July, 1998

Ran Mosenson on the Public Regulation of the Water Economy*

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Abstract

Ran Mosenson (1936-1998) developed a comprehensive approach to the public regulation of the water and electricity sectors, founded mainly on basic economic theory. Government intervention in the water economy will regulate the use of the limited natural resource and the operation of the suppliers who are natural monopolies. The regulation of water use will be in accordance with the law in Israel by which all water resources belong to the public at large. Monopolies will be controlled for quality of service and prices that will be set according to marginal cost in season and place and adjusted to cover total cost. Suppliers will pay to the public coffers for the utilization of limited resources.

Unlike many of us who work and write on a great variety of subjects, Ran Mosenson focused over the last twenty years on one issue – the regulation of public utilities, particularly electricity and water. Mosenson thought in theoretical terms: his approach to practical problems was theoretical, the solutions he suggested were grounded in basic economic theory. He came to economics from mathematics and his conception of economic models was geometric, of structures in space. Mosenson's approach to theory was uncompromisingly rigorous: he rejected even those compromises that have been accepted by most of the profession. His analysis was not, however, detached from reality: it was part of a larger view of public regulation stemming from the insights and principles provided by economic theory.

Mosenson's strength lay not only in theory. He studied his subject matter thoroughly. His knowledge of the electricity and water sectors was based on his understanding of physics and mathematics and his ability to comprehend the language of

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* Ran Mosenson (1936-1998) grew up on a kibbutz and studied in the Hebrew University and the Massachusetts Institute of Technology. In his last years he worked in the budget office of the Treasury in Jerusalem.

This paper is a translation, with minor modifications, of the Hebrew original (**Economic Quarterly**, July, 1998). Detailed references to Mosenson's work on regulation, which was all in Hebrew, is omitted. The paper was written at Dartmouth College, New Hampshire. Shlomo Yitzhaki and Meir Kohn read earlier versions and improved the presentation significantly.

engineers. He read hydrological reports, followed developments in other countries, and studied the production and transport systems for water and electricity. His clear vision and sharp analytical skills made him a sharp critic. The views he expressed – both orally and in writing – were devoid of compromise and sometimes extreme.

Mosenson offered no theoretical novelties: "there is nothing novel here, no original 'invention', just a straightforward application of a theory that is classical and familiar." His strength lay in bringing this theory to bear on practical problems, and this he did thoroughly and systematically. Mosenson had a characteristic style, but his writing was uneven: some of his papers were crystal clear, but much of his work was hard to follow. Perhaps the reason was the need to compress a complex message within a constrained framework; perhaps it was also his deep personal involvement in everything he did and his burning belief in the positions he took and the importance of the topics he raised. I cannot think of a better way to honor Mosenson's memory, and in this to contribute to the discussion on public regulation, than to collect and present, to the best of my ability, the essence of his writing and the ideas and principles that he tried to promote over the last twenty years.[1]

I shall review here Mosenson's approach to the regulation of the water economy, the part of his work with which I am most familiar; the principles he suggested for the electricity sector are very similar. Logically, one might prefer to progress from the general picture to the details, but the review will be more comprehensible if we go in the other direction, beginning with the technical and then going on to the broader issues. Everything I present will be from the work of Ran Mosenson, but only particular expressions or paragraphs that emphasize Mosenson's approach or style will be quoted explicitly (my translations). Before proceeding with the review, it may be helpful to summarize briefly the salient features of the water economy in Israel.

Main features of the water economy

The natural source of water in Israel is winter rain. This accumulates mainly in the Sea of Galilee and in two underground aquifers – one under the coastal plan between Haifa and Gaza and the other under the mountains, mostly in the West bank and down to the Negev. Water is stored as well in several smaller aquifers and reservoirs. The National Conveyor, constructed 35 years ago, moves water from the Sea of Galilee in the north and from wells in the center of the country to the south and to the Negev. Approximately 60 percent of water is supplied by a single, government-owned company, Mekorot, which also operates the National Conveyor; the rest is supplied by regional cooperatives, municipalities, and private well-owners.

By law, all water sources in the country are publicly owned, and their utilization is controlled by the Water Commissioner. Allocation is administrative, the Commission issues permits for production (extraction) to suppliers as well as allocations (quotas) for consumers. In the past, these quotas constrained the use of water in agriculture. However, more recently, with prices for water higher and prices for agricultural products lower, agriculture fails to exploit all of its allocation. Households, on the other hand, were never

[1] In the last year of his life, Mosenson offered a course on public regulation in the Department of Economics in Jerusalem. He managed to do this only once.

constrained in their consumption, and formal ineffective, quotas for this sector were abolished several years ago.

The prices charge by Mekorot are set by the government and published officially. Prices are set lower for agriculture and higher for the household sector (this refers to the price at the city gate: distribution to urban consumers is in the hands of local authorities). Industry and some special consumers also pay lower prices. The prices charged by Mekorot are subsidized, with the government covering approximately 30 percent of the cost. In the past, part of the subsidy was implicit: While Mekorot operated the government-financed National Conveyor, its capital cost was not reflected in water prices. Hovewer, since 1993, Mekorot has been working under a "cost agreement," by which it purchased the capital assets of the water economy and their depreciation became a recognized component of its cost. Government support has therefore become explicit.

Mekorot's consumers, within each sector, pay essentially identical prices. At the same time, many other users have access to lower-cost water. An "equalization fund" was set up, as a subsidiary of the Water Commission, to levy duties on low-cost suppliers to finance grants to those who face higher cost. Mekorot, which supplies users located far from the sources of water and at higher altitudes, received the lion's share of the grants. Under the 1993 cost agreement, Mekorot is now fully compensated by the government, and no longer entitled to these grants. As a result, the fund lacks a purpose and continues to accumulate financial surpluses. [Payments to the equalization fund have been replaced recently by an extraction levy (February 2001).]

For the last several decades, agriculture has been using approximately two thirds of the country's water, including recycled and brackish water. Increasing population and the peace agreements have expanded the demand for potable water and it can be expected that future supply will come from desalination of sea water in growing amounts.

Public intervention

There are two main justifications for public intervention in the water economy. One is that the lakes and aquifers from which water is extracted are common resources, and the other is that water suppliers are natural monopolies. Natural monopolies are generally operated as public utilities, their prices controlled and set to cover costs, including a return on equity capital. The determination of these prices raise a difficult problem. If the public utility produces a single product (or service), price can be set equal to average cost, so that total revenue covers total cost. Usually, however, public utilities produce a number of products – for example, water in the summer and water in the winter; or water near its source in the north and water far from it in the south or in the mountains (similarly, electricity at peak-load and low-load hours). Production is therefore joint. Some factors – pipelines, pumps, labor, management – are common to all seasons and places; while others, especially energy, can be attributed separately to each season and place. The problem that emerges is, What prices to set for the different products, for water in different seasons and locations?

For the joint production of several products, total cost remains a meaningful concept and is appropriately measured by conventional accrual accounting. However, for

joint production, the average cost of an individual product is meaningless, and it cannot therefore serve as the basis of pricing. But, and this is the crucial point, even though average cost is meaningless, marginal cost is well defined. Consequently, as we shall see presently, prices for public utilities under joint production can be determined in a two-stage process: marginal costs determine relative prices and total costs determine the level of prices. We begin therefore with a discussion of marginal costs.

Basic relations

Mosenson never tired of explaining that water pricing must be based on marginal costs (he preferred to call them incremental costs). His argument had several elements:

(a) marginal cost is the only feasible basis for pricing under joint production;

(b) the marginal cost of water supply, for each place and season, is easy to calculate;

(c) charging for water according to marginal cost will approximately cover total cost;

(d) marginal-cost prices (prices equal to marginal costs) can be scaled to cover total cost.

Item (a) was discussed above; we proceed to Item (b). Initially, we limit our discussion to the **horizontal** conveyance of water, assuming no altitude differences in points of delivery. We also assume that the factors of production are combined optimally in the supply of water and that water is supplied under conditions of constant returns to scale. These latter two assumptions are discussed below.

Three main factors of production are employed in the supply of water – capital, labor, and energy. Simplifying slightly, capital and labor can be combined into a fixed factor, with energy regarded as the sole input that varies with the volume of water supplied. It is easy to track the consumption of energy, mostly electricity, in water projects. With this information it is possible to calculate the average energy cost for every place and time. From this it takes only "a click of a key" to derive the marginal cost for a horizontal system.

By an accepted engineering formula, the average energy cost in a horizontal pipeline of given length is proportional to the volume squared. Let x be the volume of water moved through the pipeline in cubic meters per unit time (day, hour, month, or season), and K a constant characterizing the diameter of the pipeline, its length, friction, and the per-unit price of energy. Then average variable (energy) cost in dollars per cubic meter is

$$AVC = Kx^2 \tag{1}$$

and total variable cost is

$$TVC = xAVC = Kx^3. \tag{2}$$

Marginal cost, the first derivative of total variable cost, is three times the average cost:

(3) $$MC = 3Kx^2 = 3AVC.$$

From equation (3), if we know the average cost, the calculation of the marginal cost is immediate: just multiply *AVC* by three. However, energy is only one of the factors of production. What about the other factors? The answer is simple and relies on the following well-known result from price theory: if a product, *x*, is produced with two factors, *a* and *b*, then, **if the use of factors is optimal**,

(4) $$MC = MC_a = MC_b$$

That is, the marginal (incremental) cost of producing an additional unit of *x* equals the marginal cost of producing it by increasing the amount of *a* which, in turn, is equal to the marginal cost of producing it by increasing the amount of *b*.

Although equation (4) is a well-known result, it is often forgotten. A common error is to assert that marginal cost in the short run is the marginal cost with respect to energy while marginal cost in the long run is the marginal cost with respect to energy **plus** the marginal cost with respect to capacity. In reality, we see from (4) that long-run marginal cost is **either** the marginal cost with respect to energy **or** the marginal cost with respect to capacity (the two marginal costs are equal in the long run, when costs are minimized with respect to use of the two factors). Taking the sum of the marginal costs gives exactly double the correct number. This mistaken assertion has even appeared in official publications (for example, NARUC, 1992) and therefore "one should be careful in following the methods accepted in Europe and in the United States as they are in part ignorant of existing 'classical' theory."

Is the assumption of optimal use of factors of production reasonable? First, the concept of cost has no meaning unless factors are used optimally: if the combination of factors is not optimal, output can be increased with no additional cost or even with a reduction in cost. Second, prices based on the assumption of optimal use of factors will direct users towards an appropriate allocation of inputs.

Costs

Consider a plant (or firm) using two factors of production – one fixed ("capital"), the other variable (energy). If these factors are combined optimally, the plant is of optimaum scale. At this scale, the marginal cost curve, *MC*, cuts the average total cost curve, *ATC*, at its minimum. At this point marginal cost is equal to average cost,

(5) $$ATC = MC,$$

so that a marginal-cost price exactly covers costs.

To calculate, average fixed costs, *AFC*. note that

(6) $$AFC + AVC = MC$$

and, therefore, by (3),

(7) $$AFC = MC - AVC = 2\,AVC$$

That is, the average cost of capital is twice the average cost of energy [for the particular cost function (1)]. Note that this ratio of costs, 2:1, is independent of the prices of the factors of production. When the price of energy is high, more capital will be used (for example, larger diameter pipelines), when the price of energy is low and capital relatively expensive, suppliers will economize on capital (again, we disregard labor whose role in water supply is comparatively minor).

An important practical conclusion follows from equation (5): charging for water according to marginal cost will cover total cost. This conclusion is consistent with the Euler equation for a constant returns to scale production function

(8) $$P_x x = VMP_a a + VMP_b b\,,$$

where VMP_i is the value of marginal product of the *i*th factor; P_x is the price of output, x the quantity of output, and a and b the quantities used of the two factors. For a firm in competitive equilibrium, the price of the product is equal to marginal cost and the price of input i equals the value of its marginal product. Hence, equation (8) can be rewritten

(8a) $$MCx = P_a a + P_b b\,.$$

Therefore, by charging marginal cost, the firm covers total cost, the sum of the costs of all factors.

We need to extend the last result to the joint production of several outputs. Suppose a firm produces jointly two outputs, x_1 and x_2 (water supplied in winter and water supplied in summer), with two factors, a and b. Factor a is used jointly in producing the two products, the input of factor b can be meaningfully divided between the part used in the production of x_1 , b_1 , and the part used in the production of x_2, b_2. The production of both outputs is characterized by constant returns to scale. Minimizing cost, given x_1 and x_2 (the quantities of water supplied in the two seasons), one obtains

(9) $$MC_1x_1 + MC_2x_2 = P_a a + P_1 b_1 + P_2 b_2\,.$$

That is, the sum of outputs times corresponding marginal costs equals the sum of the costs of all inputs. This means that marginal-cost pricing of each of the outputs will cover total cost of the joint-production firm.

The solution of the same cost minimization problem also yields an expression for the value of marginal product of factor a

(10) $$VMP_a = VMP_a^1 + VMP_a^2$$

where VMP_a^j is the value of the marginal product of factor a in the production of output j. That is, the value of the marginal product of the joint factor (for example, an additional unit of capital that operates year round) is the sum of the its marginal contribution across seasons and locations. The joint factor is a "common input," common to all jointly produced services. Equation (10) provides a basis for decisions on investments in the joint factor.

Cost minimization and the structure of prices

Until now, we have considered the conveyance of water in a horizontal system. We now extend the analysis to the other aspects of water supply. The presentation here is heuristic; Mosenson provided a detailed mathematical treatment in his 1986 paper.

The total cost of water supply can be written as the sum of its component costs

(11) cost of supply = cost of production + cost of horizontal conveyance + cost of lifting + cost of replenishment

The two main items in equation (11) are the cost of horizontal conveyance and the cost of lifting. The cost of production (extraction) refers to production from wells and is not an important item in the cost of the national water system. Similarly, replenishment (artificially adding water to the aquifers in the winter) is done in the coastal areas and in relatively small amounts. As we saw from equation (2), the cost of horizontal transfer is a quadratic function of the throughput of water. The cost of lifting, on the other hand, is a linear function of the quantity of water and of elevation. Therefore, the marginal cost of lifting is a constant. This simplifies computation and allows us to write equation (11) as a sum (in additive form).

Equation (11) can and should be broken down in three ways:

(a) Across destinations. For example, (11) can be split between one component for the conveyance and lifting of water from the Sea of Galilee to the center of the country and another for the conveyance and lifting from the center to the Negev.

(b) Across time. For example, between peak and trough seasons.

(a) Between variable cost (energy) and fixed cost (capacity).

The breakdown between variable and fixed costs is also the breakdown with respect to time horizon; short-run cost minimization subject to capacity constraints versus long-run cost minimization, when capacity may be changed via investment. In the long run, fixed costs are variable.

Equation (11) is the basis for addressing two planning problems. The first is, given quantities demanded across destinations and seasons, how to meet this demand at the lowest possible cost (in the short run, given existing capacity, and in the long run allowing capacity to be altered). The second problem is what prices to charge for water across destinations and seasons. These two problems are really two aspects of the same problem – the primal and the dual. Its solution provides the cost of supply – and in the long run the level of investment – as well as the value of quantities supplied and prices.[2]

The solution to the dual provides an array of values that, when used appropriately, have important practical implications:
(a) the marginal cost of supplying water to different destinations and in different seasons, which may be used to set appropriate prices;
(b) values for the marginal contribution of capacity, which may be used (together with costs of capital and other fixed costs) to determine investment and expansion plans;
(c) shadow prices of water at its various sources.
The magnitudes of these prices are related to the magnitudes of the quantities supplied in a connection "that depends in its structure on the elegant duality of projective geometry."

The economic meaning of the duality of the solution to (11) is that the flows of monetary payments that correspond to the flows of water from sources to destinations should be determined according to marginal values. That is, the prices asked (equal to marginal costs) for supplying water across destinations and seasons and the prices paid for water taken from the different sources should correspond to the shadow prices of the solution. Also the payment to providers of water for replenishment should correspond to the shadow price of water in the aquifers to be replenished. This system of payments may be seen as a two-level structure: at the first level, payment for water at its sources; at the second, payment for the cost of transporting and supplying the water. In this way, each economic unit faces prices that reflect the appropriate marginal cost or contribution. At the same time, the total cost of capital and of operation of the water supply system is recovered – approximately – at the second level of the payment structure. Payments for water taken from the different sources are recognized costs for the suppliers, who will charge prices covering both these payments and their operating costs.

Accrual accounting and the level of prices

The reason for the qualification "approximately" with respect to the recovery of total cost is that the solution must necessarily rely on planning data, made up of averages and estimates, rather than on the detailed recording of every operation and outlay. It is this discrepancy that motivates the suggestion that the **price structure** be calculated from marginal costs, while the **price level** be set to cover actual accounting total cost. In practice, this is done as follows. First, find calculated total cost by multiplying solution quantities by corresponding solution marginal costs. Then compare this calculated total cost with actual accounting total cost. If the two differ, scale the solution marginal costs

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[2]Formally, the primal is the problem of cost minimization subject to constraints on sources, demand, and the capacity of the conveyance network. The dual solution is the numerical values of the Lagrange multipliers of these constraints.

up or down as required to bring calculated total cost into equality with accounting total cost.[3]

The economic measure of total cost is different from the corresponding accounting concept. The difference is that the cost of a public utility must include a return on equity that is not normally included in the accountant's concept of costs. One possibility is to calculate the cost of capital as the annual depreciation allowance plus interest on the net (non-depreciated) value of the capital assets. As we shall see below, the regulating authority will determine which capital assets are recognized and will set the interest rate to be used in calculating the return on equity.

In this way, prices will be set that will encourage the appropriate utilization of water resources and that will provide a basis for sound decisions on expanding or contracting the supply network. If expansion is indicated, suppliers will invest, and the cost of the additional capital will be recognized and rolled into water prices. If, however, there is already too much capital in place, a cost minimization solution to (11) that will both cover cost of capital and utilize all available sources of water, will not be found. Then assets will have to be marked down on suppliers' balance sheets and they will invest no further.[4] It should be noted here, because many err on this point, that the timely introduction of desalination should lower water prices, not raise them. If economically justified desalination is postponed, shadow prices of water at its sources will be comparatively high and prices to users will be higher than the cost of desalinated water.

One might argue that although accounting cost is the true total cost, from the point of view of planning and overall direction, pure marginal-cost pricing – without scaling – is preferable. If installed capacity is too small, marginal cost will be above average cost, and the comparatively high prices will encourage suppliers to invest in additional capacity. If installed capacity is too great, marginal costs and prices will indicate clearly that further investment is unwarranted. Mosenson appreciated this argument but preferred to rely on accounting cost to set the level of prices. He felt that doing so "establishes 'the rules of game' whose maintenance assures its own, automatic, economic regularity without the need to invoke complex considerations of the 'benefit to the national economy' on each and every issue."

Public regulation

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[3]This suggestion is not original with Mosenson. It was made in the past, but the current professional literature rejects it. In the concluding section of the paper, I shall offer an explanation for Mosenson's support of this practice.

[4]This point may have practical implications. It may well be that prices that will be set to cover the total cost of the National Conveyor (including capital expenses) will be so high as to prevent full utilization. If so, lower prices will be warranted (provided they cover variable costs). Formally, this will be done by marking down part of the value of the capital assets of the National Conveyor.

As we have seen, there are good arguments for public involvement in the water economy – that water is a common resource and that suppliers are a natural monopoly. However, government intervention in economic affairs has its own problems. Mosenson used to say (paraphrasing Genesis 16:12) "it is not that government's hand is against every man, but that every man's hand is against the government." When the government intervenes in the economy, it opens itself to pressure from interest groups. The first task of public regulation, therefore, is demarcation – setting the boundary between the public and the private sectors.

The responsibility for common resources

By law, all water sources in Israel are public property. Mosenson saw in this law a lever and a guide for public regulation. "Our solution on this crucial point can be much more advanced than that in other places in the West, which we should not imitate. This is due to the constitutional standing of our water law ... established by our founding fathers (our socialist forefathers). This is something we should be proud of and rejoice in, and build on its basis a sound system, more advanced and enlightened than anything that can be encountered elsewhere."

The responsibility for upholding the law and for the protection of water sources is vested in the Water Commissioner. The extraction and pumping of water in Israel must be authorized by the Commissioner through "production permits." In parallel, the Commissioner allocates water to its different uses through quotas granted to consumers. As indicated, Mosenson saw in the production permits "a great achievement ... and another great achievement will be realized when ... water use quotas are eliminated." The role of the government is to protect the natural sources of water and nobody can take its place in performing this function. However, the decision as to who will use the water and how much (given the available supply) is outside the government's bailiwick.

Setting the boundary between the public and private sectors

The other important area in which the government should be involved is the regulation of public utilities. In Mosenson's own words (with some minor delisions):

"There are important similarities between the water sector and other sectors – for example, electricity. In the area of electricity we can learn a great deal from experience in the United States (although we do not copy the systems existing there in their entirety).

"Two institutions, which are also two important concepts, have attained a high level of development in the United States. One is the Franchised Public Utility; for short, Public Utility or PU. The second is the Investor Owned Utility; IOU for short, which is simply a PU not owned by the government (that is, it is owned neither by the federal government, nor by the state, nor by municipal authorities). A 'franchise' is a historical term for a license or an exclusive permit given to a specific company (PU) to provide a service – for example, electricity, water, or natural gas – to a specific area. The exclusiveness stems generally from the technology of the infrastructure. You would not dig up a street twice to lay competing pipelines: a single pipeline is more efficient.

"Allegedly, the responsibility for vital public infrastructure (for the provision of water, electricity, etc.) is an explicit government function. And indeed the urban water and sewage networks in Israel are operated, almost all of them, by local governments. However, the concept of the Franchised Public Utility, and particularly its crystallization as an IOU, is at least in part a privatization of this government function and its delegation to the private sector.

"The PU concept embodies a sort of 'social contract' that includes the following elements:

- In exchange for exclusivity, the PU must provide service to all users within the boundary of the franchise, without discrimination, and in appropriate quantities and quality. (In contrast, no such obligation falls on a private farmer growing tomatoes for the market: he may rest and stop producing whenever he wishes.)

- The obligation to ensure service in the long run entails the forecasting of future demand and being prepared in every respect to meet it in a timely fashion. This requires the preparation of long-run plans, the securing of plant sites, building permits, and rights of way in accordance with local zoning regulations, and investment, including the purchasing of equipment. Here in particular, the delegation of public responsibilities to the private sector is striking. (For example, the Israeli government, lacking the means even to prepare development plans for the electricity sector, delegates this function to the Electric Company, along with the securing of plant sites, etc., etc.)

- In order to protect the public from the power of the PU's exclusivity – and from possible arbitrariness or even abuses – the PU accepts public monitoring and regulation in two interconnected areas:

(a) the fulfillment of its obligation to provide service to all users, without discrimination, and in appropriate quantities and quality.

(b) the setting of prices for its services.

- The rule for setting prices is the principle of cost of service, with the cost including a fair rate of return on equity. However, not every outlay is necessarily recognized and accepted as a 'cost' for purposes of price setting (this, again, is to prevent abuse and the inflation of cost).

- The guiding principle of public regulation (in the above two areas) is **openness,** including the proper disclosure, in a condensed and transparent form, of all the information relevant to the setting of prices customers are asked to pay (and which they may challenge if the need arises). One cannot rely on regulators acting in a discretionary manner.[5]

-An integral part of the PU concept is the institution responsible for monitoring the PU's. In the United States this is called the PUC (Public Utility Commission), and it monitors in a uniform fashion all PUs in a given state (water, electricity, natural gas, etc.). Currently, an 'Authority for Public Utilities–Electricity' is being established in Israel, and it should be seen as showing the way for regulation of public utilities in other areas, water in particular…"

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[5] If in a province you see the poor oppressed, right and justice violated, do not be surprised. You will be told that officials are under the supervision of supervisors, who are supervised in turn. (Ecclesiastes 5:7)

Finances

The finances of the water economy have two aspects – pricing and cost recovery. As we have seen, prices should be set according to the marginal-cost principle. This is the only objective method and it provides consumers and suppliers with the proper incentives. Mosenson explained the importance of proper pricing for suppliers with the help of an example: A town in the coastal plain, operates several wells from which it supplies water to the residents at prices set by the Ministry of the Interior. This operation leaves the town with a substantial budgetary surplus. In a rainy year, when hydrological considerations suggest increasing utilization of Sea of Galilee water and replenishing the coastal aquifer, the Water Commissioner may order the town not to use its wells and to purchase National Conveyor water instead. But the town will have to pay the full price for water from the National Conveyor. Under these terms, the town will fiercely resist the orders of the Commissioner, who is acting properly according to his responsibilities. If, however, all suppliers are charged marginal-cost prices, the town will face the same cost whether it uses water from its own wells or water from the Sea of Galilee supplied through the National Conveyor. Water in one place and of a given quality will have a single price, whether purchased from the national network or from independent local producers.

With respect to cost recovery, "the main point (in establishing the PUs) is to set up units that operate and report according to the financial methodology of accrual accounting, which insists on consistent valuation (honoring the law of the preservation of value) with no gaps or leakage. This is the whole thing in a nutshell!"

Mosenson regarded "honoring the law of the conservation of value" as of greater importance than the issue of public versus private ownership of water utilities. He repeatedly warned of finances "that in the public sector are not always sound." Public finances are unsound because the government uses not accrual accounting but cash-flow accounting, based on current flows of receipts and payments rather than on assets and liabilities. Moreover, political pressures lead to creativity in its accounting with dire consequences.

What are the advantages of sound finances along the lines suggested? "First and foremost: independence and responsibility. This sort of financial framework, that prevents uncontrolled capital consumption, is a precondition for investors to lend to such a unit and to invest in it. The result: independence! That is, the ability to raise resources (in the capital market) that it needs for development and investment, along with the complete elimination of reliance on government budgets for these purposes. Government money here is only an unnecessary and harmful waste!"

The prime example of flawed finances that Mosenson always had in mind, and on which he wrote many times, was the management of the assets of the water economy. The National Conveyor was owned by the government but was handed over to the water company, Mekorot, for operation. Water prices set by the government and charged by Mekorot failed to cover completely the cost of water supplied – even with the subsidy the company received – since cost calculations ignored the capital cost of the National Conveyor. Although Mekorot's operating costs were covered, the company could not act independently in the capital market and all its investments were financed out of the

government's budget. In this way, investment planning of the largest company in the water economy became part of the government's budget policy and was not assessed on its own merit. When budgets were tight, finance was lacking even for worthy projects. On the other hand, the company was often able to obtain funds without passing any market test: it had only to convince officials of the need for additional investments. (The 1993 "cost agreement" between the government and Mekorot has corrected some of these failings.)

Moreover, "it is worth emphasizing that our concept of sound finance is not the deceptive one of a 'closed economy' that is only good to prevent cross-subsidization (which is an important but only partial aspect of regulation). Here we are talking on **financial balancing of a system that is open**, not 'closed,' with outlet pipes to drain surpluses (dividends to equity holders) and inlet pipes to draw in resources in case of shortages (loans and even new capital)." The revenue collected from charging for water at its sources should contribute to the government's budget: water at its source belongs to the public, and payments for its use should go to the public fisc. The alternative of establishing a fund with the money collected and having the water sector rely on it for its financing would create an undesirable closed economy. When the fund was in surplus, investment would flourish, even if unwarranted; when it was depleted, investment would be delayed even when necessary.

The Water Commissioner

In general, with PUs being given responsibility for their areas, including the responsibility for long-run planning, it would seem that the only role remaining for the government is that of monitoring. However, water differs from other utilities in that there is an additional ecological dimension – the utilization of a common resource. The person charged with this responsibility is the Water Commissioner.

The Water Commissioner is responsible for collecting information (the Hydrological Service is a part of the Commission). The Commissioner manages water sources and regulates production through production permits; and – the dual of this – it sets the price of water at its natural sources and collects payment for it. Finally, the Commissioner is responsible for the long-run planning of the water economy. The Commissioner will be the one to decide (or to recommend) when desalination should begin in Israel and whether and to what extent the coastal aquifer should be connected to the national water system.[6]

The Commissioner ought to adhere to constitutional and statutory principles and should avoid any sectoral discrimination. Mosenson believed that monitoring and regulation of water suppliers (each a local monopoly) should be entrusted to a national

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[6] The coastal aquifer, from Mount Carmel in the north to Gaza in the south, stores water in sandy layers. The movement of water in sand is relatively slow and the cost, in water loss, of excessive recharging or short period over-utilization, is low. The reservoir can therefore be suitably used as emergency storage for dry spells. However, large parts of this aquifer are utilized by private parties (individual farmers, regional cooperatives, and municipalities) and are not connected to the national system. Their connection would entail heavy investments.

public utilities commission that would regulate all public utilities. This body, as indicated, would monitor prices and service quality; the Water Commissioner would be restricted to managing natural water sources.

Mekorot

Traditionally, the water economy has relied on three institutions. Tahal, the government-sponsored water engineering institute, was the official planner and also gathered information on water in the country. Mekorot built and operated the supply systems. And the Water Commissioner directed development and was responsible for managing resources. Over time, Tahal lost its primacy as private engineering firms became established. The Water Commission lacked the capability to take over Tahal's planning function. Mekorot's power increased, both because of the relative decline of the other two institutions and because of the 1993 cost agreement with the government, which gave it greater power and granted it financial independence.

Up to 1980, during the "heroic" period of rapid and intensive expansion, it was convenient to have a single entity, Mekorot, as the primary instrument of the government in the water sector. More recently, matters have changed. Most development today is of water systems to meet urban needs (sewage collection and recycling plant are being constructed, and desalination plants are on the way). This shift in focus alters the character of the water economy, reduces integration, and increases the relative importance of regional and local systems. Another change to be expected is the "incorporation" of municipal water systems: instead of being departments of local government they will increasingly become independent units, distinct from the local authorities (although supervised by them).

These expected developments open up the water economy to competition - in the treatment of sewage, recycling, local supply, and, in the future, desalination. Mekorot, the largest monopoly, is endeavoring to enter all these new areas and to retain them for itself.[7] If successful, its monopoly will be strengthened and regulating it will become more difficult. On this issue, Mosenson made two important points.

(a) Even as it stands, Mekorot is too big, and it should be broken up into separate sub-companies. This recommendation is grounded in the theoretical analysis. Equation (11) applies equally to any water plant. In relatively small plants, fixed costs are common to all outputs jointly (for example, supply in the different seasons) and only energy use can be attributed to individual outputs. Big suppliers, Mekorot in particular, operate many plants. These are interconnected, but the larger plants can also be considered separately in the sense that both variable and fixed costs can meaningfully be calculated for each separately. There is no technical reason for all the plants and networks now run by Mekorot to be operated by a single company. They could be split up under several independent units; for example, a company operating the National Conveyor, a company supplying water in the north, and another supplying water in the south. The solution of the dual problem underlying (11) will give the needed transfer prices for water between

[7] A strategy strongly supported by its employees, who enjoy, thanks to the monopoly, comparatively high wages.

companies, and, since production assets will be separated, it will enable meaningful calculation of total costs for each separate unit. Obviously, the recommendation to break up Mekorot rests implicitly on the assumption that the economies of scale fail to outweigh the diseconomies – structural, economic and political – of the current concentration of power.[8]

(b) Mosenson emphasized that the 1993 cost agreement, under which the government covers the difference between Mekorot's total cost and revenue, is incomplete: Because the agreement does not require separate calculation of costs in the individual sub-units of the company, cross-subsidization within Mekorot is still possible. Internal budgetary transfers will give the company an unfair advantage over its competitors in areas that in the future will be opened up to competition.

Mosenson as a critic

I have already mentioned that Mosenson was a sharp critic. He castigated municipalities that charged their residents high prices for water and used the receipts for other local expenses while at the same time neglecting their water systems. "This is capital consumption (creating nothing out of something)... it is also hidden financing and a violation of the principle of openness and proper disclosure, flouting budget laws that require open appropriation and financing of any public expense and its confirmation by lawmakers. This is fraud in the town square (in public)! (And we are so used to this behavior that just calling it by its proper name seems like hyperbole.)"

After demonstrating that the value of the marginal productivity of water in cotton production in the south was at most half the marginal cost of supplying it, he wrote: "Such a gap between cost and returns at a time that we are racing compulsively towards further massive development implies that we have lost our sense of direction.… A substantial part of cotton cultivation (although not all of it!) is made possible only by the heavy and hidden subsidization of water. But the 'population dispersion value' of this crop is quite limited: cotton does color large stretches of land green, but with labor input of less than ten days per hectare per year ... A single person can grow over 20 hectares of cotton which consume upward of 100,000 cubic meters of water. At a subsidy rate of $0.20 per cubic meter, such a person is supported, via the pipeline, to the tune of more that $20,000 a year. Hard as it is to say and to hear, a system has developed here to exploit the water subsidy with purchased inputs and capital and with very little use of labor (and so little effect on the dispersion of population) and a substantial destruction of resources. The same subsidy could have been used for much, much greater and more useful purposes."

Another example is Mosenson's critique of the proposal (since executed) to add a fourth pump to draw water from the Sea of Galilee for the National Conveyor. Proponents justified this investment in terms of increasing water yields and improving stability and reliability of supply. The reason yields would increase is that more pumping would lower

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[8] The 1993 cost agreement requires Mekorot to divest subsidiaries that do not play an integral role in water supply. These parts of the agreement have yet to be implemented.

water levels in the lake in the fall and, consequently, create a greater capacity to capture rain in the winter. Mosenson's critique was that while lowering the level of the lake would indeed increases **average** supply, it would also increase the risk of shortage in drought years: "The issue of reliability of supply requires a clear **systemic** approach."

In Mosenson's view, many economically unwarranted projects were undertaken in the water economy despite the system's professional excellence. And he asked: "How can we reconcile this broad and deep knowledge with evident blindness and impotence?" His answer? Projects are approved in cycles: a project to increase supply adds to energy requirements; this results in a project to save energy; than another project to develop supply, and so the wheel turns. "This is a circular process of approval – a perpetual motion machine that powers its own movement, that can go around and around indefinitely even if the process as a whole entails losses (destruction of economic resources) and cannot be justified. The error in this process, almost systematically, is a lack of proper (or of any) evaluation of the cost of burdening the system with additional assets. The energy cost of conveyance is calculated, if at all, as its **average** value, but this is only one third of the **marginal** energy cost, which is what is relevant for this purpose."

Summary and evaluation

The fundamental issue in Mosenson's writing is to determine the boundary between the responsibility of the government and the responsibility of private individuals. Mosenson's government is not omniscient: it knows little of the possibilities open to the private sector. And his government is subject to pressure: as the areas in which it intervenes expand, the pressure of interest groups intensifies accordingly. In some areas, however, there is no alternative to government responsibility: "and it will not avail us even if we do not wish it." In these areas, the responsible government agency must operate according to sound principles. The rule must be the rule of law and not the "rule of discretion" which invites pressure and violates the basic rights of private individuals.

The functions of the state in the water economy are (a) to regulate utilization of natural source of water, and (b) to control the quality of service and the prices charged by public utilities. Since regulation and control are difficult and expensive, creating the right conditions is important. Thus, Mosenson's advocacy of breaking up Mekorot, of explicit charges for water at its sources, of transparency and openness. Prices should maintain the **cost principle** – the price structure conforming to marginal cost and the level of prices dictated by the need to recover total cost. Mosenson strongly opposed the idea (now fashionable in economic theory) of directing the behavior of economic units through appropriate incentives. "The word 'directing' gives me hives. Whoever takes on the authority 'to direct' generally invites pressures that will 'direct' him. A sound public order must to my mind rest on objective rules, with no discretion to engage in 'direction' through 'incentives'."

The issue of how to set prices for public utilities in order to recover costs is not a new one, and the suggestion to use marginal-cost prices scaled to cover total cost has been made before. However, the fashionable approach today is Ramsey pricing (see, for example, Atkinson and Stiglitz, 1980, p. 461). This involves setting prices to cover cost in a way that minimizes the loss of consumer surplus: consumers with lower elasticity of

demand are made to pay higher prices. Applied to water, this would mean that household would pay comparatively high prices, while agriculture would pay lower prices. Mosenson rejected this approach completely. While I did not find in Mosenson's writing an explicit explanation of this position, there seem to be three supporting arguments consistent with his general philosophy. (a) The prices users face would not equal marginal costs: this undermines the efficient use of scarce resources. (b) Ramsey prices imply transfers from those paying higher prices to those paying lower prices: we have no right to favor one group of consumers over another. (c) Ramsey prices must be based on estimates of demand: such estimates are necessarily highly uncertain, while cost is known with considerable accuracy (and this is all we need for marginal-cost pricing).

The justification for Ramsey pricing most often cited in the literature is not joint production but rather the economies of scale that, many argue, characterize public utilities. Mosenson was skeptical about these economies of scale: "In a distribution network, whatever you 'profit' from large-diameter pipes, you lose from the greater distances between them." In a 1986 paper he devoted a great deal of space to deriving and drawing the long-run average cost function (the Viner curve) of pipes of different diameters. His conclusion was that, for the diameters now used to transfer water, the economies of scale were insufficient to justify abandoning marginal-cost pricing. "And if, nonetheless, there are increasing returns, so that total cost is somewhat higher than the value of output at marginal prices, it does not seem to me so important who is made to pay the difference – the consumer or the tax-payer (in the form of support), who may actually be the same person." The principle of marginal pricing was, in Mosenson's view more important than the requirement that the cost of a public service be covered in its entirety by its users.

Limited information is the basis for Mosenson's insistence on a price structure derived from minimizing costs according to equation (11). From a wider perspective, equation (11) ought to be embedded in a general equilibrium model of products and services in the economy as a whole or at least in the sector using water. The solution of such a general equilibrium model would give the quantities and prices of all products and services in the economy, including those of water. While such a model has many conceptual advantages, it is impractical: it is "heroic" and based on an illusion of knowledge. For practical purposes, we should be modest and settle for the more limited approach of cost minimization.

As we have seen, Mosenson criticized the practice of subsidies. One might therefore be tempted to think that he objected to them in principle. This was not the case. Rather, he believed that it was not the place of the economist to dictate to the lawmaker whether or not to subsidize water prices. If, however, lawmakers did decide to do so, subsidies should be open, transparent, and on-budget. Despite the importance he attached to marginal-cost pricing, Mosenson did not oppose subsidies to water prices, for all consumers or for some. He recommended use of the formula,

(12) Marginal cost = consumer price + subsidy,

applied explicitly and separately to each product and service. Yet, his acceptance of subsidies is problematic. In principle, even with price support, water prices must be set at levels that constrain demand not to exceed the amount available from natural sources (so long as there is no desalination). Past experience, however, has shown that price support invites pressures that result in prices that are too low to equilibrate supply and demand. As a result, water consumption has exceeded hydrological potential and the water economy was brought several times to the point of severe crisis. In Mosenson's opinion, this problem would not have been as acute had support been open and transparent: its cost and its effect would then have been clear, and lawmakers would have been careful, preventing any harm.

From the role of government to the role of private individuals. Once government sets the rules by which prices are to be determined, then "the primary economic function of prices, marginal-cost prices, is to provide the user with the complete and precise information he needs to determine the optimal use of water ... Prices, according to this view, are **not** an incentive for good behavior, since nobody knows what good behavior is ... This is an important point on which many err. Its importance is both practical and ethical. There is no practical substitute for the freely made decision of the user, based on the information at his disposal. And it expresses the fundamental ethical postulate of honoring the independence of the user and his sovereignty in choosing his actions and behavior according to what is 'good' **for him**."

Ran Mosenson was a disappointed man. He felt that he had failed to convince others on the issues with which he had struggled and which were for him at the core of social and public life in Israel. Yet, despite the many who disagreed with him and rejected his proposals, his disappointment was not entirely justified. His model has provided the basis for developing a proposal for the management of a joint water economy for Israel and its neighbors; the same basic model is now incorporated into an international research effort centered at Harvard University. A number of recent developments have moved the system in the direction Mosenson advocated. Peak-load pricing has been applied in electricity, and a public utility authority (commission) has been established for this sector. The 1993 cost agreement with Mekorot has increased its independence and responsibilities. Likewise, water quotas have lost their importance and much of the administrative arbitrariness in the allocation of this basic factor of production has been eliminated. The equalization fund has completed its task. Charging for water at its sources is now being discussed at the practical level. I cannot gauge Mosenson's share in furthering these reforms, and I cannot guess what would have happened without his efforts. However, he was without doubt among the first (in water he was the first) to identify the basic problems of our public utilities sector and to offer comprehensive, consistent, and complete solutions. He was also one of a select few economists, especially at the Treasury, who pushed the cart of electricity and water reform up the hill of resistance of interest groups and of protectors of the status quo.

In his effort to persuade, Mosenson wrote a great deal, replete with references to economic theory and to the best practice in the advanced countries. All of it was in Hebrew and much of it was distributed in hand-written manuscripts. He always went back to basic principles, to explain them anew to those who found them hard to grasp. In his

death we lose a friend, an honorable man, courageous and wise, a man of letters, and a great treasure of knowledge.

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