrium characterized by the equilibrium quota allocation rule $Q(p_{it}, \mathbf{x}_{it})$.

Our estimation strategy is based on maximization of the sample likelihood. Let $\Pr_{it}(w_{it}, q_{it} | p_{it}, q_{it-1}, \mathbf{z}_{it}, \mathbf{x}_{it}, \boldsymbol{\theta})$ be the probability of observing a pair of water consumption $w_{it}$ and quota $q_{it}$, where $\boldsymbol{\theta}$ is the set of parameters of the functions $D(p_{it}, \mathbf{z}_{it})$ and $Q(p_{it}, \mathbf{x}_{it})$ and the joint density distribution functions of $\alpha$, $\varepsilon$, and $u$. This probability encompasses all the combinations associated with the options in (8) and (9), as elaborated below.

$$\begin{aligned} &\Pr_{it}(w_{it}, q_{it} | p_{it}, q_{it-1}, \mathbf{z}_{it}, \mathbf{x}_{it}, \boldsymbol{\theta}) = \\ &\quad \Pr\left[\alpha_{it} + \varepsilon_{it} = w_{it} - D(p_{it}, \mathbf{z}_{it}), \alpha_{it} \le \min(q_{it}, q_{it-1}) - D(p_{it}, \mathbf{z}_{it}), u_{it} = q_{it} - q_{it-1}\right] \\ &+ \Pr\left[\alpha_{it} + \varepsilon_{it} = w_{it} - D(p_{it}, \mathbf{z}_{it}), q_{it-1} < D(p_{it}, \mathbf{z}_{it}) + \alpha_{it} \le q_{it}, u_{it} = q_{it} - Q(p_{it}, \mathbf{x}_{it})\right] \\ &+ \Pr\left[\varepsilon_{it} = w_{it} - q_{it}, q_{it} < D(p_{it}, \mathbf{z}_{it}) + \alpha_{it} \le q_{it-1}, u_{it} = q_{it} - q_{it-1}\right] \\ &+ \Pr\left[\varepsilon_{it} = w_{it} - q_{it}, \alpha_{it} > \max(q_{it}, q_{it-1}) - D(p_{it}, \mathbf{z}_{it}), u_{it} = q_{it} - Q(p_{it}, \mathbf{x}_{it})\right] \end{aligned} \tag{10}$$

The sample likelihood function is

$$L = \prod_i \prod_t \Pr_{it}(w_{it}, q_{it} | p_{it}, q_{it-1}, \mathbf{z}_{it}, \mathbf{x}_{it}, \boldsymbol{\theta}) \tag{11}$$

Assuming that the random variables $\alpha$, $\varepsilon$, and $u$ are statistically independent and normally distributed, such that $\alpha \sim N\left(0,\sigma_\alpha^2\right)$, $\varepsilon \sim N\left(0,\sigma_\varepsilon^2\right)$, and $u \sim N\left(0,\sigma_u^2\right)$, the likelihood function in (11) is readily derivable in terms of the standard normal density (Appendix B).

### *B. The Price Formation Equation*

The price formation parameters are estimated at the regional level. Let $N_{jt}^l$ and $N_{jt}^h$ be the number of price and quotas' effective observations, respectively, in region *j* in year *t*; $W_{jt}$ stands for total water consumption in the same observation. With our linear specification for the demand function, Eq. (6) becomes:

$$p_{jt} = \boldsymbol{\zeta}\mathbf{c}_{jt} + \psi\beta\theta \frac{W_{jt}}{N_{jt}^l + \lambda\left(1-\theta\right)\left(\frac{\beta}{1+\beta}\right)^2 N_{jt}^h} + \upsilon_{jt} \tag{12}$$

where $\mathbf{c}_{jt}$ is a vector of region-level supply cost-related variables, $\boldsymbol{\zeta}$ is the set of corresponding coefficients, and $\upsilon_{jt}$ is an error term. The parameter $\lambda$ indicates the politicians' "conjectural variation," i.e., the degree by which $\partial q^*\left(\nu\right)/\partial p$ is taken into account when determining the price. If $\lambda = 1$, then the politicians have complete comprehension of the mechanism by which *p* affects $q^*\left(\nu\right)$ in Eq. (4), and this effect is perfectly accounted for when setting the price (Eq. (6)). At the other extreme $\lambda = 0$, and $\partial q^*\left(\nu\right)/\partial p$ is ignored.

Eq. (12) is highly nonlinear; and $N_{jt}^l$, $N_{jt}^h$, and $W_{jt}$ may be endogenous. We therefore employed a nonlinear limited information maximum likelihood (LIML) procedure (Amemiya 1986, pp. 252-255) to estimate it, and found that the hypothesis of $\lambda = 0$ could not be rejected, implying that (12) is reduced to:

$$p_{jt} = \boldsymbol{\zeta}\mathbf{c}_{jt} + \delta_3 W_{jt}/N_{jt}^l + \upsilon_{jt}\ , \tag{12'}$$

where $\delta_3 \equiv \psi\beta\theta$. Accordingly, and to improve the efficiency of the estimation procedure, in the sequel, we employ Eq. (12') and a linear LIML procedure to estimate the model parameters. In particular, we note that using Eqs. (7) and (12’), $\theta$ is identifiable through $\theta = \delta_3\delta_1\left(\delta_1 - \delta_2\right)/\delta_2$ .

*C. Data and Variables*

The estimation is based on a panel of 1,051 observations of freshwater use in agriculture. The information covered prices and quotas for the years 1985-88, encompassing 303 villages located in 23 water-price regions. The observations in the panel were selected according to three criteria: (a) the villages included used only fresh water; they did not apply brackish or recycled water; (b) the included villages received their water from Mekorot only, whose prices were, and still are, set by the government; (c) villages with cultivated areas of less than 50ha or water quotas of less then 200,000 $m^3$ / year were excluded from the sample. In the period of the study, water use in the sample villages accounted for 20% of agricultural freshwater consumption in the country.

Table 2 provides descriptive statistics of the variables in the dataset and their sources. Water use, quota, price, and cost were explicitly incorporated into the theoretical formulation presented above. The other variables in the table are the components of the vectors $\mathbf{z}_{it}$ and $\mathbf{x}_{it}$ in Eqs. (8) and (9). Note that on average, water consumption was lower than village quota. In fact, the consumption of water was less than the quota in 56% of the observations (not in the table). As suggested earlier, this is an indication of a separating equilibrium.

Delivery costs, in 1987 US dollars, were available by Enterprise, a part of Mekorot's network covering a delivery area, mostly to points of similar altitudes (Shaham 2007) and assigned to villages as per their water utilization. As indicated, prices in the study period (1985-88) were region specific. For the region-level analysis, village costs were aggregated to 23 regional averages.

Capital and operating outlays form the fixed part of water supply’s cost; unlike energy, they do not vary with the quantity delivered. Capital costs were often neglected when prices were determined because a large portion of Mekorot's investment was covered by public budgets. Moreover, in 17 of the 23 regions, average price was lower even than energy cost, and in all regions it was lower than total cost.

Farmers did not face the full cost of the input they used; apparently they succeeded in lobbying for lower prices.

The last two variables in Table 2 are at the nationwide, not village, level. Enrichment is the annual recharge of rainwater added to the reservoirs — the aquifers and the Sea of Galilee — and terms of trade is an index of the ratio of the price of agricultural products (field crops and orchards) to the price of farm inputs.

### *D. Estimation Results*

We begin with the estimation of Eqs. (8) and (9). The goodness of fit is evaluated by comparing the predicted to the actual distribution of the variables, in our case water use and quotas. The scatter diagrams in Figure 1 present the predicted (expected) values versus the observed magnitudes for both consumption and quotas.[2] The correlation between the predicted and observed series is 0.91 for quotas and 0.63 for water consumption, both indicating reasonable fit. We also compare the distributions of the actual and the predicted quantities. While the distribution of predicted consumption is less dispersed than the one corresponding to the actual quantities, all other moments are quite similar. In particular, note that the average water use and quota predicted by the model are 958 and 1,028 (1,000 $m^3$), compared with the actual average use and quota of 940 and 1,033 respectively.

The estimation results are summarized in Tables 3a for Eqs. (8) and (9) at the village level, and 3b for the setting of prices. In Eq. (8), based on the estimated values of $\sigma_\alpha$ and $\sigma_\varepsilon$ of the error terms in the demand function, 61% [383/(383+241)] of the unexplained variation in water consumption is associated with the heterogeneity among villages. As expected, the price coefficient ($\delta_1$) is negative and significant; the elasticity of demand will be discussed below.

Only a few of the village-specific variables seem to significantly affect annual water demand, among them elevation, indicating cooler, hilly areas; and cultivatable land in the village, particularly areas of orchards. Water consumption is relatively

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[2] The expected values were calculated in the simulations presented in Section IV below.

higher in the drier south; cooperative villages use less water than communal entities; and improved terms of trade encourage intensification of water utilization.

The estimated parameters of the quota allocation function, presented in the second column of Table 3a, are consistent with the theory. The price coefficient ($\delta_2$) is negative; i.e., higher prices reduce the intensity of the political activity. The two components of the delivery cost operate in opposite directions: On the one hand, higher energy cost, which indicates an increased marginal cost, increases the equilibrium VMP in Eq. (4), and hence adversely affects the allotted quotas in the political equilibrium. On the other hand, capital and operational costs serve as indicators of installed capacity and lower marginal cost, and therefore, villages connected to capital-intensive enterprises enjoy comparatively higher quotas.

As indicated, the political determination of the quotas is a reallocation process, modifying historical distribution; hence the significant effect of $q_{t-1}$, which is introduced in the empirical estimation to control for quota-adjustment constraints and farm characteristics. The interpretation of most other parameters in the quota equation is straightforward; we comment only on April rainfall and annual recharge. While spring rainfall's effect on demand is not significant, a good rain may reduce farmers' pressure for higher quotas, hence the negative sign in the second column.

As for natural enrichment, reservoirs enable smoothing of supply by carrying water from rainy to drier years. In light of this possibility, the withdrawal policy often recommended is to limit extraction to "safe yield," a stable quantity that may constitute an essentially constant yearly supply. The disadvantage of this policy is that it allows some water to drain into the ocean (or in our case the Dead Sea). A positive effect of annual recharge on quota allocation, as shown in Table 3a, is an indication of political pressure to "make use of every drop of water" and extract yearly the entire recharged quantity. Such a policy increases the risk of shortages and severe crises in drought years, and may even damage the reservoirs. As Zusman and Amiad (1977) showed, the agricultural lobby in Israel and the politicians it influenced tended to be shortsighted.

The ratio $\beta/(1+\beta)$ is estimated at 0.48, where the equality to both zero and one is rejected in the 5% confidence level. Again, Zusman and Amiad (1977) reported

$\beta/(1+\beta)$ values of similar magnitudes, considerably higher than those obtained in studies of the influence of lobbying on trade policies (Gawande and Magee 2010).

The price formation equation, estimated at the regional level, is reported in Table 3b. There are 72 region-year observations and they were weighted by the number of villages in the region (weighting did not affect the estimates markedly). Based on the estimates, higher capital and operating costs increase equilibrium prices, whereas energy costs do not exhibit a significant impact. The $\delta_3$ ($=\psi\beta\theta$) coefficient is negative and statistically significant, thereby rejecting the hypothesis of no political pressure.

The point estimation for the lobbying participation rate, $\theta$, is 0.23, indicating considerable free-riding. Moreover, the latter conclusion is strengthened by noting that $\theta$ is significantly less than 1 (no free-riding). Finally, we could not rule out the possibility that $\theta = 0$, indicating zero organization for price lobbying.

## IV. Simulations

The parameters estimated in the previous section are employed here for simulations. The simulations are of expected village water use and quotas conditional on prices, village characteristics, and the estimated political and technological parameters. Expected values were calculated by numerical integration of the estimated bivariate likelihood function:

$$E\left(w_{it}\right) = \iint w \Pr\left(w, q \middle| p_{it}, q_{it-1}, \mathbf{z}_{it}, \mathbf{x}_{it}, \hat{\boldsymbol{\theta}}\right) dwdq \tag{13}$$

$$E\left(q_{it}\right) = \iint q \Pr\left(w, q \middle| p_{it}, q_{it-1}, \mathbf{z}_{it}, \mathbf{x}_{it}, \hat{\boldsymbol{\theta}}\right) dwdq \tag{14}$$

The range for the numerical integration was the observed quantities $\pm 10$ millions m$^3$, with 100 partitions. We begin with the demand elasticity.

## *A. Price Elasticity*

Prices are endogenous in our model. Still, the question may be asked, how does water consumption change with its price? Three concepts of elasticity emerge. The first is the calculated individual village demand elasticity, computed utilizing the regression coefficient at the sample mean (Tables 2, 3a); this elasticity value is -0.87 (-7,619*0.11 / 958). The second concept is the "constrained market elasticity," corresponding to a market experiment wherein villages constrained by their quota do not respond to a change in the prices, and the quotas are assumed irresponsive to price changes. The calculation is conducted by a simulation of Eq. (13) for prices 5% above and below the observed sample levels, holding the sample quotas constant. The value of the elasticity thus computed is -0.19, or slightly higher than the short-run elasticity value of -0.13 estimated by Bar-Shira et al. (2006).

To obtain the third elasticity concept, recall that the quotas may change when prices change. Simulation of Eq. (14) with 5% price changes yields "elasticity" of quota with respect to price of -0.27. The third concept is accordingly the "unconstrained market elasticity," reached by simulation of Eq. (13) with price changes of 5%, this time allowing quotas to change. The computed elasticity is now -0.50.

Quantitative controls for irrigation water are employed in many countries. The above findings imply that, at least for conditions in Israel, assertive price policy may greatly enhance the effectiveness of direct control instruments.

## *B. Exogenous Changes*

In this subsection, we investigate the impact of exogenous shocks on the separating equilibrium, quantifying the comparative statics effects. Table 4 reports the results, expressed in terms of elasticities. The first two rows show variations associated with the first stage, i.e., the price formation and the allocation of users between the two interest groups, indicated by the probability $\Pr(\nu \le p^*)$. The price change was calculated using Eq. (12'), wherein $W_{jt}$ equals the regional sum of village-level expected value of consumption, $E(w_{it})$, as computed by Eq. (13), and $N_{jt}^l = N_j \Pr_{jt}(\nu \le p^*)$, where $N_j$ is the number of villages in region *j* and $\Pr_{jt}(\nu \le p^*)$

is the region's average probability of $D\left(p_{it}^{*}, \mathbf{z}_{it}\right) + \alpha_{it} \le q_{it}$; the latter was calculated by a variant of Eq. (10) that includes the terms corresponding to this condition only. Recalling $\lambda = 0$, the price, $E\left(w_{it}\right)$ and $\Pr_{jt}\left(\nu \le p^{*}\right)$ were all calculated while holding the quotas at their observed levels. The equilibrium values' responses shown in the last four rows of Table 4 incorporate the second-stage effect; they were computed by introducing the exogenous change as well as the updated price from the first stage into Eqs. (13) and (14), while allowing the quotas to change according to the estimated function $Q\left(p_{it}^{*}, \mathbf{x}_{it}\right)$.

From the theory (subsection II.C), we already know that a rise in the terms of trade and the technology level would lead to a price reduction, increased quotas, and deadweight losses. The simulation results (first column of Table 4) demonstrate that these effects are sizeable. In particular, note that the water price elasticity with respect to the terms of trade is -2.73. In the five decades 1952-2002, crops' terms of trade in Israel declined by more than 50%, while the water price tripled (Kislev and Vaksin 2003). Political scientists (e.g., Menahem 1998) tend to attribute those changes to erosion in the farmers' lobbying or a shift in society's and politicians' attitudes toward agriculture. The above political-economic model with steady political organization ($\theta$) and government attitudes ($\beta$), provides an alternative explanation for the water-price hike; namely, an exogenous decline in the terms of trade.

The effect of a change in the historical quotas, as indicated by the elasticities in Table 4, is opposite in sign and an order of magnitude smaller than the effect of the terms of trade.

The equilibrium values' elasticities in Table 4, with respect both to $\beta$ and $\theta$, are less than 1, yet significant and tend to be similar in their magnitudes. While lower communication costs in the future may lead to increased transparency of governmental policies and higher politicians' ethical norms (lower $\beta$), they may also strengthen farmers' organization and lobbying (larger $\theta$). The simulations results suggest that such changes may offset each other, thereby perpetuating overutilization of water resources.

*C. Political Equilibria*

If, as in agriculture in Israel, both prices and quotas are effective, the sector can be characterized as being, in our terms, in a separating political equilibrium. If prices are low and the quantity demanded exceeds the quota in every water-consuming unit, a pooling quota equilibrium emerges; a pooling price equilibrium appears where prices are set high and the quotas also high enough. In this subsection, we simulate the two pooling equlibria and compare them to the observed separating equilibrium. Before proceeding with the simulation, it will be useful to review the implications of the theory concerning the normative ranking of the three equilibria.

Finkelshtain and Kislev (1997) examined the relative efficiency of pooling price and pooling quota equilibrium in a regulated sector with homogeneous users. It was shown that if the demand elasticity is higher than the share of the resource utilized by the politically organized users, pooling price equilibrium dominates quotas equilibrium. Considering the estimated parameters in our study (demand elasticity -0.87, lobbying participation rate 0.23), one would accept the supremacy of the price regime.

However, this need not always be the case. In principle, where delivery costs vary between water users, the individually tailored quotas could potentially perform better than a uniform price regime that does not account for cost differences. In such a case, a two-pronged instrument may be superior. The conclusion drawn from this discussion is that normative ranking of the various equilibria is an empirical question.

Turing to the simulations, water consumption and quotas for the pooling quota equilibrium were simulated for each village separately, by Equations (13) and (14), setting $p_{it} = 0$ for all *i* and *t*. For the pooling price equilibrium, we used Eq. (6'), and it becomes:

$$p_{it}^{*} = \frac{\overline{c}_{jt} - \beta\theta\overline{\omega}_{jt}}{1 - \beta\theta} \qquad (15)$$

where $\overline{c}_{jt}$ and $\overline{\omega}_{jt}$ are the regional average costs and the estimated intercept of the linear VMP function respectively. Village-level water consumption for the pooling-price equilibrium was simulated by Eq. (13) using the regional prices calculated in (15). Village magnitudes were then averaged.

As indicated earlier, the political equilibrium is not welfare maximizing. Deadweight losses for the equilibrium values were calculated by

$$\Delta W_{it} = \tfrac{1}{2}\left(c_{it} - \pi^{*}_{wit}\right)^{2} / \psi \qquad (16)$$

and averaged over the sample.

The results are reported in Table 5 in terms of expected per-village values, averaged over the sample. For the circumstances in Israel and for the period of the study, the pooling price equilibrium was dominant in terms of welfare (recall that prices were set regionally). The average price under the pooling-price regime is, as shown in Table 5, twice the observed average, and closer to the marginal cost, thereby yielding higher welfare. The VMP under the pooling-quotas equilibrium is lower than the observed value, implying that pooling-quotas equilibrium is inferior to the other possibilities. Thus, despite the cost and technological heterogeneity that may lead to superiority of quotas or of an integrated regime, pooling price equilibrium dominates. The principal factor leading to this result is free-riding in lobbying. The uniform price regime in each region allows, or even encourages, considerable free-riding in farmers' organization relative to the individual quota regimes, and therefore yields a welfare-superior equilibrium. To show this, we simulate the pooling price regime in the extreme case of perfect lobbying, $\theta = 1$. As can be seen in the last column of Table 5, the normative ranking is reversed in this case, and both the separating and pooling quota equlibria are better.[3] One can only speculate that a nationwide uniform price could lead to even less effective lobbying and higher welfare.

## V. Concluding Comment

Realizing that political involvement tends to distort resource allocation and reduce social welfare, several years ago the Knesset (Israeli parliament) established an independent Water Authority with the power to determine water allotments and

[3] We have also tried to simulate a separating equilibrium with $\theta = 1$ but could not find positive prices associated with this equilibrium. The implication is that for the circumstance of the study, if all farmers were to participate in the lobbying activity for lower price, the regulation regime would have become a pooling quota equilibrium with water utilization determined solely by quantitative allocation.

prices. The law specifically and explicitly prevented the minister (Cabinet member) responsible for the water sector from involvement in the areas of responsibility assigned to the Water Authority.

While the intent was laudable, the legislators could not adhere to the law they themselves approved and could not resist the temptation to influence prices. During 2009, when the Authority was deliberating a new price structure, its Director-General was summoned six times to parliamentary committees and was even threatened with the law being amended unless prices were structured consistently with political desires, reflecting public outcry and goals of interest groups. Indeed, as of this writing (July 2011), the Knesset is considering a proposal to reverse the law: ‘‘The power to regulate prices must be restored to the members of the parliament, the reality being that the bureaucracy has been raising prices at will …” This time, the prices to be set are for urban water, however the same attitude can be expected to emerge when agricultural tariffs and allocations are considered. It appears impossible to “sanitize” the political process from involvement — even in the details — of administrative functions.

## References


Amemiya, Takeshi. 1986. *Advanced Econometrics*. Cambridge, MA: Harvard Univ. Press.

Bar-Shira Ziv, Israel Finkelshtain, and Avi Simhon. 2006. “The Econometrics of Block Rate Pricing in Agriculture.” *Am. J. Agr. Econ.* 88 (November): 986-999.

Buchanan, James M. and Gordon Tullock. 1975. “Polluters‘ Profits and Political Response: Direct Controls Versus Taxes.” *Am. Econ. Rev*. 65(1): 139-147.

Burtless, Gary and Jerry A. Hausman. 1978. “The Effect of Taxation on Labor Supply: Evaluating the Gary Negative Income Tax Experiment.” *J.P.E.* 86 (December): 1103-1130.

Damania, Richard, Per G. Fredriksson, and John A. List. 2003. “Trade Liberalization, Corruption, and Environmental Policy Formation: Theory and Evidence.” *J. Env. Econ. and Manage.* 46 (November): 490-512.

EPA. 2001. *The United States Experience with Economic Incentives for Protecting the Environment*. EPA-240-R-01-001. Washington, DC: USA.

— 2004. *International Experiences with Economic Incentives for Protecting the Environment*. EPA-236-R-04-001. Washington, DC: USA.

Finkelshtain, Israel and Yoav Kislev. 1997. "Prices vs. Quantities: The Political Perspective." *J.P.E.* 105 (February): 83-100.

— 2004. "Taxes and Subsidies in a Polluting and Politically Powerful Industry." *J. Asian Econ.* 15(June): 481-492.

Fredriksson, Per G. 1997. "The Political Economy of Pollution Taxes in a Small Open Economy." *J. Env. Econ. and Manage.* 33(May): 44-58.

Hadar, Josef and Russell William R. 1969 "Rules for Ordering Uncertain Prospects." *Am. Econ. Rev*. 59(Mar): 25-34.

Gawande, Kishore and Christopher Magee, C. 2010. "Free-Riding on Protection for Sale." Online, accessed January 15, 2010: http://www.facStaff.bucknell.edu/cmagee/Free%20Riding%20on%20Protection%20for%20Sale.pdf.

Grossman, Gene M. and Elhanan Helpman. 1994. "Protection for Sale." *Am. Econ. Rev*. 84 (September): 833-850.

Greene, William H. 2003. *Econometric Analysis*, 5th ed., Upper Saddle River, NJ: Pearson Education.

Kislev, Yoav. 2006. "The Water Economy of Israel" in: *Water in the Middle East* K. David Hambright, F. Jamil Ragep, and Joseph Ginat (eds.) Norman, OK: U. of Oklahoma Press.

— and Yevgenia Vaksin. 2003. *A Statistical Atlas of Israeli Agriculture* [Hebrew]. Research Paper, Rehovot, Israel: Center for Agricultural Economic Research.

Margoninsky, Yossi. 2006. "The Political Economy of Rent Seeking: The Case of Israel's Water Sector." *J. Comp. Policy Analysis* 8 (January): 259-270.

Menahem, Gila. 1998. "Policy Paradigms, Policy Networks, and Water Policy in Israel." *J. Pub. Pol.* 18(September-December): 283-310.

Mizrahi, Shlomo. 2004. “The Political Economy of Water Policy in Israel: Theory and Practice.” *J. Comp. Policy Analysis* 6 (September): 275-290.

Moffitt, R. 1986. “The Econometrics of Piecewise-Linear Budget Constraint: A Survey and Exposition of Maximum Likelihood Method.” *J. Business and Econ. Statistics* 4(July): 317-28.

Molle, Francois. 2009. “Water Scarcity, Prices, and Quotas: A Review of Evidence on Irrigation Volumetric Pricing.” *Irrigation and Drainage Systems* 23 (February): 43-58.

OECD. 2010, *European Environment Agency, OECD/EEA Database on Instruments Used for Environmental Policy and Natural Resources Management*, http://www2.oecd.org/ecoinst/queries/index.htm.

Ravikovitch, Shlomo. 1992. *The Soils of Israel: Formation, Nature, and Properties*. [Hebrew]. Israel: Hakibbutz HaMeuchad Publications.

Roelfsema, Hein. 2007. “Strategic Delegation of Environmental Policymaking.” *J. Env. Econ. and Manage.* 53 (March): 270-275.

Rothschild, Michael and Joseph Stiglitz, 1976. “Equilibrium in Competitive Insurance Markets: An Essay on the Economics of Imperfect Information.” *Quart. J. of Econ.* 90(4):629-49.

Shaham, G. 2007. Water Supply Cost by Village [personal communication, Hebrew].

Yu, Zhihao. 2005. “Environmental Protection: A Theory of Direct and Indirect Competition for Political Influence.” *Rev. Econ. Studies* 72 (January): 269–286.

Zusman, Pinhas. 1976. “The Incorporation and Measurement of Social Power in Economic Models.” *Inter. Econ. Rev.* 17 (June): 447-462.

— 1997. “Informational Imperfections in Water Resource Systems and the Political Economy of Water Supply and Pricing in Israel” in *Decentralization and Coordination of Water Resource Management*, Douglas D. Parker and Yacov Tsur (eds.) Boston: Kluwer.

— and Amotz Amiad. 1977. “A Quantitative Investigation of a Political Economy: The Israeli Dairy program.” *Am. J. Agr. Econ.* 59 (February): 88-98.

# Appendix A – Comparative Statics

The recursive decision-making process implies that the comparative statics exercises should be executed in two stages. The effect of an exogenous change on the price is analyzed in the first stage. In the second stage, the transformation in the quotas due to the direct effect of the exogenous change and the indirect effect (through the price) are examined.

## *A. The Price*

Recalling Eq. (6), for any exogenous parameter, $a$, $\frac{dp^*}{da} = -\frac{G_{pa}}{G_{pp}}$ and since $G_{pp} < 0$, it follows that $\text{sgn}\left(dp^*/da\right) = \text{sgn}\left(G_{pa}\right)$. The results regarding *β*, *θ*, and *c* are shown first:

$$G_{p\beta} = -\theta\left[W\left(p, f\left(\nu\right)\right) - \int_{\nu^l}^{\nu^h}\left(\pi_w\left(p,\nu\right) - p\right)w_p f\left(\nu\right)d\nu\right] < 0, \qquad \text{(A1)}$$

$$G_{p\theta} = -\beta\left[W\left(p, f\left(\nu\right)\right) - \int_{\nu^l}^{\nu^h}\left(\pi_w\left(p,\nu\right) - p\right)w_p f\left(\nu\right)d\nu\right] < 0, \qquad \text{(A2)}$$

$$G_{pc} = -c\int_{\nu^l}^{\nu^h} w_p f\left(\nu\right)d\nu > 0 \qquad \text{(A3)}$$

We shell now examine the impact of a technological improvement or an increase in the terms of trade. We model such changes by a shift in the distribution of $(\gamma, q^0)$, such that the ex-post conditional distribution of $\gamma$, conditioned on any $q^0$, FSD the ex-ante one. For the comparative statics exercises, we examine the effect of small changes in the distribution. An increase in a parameter, $a$, represents FSD shift of the conditional distribution of $\gamma$, conditioned on $q^0$, if and only if:

$$\int_{\gamma^l}^{\gamma} Z_a(x,a \mid q^0)dx \le 0 \quad \forall \gamma \in (\gamma^l, \gamma^h),\ \ q^0$$

Define $\gamma^p(q^0, p)$ by $\pi_w(q^0, \gamma^p) = p$. That is, for any price and quota level, $\gamma^p(q^0, p)$ is the level of technology for which the VMP of water equals its price. Using this notation, water consumption can be rewritten in terms of $\gamma$:

$$w(q^0, p, \gamma) = \begin{cases} D(p, \gamma) & \gamma \in [\gamma^l, \gamma^p] \\ q^0 & \gamma \in (\gamma^p, \gamma^h] \end{cases}$$

We can now rewrite Eq. (6) in terms of the quota distribution and the conditional distribution of $\gamma$, given $q^0$:

$$\int_{q^l}^{q^h} \left[ \int_{\gamma^l}^{\gamma^h} \left(\pi_w(p, \gamma) - c\right) w_p Z\left(\gamma, a \mid q^0\right) d\gamma \right] k(q^0) dq^0$$
$$= \beta\theta \int_{q^l}^{q^h} \left[ \int_{\gamma^l}^{\gamma^h} \left( w(p, q^0, \gamma) - \left(\pi_w(p, \gamma) - p\right) w_p \right) Z\left(\gamma, a \mid q^0\right) d\gamma \right] k(q^0) dq^0$$

Examining the effect on $p$:

$$\begin{aligned} G_{pa} = & \int_{q^l}^{q^h} \left[ \int_{\gamma^l}^{\gamma^h} \left(\pi_w(p, \gamma) - c\right) w_p Z_a\left(\gamma, a \mid q^0\right) d\gamma \right] k(q^0) dq^0 \\ & - \beta\theta \int_{q^l}^{q^h} \left[ \int_{\gamma^l}^{\gamma^h} \left( w(p, \gamma) - \left(\pi_w(p, \gamma) - p\right) w_p \right) Z_a\left(\gamma, a \mid q^0\right) d\gamma \right] k(q^0) dq^0 \end{aligned} \tag{A4}$$

Assuming that $w_{p\gamma} = 0$, all three: $\left(\pi_w(p, \gamma) - c\right) w_p$, $\left(\pi_w(p, \gamma) - p\right) w_p$ and $-w(p, \gamma)$ are decreasing functions of $\gamma$ and hence their expected value is decreasing in $a$ (Hadar and Russel (1969)). Therefore, $G_{pa} < 0$, proving that the price decreases with FSD shift in $Z\left(\gamma, a \mid q^0\right)$. An increase in the historical quotas is modeled by a shift in the distribution of $(\gamma, q^0)$, such that the ex-post conditional distribution of $q^0$, conditioned on any $\gamma$, FSD the ex-ante one. Following the same line of proof as of the technological improvement, it can be shown that $G_{pa} > 0$, proving that the price increases with FSD shift in $k\left(q^0, a \mid \gamma\right)$.

*B. The Quotas Allocation*

Recalling Eq. (4), for any exogenous parameter, $a$, $\frac{dq^*}{da} = -\frac{G_{qa}}{G_{qq}}$ and since $G_{qq} = \pi_{ww}\left(q^*\left(\nu\right),\nu\right) < 0$, it follows that $\operatorname{sgn}\left(dq^*/da\right) = \operatorname{sgn}\left(G_{qa}\right)$. Employing Eq. (4) it can easily verified that $G_{q\theta} = 0$, $G_{qc} = -\frac{\beta p^*}{1+\beta} < 0$ and $G_{q\beta} = -\frac{p-c}{(1+\beta)^2} > 0$. Moreover, the changes in the initial quota distributions and technological level have no direct effects on the quota allocation rule.

## Appendix B - Likelihood Function

Let $\varphi = \alpha + \varepsilon$ and let $g_{\varphi\alpha}(\varphi,\alpha)$ denote the joint density of $\varphi$ and $\varepsilon$, where the density $g_{\varphi\alpha}$ is bivariate normal with parameters $\sigma_\varphi^2 = \sigma_\alpha^2 + \sigma_\varepsilon^2$, $\sigma_\alpha^2$, and $\rho = \frac{Cov(\alpha,\alpha+\varepsilon)}{\sigma_\varphi\sigma_\alpha} = \frac{\sigma_\alpha^2}{\sqrt{\left(\sigma_\alpha^2+\sigma_\varepsilon^2\right)\sigma_\alpha^2}} = \frac{\sigma_\alpha}{\sigma_\varphi}$. In the same manner, $g_{\varphi\alpha u}$ and $g_{\alpha\varepsilon u}$ are the joint densities of $\varphi$, *α,* and *u;* and *α, ε,* and *u* respectively. The distribution of $\alpha$ conditional on $\varphi$ implies $g_{\varphi\alpha}(\varphi,\alpha) = g_{\alpha|\varphi}(\alpha|\varphi)g_\varphi(\varphi)$, and due to the independence of *α, ε,* and *u* there are $g_{\varphi\alpha u} = g_{\alpha|\varphi}g_\varphi g_u$ and $g_{\alpha\varepsilon u} = g_\alpha g_\varepsilon g_u$. Omitting nonessential indices and functions' operators, the probability of observing a certain pair of *w* and $q_t$ can be expressed in terms of *g*:

$$
\begin{aligned}
&L\left(w,q_t,\boldsymbol{\theta}\right) = \\
&g_\phi\left(w-D\right)g_u\left(q_t-q_{t-1}\right)\int_{-\infty}^{\min\left(\hat{\alpha}^t,\hat{\alpha}^{t-1}\right)} g_{\alpha|\phi}\left(\alpha\right)d\alpha + g_\phi\left(w-D\right)g_u\left(q_t-Q\right)\int_{\hat{\alpha}^{t-1}}^{\hat{\alpha}^t} g_{\alpha|\phi}\left(\alpha\right)d\alpha \; + \\
&g_\varepsilon\left(w-q_t\right)g_u\left(q_t-q_{t-1}\right)\int_{\hat{\alpha}^t}^{\hat{\alpha}^{t-1}} g_\alpha\left(\alpha\right)d\alpha \; + \; g_\varepsilon\left(w-q_t\right)g_u\left(q_t-Q\right)\int_{\max\left(\hat{\alpha}^t,\hat{\alpha}^{t-1}\right)}^{\infty} g_\alpha\left(\alpha\right)d\alpha
\end{aligned}
$$

where $\hat{\alpha}^t = q_t - D$ and $\hat{\alpha}^{t-1} = q_{t-1} - D$. The distribution $g_{\varphi\alpha}$ is bivariate normal, hence $g_{\alpha|\varphi}(\alpha|\varphi)$ is distributed $N\left(\rho^2\varphi,\sigma_\alpha^2\left(1-\rho^2\right)\right)$. Using $\phi$ and $\Phi$ to denote the density and the cumulative distribution functions of a standard normal random variable respectively, the probability function can be written:

$$
\begin{aligned}
&L\left(w, q_t, \boldsymbol{\theta}\right) = \\
&\frac{1}{\sigma_\phi}\phi(h)\frac{1}{\sigma_u}\phi(o)\Phi\left(\min\left(r^t, r^{t-1}\right)\right) + \frac{1}{\sigma_\phi}\phi(h)\frac{1}{\sigma_u}\phi(y)\left|\Phi\left(r^t\right) - \Phi\left(r^{t-1}\right)\right| + \\
&\frac{1}{\sigma_\varepsilon}\phi(s)\frac{1}{\sigma_u}\phi(o)\left|\Phi\left(k^{t-1}\right) - \Phi\left(k^t\right)\right| + \frac{1}{\sigma_\varepsilon}\phi(s)\frac{1}{\sigma_u}\phi(y)\left[1 - \Phi\left(\max\left(k^t, k^{t-1}\right)\right)\right]
\end{aligned}
$$

where $o = \dfrac{q_t - q_{t-1}}{\sigma_u}$, $h = \dfrac{w - D}{\sigma_\varphi}$, $r^t = \dfrac{\hat{\alpha}^t - \rho^2\left(w - D\right)}{\sigma_\alpha\sqrt{1-\rho^2}}$, $r^{t-1} = \dfrac{\hat{\alpha}^{t-1} - \rho^2\left(w - D\right)}{\sigma_\alpha\sqrt{1-\rho^2}}$,

$y = \dfrac{q_t - Q}{\sigma_u}$, $s = \dfrac{w - q_t}{\sigma_\varepsilon}$, $k^t = \dfrac{\hat{\alpha}^t}{\sigma_\alpha}$, and $k^{t-1} = \dfrac{\hat{\alpha}^{t-1}}{\sigma_\alpha}$.

Table 1 – Comparative statics of separating equilibrium

| **Parameter** | **Impact on** $p^*$ | **Impact on** $q^*(\nu)$ |
|---|---|---|
| $\beta$ | - | + |
| $\theta$ | - | + |
| $c$ | + | - |
| $z(\gamma)$ [a] | - | + |
| $k^0(q^0)$ [a] | + | - |

a. Analyzed based on a linear water's VMP function

Table 2 – Description of variables

| **Variable** | **Spatial unit** | **Units** | **Mean / Frequency** | **Std. Dev.** |
|---|---|---|---|---|
| Freshwater use[a] | Village | [$10^3$ $m^3$ $year^{-1}$] | 958 | 472 |
| Freshwater quota[a] | Village | [$10^3$ $m^3$ $year^{-1}$] | 1,028 | 408 |
| Freshwater price[a,b] | Region | [$ $(m^3)^{-1}$ ] | 0.11 | 0.02 |
| Energy delivery costs[c,b] | Village | [$ $(m^3)^{-1}$ ] | 0.23 | 0.10 |
| Capital & operation costs[c,b] | Village | [$ $(m^3)^{-1}$ ] | 0.14 | 0.08 |
| October rainfall[d] | Village | [mm $month^{-1}$] | 35.9 | 26.2 |
| April rainfall[d] | Village | [mm $month^{-1}$] | 22.3 | 22.5 |
| Annual rainfall[d] | Village | [mm $year^{-1}$] | 526 | 183 |
| Elevation above sea level[a] | Village | [m] | 183 | 223 |
| Agricultural land[a] | Village | [$10^3$ $m^2$] | 2,745 | 2,201 |
| Orchards, area[a] | Village | [$10^3$ $m^2$] | 738 | 578 |
| Light soil[d] | Village | Dummy | 2% | - |
| Medium-light soil[e] | Village | Dummy | 44% | - |
| Heavy-medium soil[e] | Village | Dummy | 6% | - |
| Heavy soil[e] | Village | Dummy | 48% | - |
| North[a] | Village | Dummy | 37% | - |
| Center[a] | Village | Dummy | 43% | - |
| South[a] | Village | Dummy | 20% | - |
| Cooperative (*moshavim*)[a] | Village | Dummy | 78% | - |
| Communal (*kibbutzim*)[a] | Village | Dummy | 22% | - |
| Natural enrichment[f] | Nationwide | [$10^6$ $m^3$ $year^{-1}$] | 1,280 | 313 |
| Terms of trade[g] | Nationwide | Index (1952=100) | 65.2 | 1.30 |

a. Obtained from the Agriculture and Rural Development Ministry

b. Monetary terms are in 1987 US dollars

c. Calculated using data obtained from engineer Gabriel Shaham [personal communication]

d. Obtained from the Israeli Meteorological Service

e. Based on Ravikovitch (1992)

f. Enrichment of natural storages in the previous year as calculated by the Israeli Water Commission

g. From the dataset of Kislev and Vaksin (2003)

Table 3a – Demand and quota allocation functions

| | | |
|---|---|---|
| Observations | 1,051 | |
| Wald $\chi^2(14)$ | 159.6 | |
| $\sigma_\alpha$ | 383** | |
| $\sigma_\varepsilon$ | 241** | |
| $\sigma_{you}$ | 144** | |
| | Demand ($D$) | Quota ($Q$) |
| Price | -7,619** ($\delta_1$) | -3,686** ($\delta_2$) |
| Energy costs | - | -311.8** |
| Capital & operation costs | - | 321.0** |
| Natural enrichment | - | 0.117** |
| $q_{t-1}$ | - | 0.757** |
| Elevation | -0.858** | - |
| October rainfall | -0.994 | - |
| April rainfall | 1.761 | -3.098** |
| Annual rainfall | 0.273 | -0.004 |
| Agricultural land | 0.049** | 0.013** |
| Orchard area | 0.352** | 0.078** |
| Light soil | -75.39 | 128.7** |
| Medium-light soil | 94.08 | -29.33** |
| Heavy-medium soil | 2,645 | 139.6** |
| Terms of trade | 72.48* | 29.55** |
| Center | -6.96 | 57.66** |
| South | 258.6* | 30.35 |
| Cooperative | -164.27* | -4.41 |
| Constant | -2,849 | -1,452** |
| $\frac{\beta}{1+\beta} = \delta_2/\delta_1$ [a] | 0.48** (95% Conf.: 0.06 to 0.91) | |

* = significant at 10%; ** = significant at 5%

a. Calculated using the delta method for computing standard deviations (Green 2003)

Table 3b – Price formation equation

| **Observations** | **1,039** |
|---|---|
| Wald $\chi^2(4)$ | 202.4 |
| $W/N^l$ (instrumented)[a] | $-2.81\times10^{-5}$** ($\delta_3$) |
| Energy costs | $7.64\times10^{-2}$** |
| Capital & operational costs | -0.19** |
| Natural enrichment | $-1.21\times10^{-5}$** |
| Constant | 0.193** |
| $\theta = \delta_3\delta_1\left(\delta_1 - \delta_2\right)/\delta_2$ [b] | 0.23<br>(95% Conf.: -0.30 to 0.75) |

* = significant at 10%' ** = significant at 5%

a. Instruments include rainfall during October and April, elevation, and dummies for years and location in the central and southern areas of the country

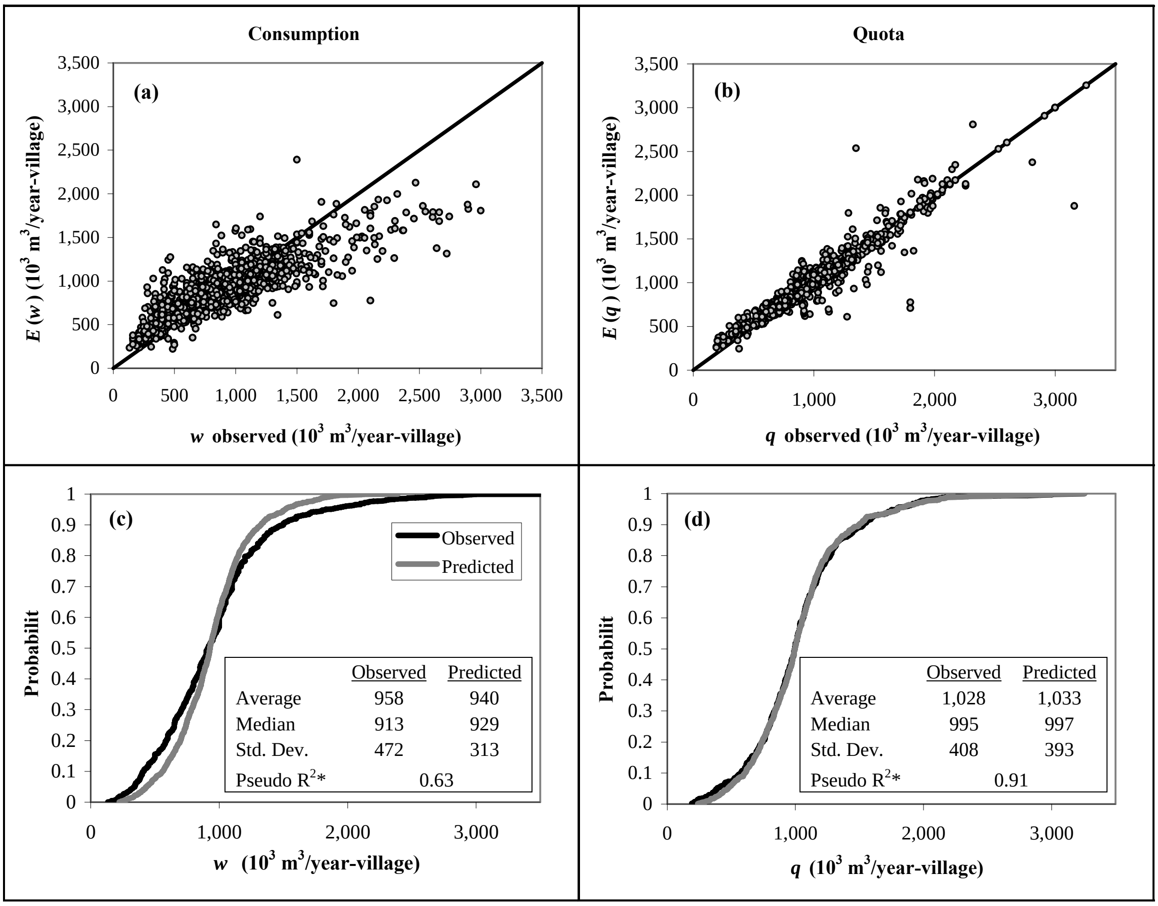
b. Calculated using the delta method for computing standard deviations

Table 4 – Impact of exogenous changes (Elasticities)

| | Stage | Terms of Trade | Rainfall | $\beta$ | $\theta$ | Energy Costs | $q_{t-1}$ |
|---|---|---|---|---|---|---|---|
| $p^*$ | I | -2.73 | -0.05 | -0.77 | -0.69 | 2.89 | 0.28 |
| $\Pr(\nu \le p^*)$ | I | -10.43 | -0.25 | -0.83 | -0.72 | 4.09 | 0.88 |
| $E(q)$ | II | 0.77 | 0.25 | 0.12 | 0.33 | -0.58 | -0.07 |
| $E(w)$ | II | 3.47 | 0.30 | 0.22 | 0.44 | -1.88 | -0.09 |
| $E$(Deadweight Loss) | II | 1.74 | 0.59 | 1.06 | 1.25 | -0.10 | -0.30 |

Table 5 – Simulated control regimes (per-village average)

| | **Separating (observed)** | **Pooling quota** | **Pooling price** | **Pooling price ($\theta = 1$)** |
|---|---|---|---|---|
| Average cost (\$ / m$^3$) | 0.37 | 0.37 | 0.37 | 0.37 |
| Average price (\$ / m$^3$) | 0.11 | - | 0.18 | 0.09 |
| $E(\pi_w(q))$ (\$ / m$^3$) | 0.19 | 0.13 | - | - |
| $E(w)$ ($10^3$ m$^3$ / year-village) | 940 | 1,403 | 835 | 1,543 |
| $E(q)$ ($10^3$ m$^3$ / year-village) | 1,033 | 1,412 | - | - |
| $E(DWL)$ ($10^3$ \$ / year-village) | 60 | 94 | 5 | 115 |




* Pseudo $R^2$ refers here to the square of the correlation between predicted and observed values.

Figure 1 – Predicted versus observed distributions of water consumption ((a) and (c)) and quota ((b) and (d))