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ECONOMIC ASPECTS OF A NUCLEAR DESALINATION AGRO-INDUSTRIAL PROJECT IN THE UNITED ARAB REPUBLIC

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Economic Aspects of a Nuclear Desalination Agro-Industrial Project in the United Arab Republic*

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The purpose of the study is to investigate the financial feasibility and social benefits and costs of nuclear desalination agro-industrial projects. As presently designed, such a complex appears to require deficit financing, provide litttle employment, retard national income growth compared to other investment opportunities, and increase the foreign exchange deficit.

THIS paper reports the results of an empirical study of nuclear desalination agro-industrial projects. In recent years the possibility of desalting sea water to produce irrigation water for large-scale commercial agriculture and industry has attracted wide attention as a means of stimulating cooperation and economic development in the Middle East. Eisenhower supported the possibility [6], and it has received varying degrees of attention in the Committee on Foreign Affairs of the House of Representatives [19] and the Committee on Foreign Relations of the United States Senate [20].

Previous studies have offered contradictory opinions on the economic feasibility of such projects. Fried and Edlund believe that it is technically and economically feasible to convert coastal desert land in Egypt into highly productive agricultural land through a large-scale desalting program [7, p. 84]. An opposing point of view held by Clawson *et al.* is that such proposals are not economically practical and in fact are "a distinct disservice to the people of the region" [5, p. 116].

Conceptual Approach

This study employs financial feasibility and national income benefit analysis.[1] The financial analysis determines project investment and operating costs, revenues, cash flows, and profitability with likely market prices and government policies. The benefit-cost analysis examines the effect of the project on macroeconomic goals such as employment, foreign trade, capital scarcity, and national income.

El-Hamman, 30 miles west of Alexandria, was selected as a potential project site because of its soil characteristics, present unsettled status, and nearness to market and port facilities. Project design was carried forward in three simultaneous phases: (1) selection of agricultural and livestock commodities for maximum profit from use of project water; (2) examination for maximum profit of industries—such as steel, aluminum, elemental phosphorus, and ammonia—that have electric-intensive production processes; and industries—such as solar salt, caustic chlorine, magnesium, nitrogenous and potassic fertilizers, and bromine—that use seawater; (3) engineering examination of 500 megawatt electric power plants (both oil fired and nuclear) operated in association with 100 or 200 MGD (million gallons per day) desalination plants to determine least costly methods of production. The 200 MGD nuclear facility was selected for detailed analysis. Goal functions employed in the analysis are separable (and probably strongly so) into these three groups. Within the context of the indicated commodities and production processes, it is unlikely that the results of an attempt at overall optimal design would have been significantly different from those of the separate optimizations outlined here.

Financial Analysis

Initial investment costs total $400 million (see Table 1) and are invested over a seven year construction period. Annual production,

* A lengthier version of this paper was presented at a seminar of the International Center for Marine Resources Development at the University of Rhode Island on April 12, 1972. Thanks go to C. C. Burwell, Naiem Sherbiny, John Moyers, Roger Woodworth, and other members of the Middle East Study Group at the Oak Ridge National Laboratory for their dedication and cooperation. Robert Kalter, Timothy Mount, Gavan Butler, the reviewers, and an editor are thanked for their comments, as is Jeanne M. Ostro for her assistance. This paper reports on research undertaken at the Oak Ridge National Laboratory through the support of the Agency for International Development and the Atomic Energy Commission and the Union Carbide Corporation. The research had been classified from 1970 until April 1972. Views expressed here are solely those of the author.

[1] There is much current interest in other project evaluation criteria such as regional development, environmental quality, and income distribution. Given the analysis here, these criteria are clearly moot in this particular case.

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Table 1. Initial investment cost, 1969 prices

Item	Domestic currency	Foreign currency	Total
	-------- million dollars --------		
Nuclear steam supply system	25.6	63.9	89.5
Electrical plant	24.4	61.5	85.9
Evaporator plant	17.0	86.0	103.0
Chemical facilities	32.2	21.6	53.8
Farm	51.4	8.0	59.4
Working capital	3.1	0.5	3.6
Total	153.7	241.5	395.2

Source: [4].

revenues, and costs of agricultural and industrial commodities are shown in Table 2.

Yield estimates are based upon specific assumptions of crop variety, soil, climate, water use, and cultivation techniques. They are generally higher than recent UAR (United Arab Republic) and Israeli yields and lower than current record yields. Mechanization is "intermediate" between that in the U. S. and the UAR. Price estimates were generally at UAR levels, with reductions made for crops such as cotton and grapefruit with anticipated future world price reductions.

Table 3. Receipts and operating costs for representative year, 1969 prices

	Domestic currency	Foreign currency	Total
	-------- million dollars --------		
	Receipts		
Farm products	31.5	7.1	38.6
Chemicals	6.1	7.2	13.3
Electricity	19.9	0	19.9
Total Receipts	57.5	14.3	71.8
	Operating costs[a]		
Nuclear steam supply system	0.5	0.5	1.0
Electrical plant	0.3	0.3	0.6
Nuclear fuel	0	6.6	6.6
Evaporator plant	0.7	0.7	1.4
Chemical facilities	1.4	0.5	1.9
Farm	16.2	2.1	18.3
Total operating costs	19.1	10.7	29.8
Net receipts	38.4	3.6	42.0

Source: [4].
[a] Includes replacement investment cost.

Most industrial products cited above were rejected because of distance from raw material sources and/or markets. Table 3 shows re-

Table 2. Selected production characteristics of UAR agro-industrial complex design with full capacity production and 1969 prices

Commodity	Yield lb/acre	Price $/cwt	Annual production (1000 cwt)	Annual revenue ($1000)	Direct annual cost ($1000)
Wheat	6,000	3	1,411	4,234	1,183[a]
Corn	9,000	2.2	119	261	847[a]
Raw cotton	3,090	10	463	4,632	1,515
Peanuts	3,800	7	462	3,237	1,180
Oranges	44,000	3	440	1,320	512
Broad beans	3,420	5	855	4,275	1,650
Spring potatoes	43,200	1.5	3,025	4,536	2,359
Winter potatoes	27,000	2	270	540	321
Tomatoes	52,000	1.2	520	624	341
Onions	33,200	1.9	1,992	3,780	1,866
Cantaloupes	18,000	4.5	90	405	223
Milk	—	5	1,080	5,400	2,475
Cull cows	—	$188 ea	1,980 ea	380	[b]
Calves	—	$ 15 ea	5,300 ea	80	[b]
Eggs	—	$0.35/doz	5.4 mil doz	1,890	1,113
Cull hens	—	$0.54 ea	0.25 mil	135	[c]
Broilers	—	19.5	147	2,860	1,575
Electricity	—	5.8 mills per KWH	3.43 bill KWH	19,900	622
Crude salt	—	0.125	31,600	3,950	1,888
Refined salt	—	1.0	6,570	6,570	[d]
Caustic	—	3.0	940	2,820	[d]

Source: [4].
[a] Includes corn and wheat grown for feed.
[b] Included in milk production cost.
[c] Included in egg production cost.
[d] Included in crude salt production cost.

ceipts and operating costs for a representative year of full production.[2]

These costs and revenues are included in the first six columns in the cash flow summary of Table 4.[3] Capital investment is naturally concentrated in the early years, but replacement investment occurs throughout the life of the project. Most notable is the foreign currency investment of $16 million each in 1992 and 1993 for replacement evaporators in the desalination plant. At the end of the production period in 2007, the farm has a resale value of $19 million. Also of interest is the salvage of nuclear fuel, which returns $2–3 million each year from 2008 through 2011. Operating costs are relatively constant over time. Fourteen years are necessary for agricultural output to reach full production, but electricity and chemicals are assumed to be produced at capacity levels in the first year of operation in 1978 and thereafter.

Domestic taxes might be applied to profit, gross receipts, value added, or property. In the first repayment analysis, the *Guide for Economic Evaluation of Nuclear Reactor Plant Designs* [13, pp. 2–5] is followed. Annual tax is computed at 4.88 percent of the value of investment capital (column 7). The tax assumption varies in subsequent analyses.

Price controls have limited inflation in the UAR. From 1959 to 1969 the consumer price index increased 2.9 percent per year [21]. This was assumed to be valid for all domestic project costs and revenues and foreign operating costs and revenues and is the basis for the price index in column 8. The Bechtel Corporation estimated that capital costs for the project would increase 8 percent per year indefinitely [1, pp. 11–12]. It is assumed here that foreign capital costs increase 8 percent per year through the construction period and that the rate of increase slows 0.5 percent per year until it reaches the 2.9 percent per year domestic inflation rate (column 9).

Price indices are utilized to define the actual net expenditures or income in columns 10 and 11. The tables indicate cost and revenue esti-

[2] The agricultural analysis summarized here was prepared by R. C. Woodworth, T. Tamura, and C. M. Farmer [24]. The industrial products analysis was prepared by H. E. Goeller, the Union Carbide Corporation, and J. C. Moyers [8].

[3] Table 4 presents in summary form every fifth year of a complete cash flow which estimates each item in Tables 1–3 for each year, 1971 to 2011 [4].

Table 4. Repayment analysis summary with original assumptions, 1971–2011

Year	Domestic capital investment (1)	Foreign capital investment (2)	Domestic operating costs (3)	Foreign operating costs (4)	Domestic sales (5)	Export sales (6)	Domestic tax (7)	Basic cost and revenue price index (8)	Foreign capital price index (9)	Actual net domestic revenues (10)	Actual net foreign revenues (11)	Domestic interest earnings (+) or charges (−) (12)	Foreign interest earnings (+) or charges (−) (13)	Domestic debt (−) or surplus (+) at year's end (14)	Foreign debt (−) or surplus (+) at year's end (15)
	million dollars in 1969 prices							1969=1.00		million dollars in actual future prices					
1971	0.000	3.306	0.000	0.000	0.000	0.000	.0000	1.0588	1.1664	0.0000	−3.8561	0.0000	0.0000	0.0000	−4.0489
1976	46.861	79.358	0.000	8.747	0.000	0.000	0.0000	1.2215	1.7138	−57.2426	−145.2673	−5.9890	−17.5750	−125.7687	−369.0756
1981	0.623	0.548	15.900	8.280	48.491	13.418	19.3069	1.4092	2.4488	17.8425	4.0984	−11.4461	−27.5203	−222.5261	−573.8271
1986	1.337	0.149	17.986	11.071	56.136	14.212	19.3069	1.6258	3.1250	28.4611	2.8602	−8.3084	−35.0064	−146.0163	−732.2748
1991	0.071	0.136	18.043	11.064	57.464	14.364	19.3069	1.8756	3.6297	37.5927	3.0005	−2.0074	−44.4387	−4.5621	−930.2128
1996	1.034	0.112	18.043	10.568	57.464	14.364	19.3069	2.1638	4.1875	41.2853	3.5504	0.0000	−57.6772	0.0000	−1171.7525
2001	0.232	0.145	18.043	11.854	57.464	14.364	19.3069	2.4963	4.8309	49.6312	1.9572	0.0000	−63.2179	0.0000	−1282.4406
2006	0.045	0.005	18.043	10.776	57.464	14.364	19.3069	2.8798	5.5732	57.7959	3.7713	0.0000	−68.1528	0.0000	−1377.1553
2011	0.000	0.000	0.000	−2.840	0.000	0.000	0.0000	3.3224	6.4296	0.0000	3.0071	0.0000	−74.5093	0.0000	−1561.6674

Source: [4].

mates for domestic UAR currency and foreign (primarily U. S.) currency. The bulk of initial investment is in foreign currency, while net receipts are essentially in domestic currency. It is reasonable to assume that foreign borrowing, purchases, and sales would be undertaken through accounts distinct from domestic accounts. Traditional foreign lenders such as commercial consortia, international banks and development funds, and foreign governments are conceivable investors. The exchange rate of $2.30=ŁE existing in 1970 was probably too high; the UAR has a large recurring balance of payments deficit. It is here assumed that domestic earnings might retire foreign debt at a ratio of 0.87 to 1 (i.e., an exchange rate of $2.00=ŁE). After discussions with financial experts in UAR development financing, a 5 percent rate was selected as a possible annual interest charge on foreign and domestic investment.[4]

Accounts open in 1971 when design work is assumed to begin on the nuclear power, evaporator, and chemical facilities. Accounts close at the end of 2011 when the last of the unused reactor fuel will have been sold. All foreign earnings are applied to the foreign account. Because of the foreign exchange problem, domestic earnings are first used to retire domestic debt. Subsequently they are applied to foreign debt at the 0.87 conversion factor. Interest is charged to accumulated debt at the end of each period and to any excess of costs over revenues when debt exists. If foreign debt is retired, both accounts accumulate surplus and interest earnings separately. These definitions result in the remaining four columns in Table 4. As a consequence of these assumptions, domestic debt is retired in 1992, but foreign debt grows throughout the period until it reaches $1.6 billion at the end of the project (see Tables 4 and 5).

It is simple to program these relationships (see Appendix) in order to examine the sensitivity of the results to changes in assumptions. Suppose the fixed capital tax is replaced by a value added tax. In the latest year with available data (1960), the ratio of (a) tax payments by all producing units to the government, divided by (b) total value added by all economic activity was .229.[5] For a project, value added is wages plus annual net return before taxes. With a 22.9 percent annual value added tax replacing the annual fixed capital tax, foreign debt falls to $283 million by 2011.

Further tax assistance might be offered by setting taxes at 5 percent of gross receipts. In this case surpluses accumulate. Domestic surplus reaches $645 million and foreign surplus is $57 million at the end of the project.

Other financial arrangements might be undertaken in which the original fixed capital tax is used. If foreign components of the nuclear steam supply and the electrical plant are donated and domestic earnings are accepted

[4] Official exchange rate as of August 1, 1972 was $2.35 =ŁE. This reflects both the absence of a UAR devaluation and the recent U. S. devaluation. The approach here and in the benefit-cost analysis following is analogous to the shadow exchange rate of McGaughey and Thorbecke [11, pp. 33–36]. These questions were discussed at a seminar to consider financial analysis on September 28–29, 1969. Personnel with Middle East responsibilities in an international development fund, a U. S. Development Agency, and a commercial bank participated [14, 15]. Also, see Chandavarkar [3].

[5] The .299 figure is calculated from data in Mead [12, p. 276].

Table 5. Summary of repayment analyses with assumed actual future prices[a]

Repayment assumptions	Year domestic debt retired	No forgiveness, end of project[b] debt (−) or surplus (+)		Foreign debt forgiven	
		Domestic ($1,000,000)	Foreign ($1,000,000)	Year	Amount ($1,000,000)
Original	1992	0.0	−1561.7	1978	461.7
Tax=22.9 percent of value added	1986	−13.4	−282.6	2009	251.2
Tax=5 percent of gross revenue	1984	645.3	57.3	[c]	[c]
Donated foreign nuclear and electrical investment, official exchange rate	1992	0.0	−160.6	2009	145.7
No interest on foreign capital	1992	192.3	78.5	[c]	[c]

[a] Beginning of year basis.
[b] Project ends in 2011.
[c] Surplus.

for remaining foreign debt, then that debt is $161 million at the end of 2011.

Suppose no interest is charged or accrues to the foreign account. Here a surplus results of $192 million domestically and $78.5 million in the foreign account.

Five analyses are summarized in Table 5. Included is foreign debt forgiveness for the year with minimum foreign debt. This amount indicates the smallest debt that could be written off as a grant subsidy to enable the project to operate to its termination and leave no outstanding debt. For example, in the original case either $461.7 million dollars could be forgiven in 1978 or the project would come to its end in 2011 with $1.562 billion in outstanding foreign debts. Financial viability apparently requires substantial tax assistance, foreign capital donations, or both.

National Income Benefits and Costs

Particular economic objectives to be considered are national income, employment, capital scarcity, and foreign trade.

There are three categories of domestic employment in the complex: construction labor, agricultural labor, and skilled technicians and engineers. In each case it seems likely that unemployment or substantial underemployment characterizes UAR labor markets. Therefore it is assumed that the wages of such labor add value to national income.[6] Admittedly this is a controversial position. The cited evidence is weak. It might be argued that some fraction less than one is the correct proportion of domestic wages that is an addition to national income. As noted below, the particular asssumption employed makes little difference in the conclusions. Domestic wages total $50.6 million during construction and are $3.1 million annually during project operation. Direct employment would be 9000 man-years per year during production.

A social discount rate of 10 percent is consistent with benefit-cost analysis in developing countries in general [11; 10, p. 184] and the UAR in particular [16]; it is utilized here.

The UAR has a chronic foreign exchange deficit and is at times unable to import needed fertilizers, replacement parts, and other industrial necessities because of this [17, 21]. By taking the preceding discussion of convertability as a guide, imports are penalized 15 percent and exports and import substitutes are given a premium of 15 percent. (At full production, domestic import substitute sales are $6.5 million of a total $57.5 million domestic sales.)

It is generally assumed in benefit-cost analysis that inflation affects all benefits and costs equally; therefore, the sign of net benefits and the size of the benefit-cost ratio are unaffected. However, the discussion of inflation above suggests that the nuclear steam supply, evaporator, and other foreign capital prices will increase faster than other prices. This greater rate of increase is 5.1 percent (8 percent minus 2.9 percent) through 1977, and the rate of increase decreases 0.5 percent annually until it stabilizes at zero. Thus there is an overall 1969 price base with an allowance for relative price increase in foreign capital components.

Particular measures of national income benefits and costs used here are net present value, benefit-cost ratio, and internal rate of return. They are defined as follows:

$$B = \sum_{t=1}^{41} \sum_{i=1}^{4} B_{it}(1 + r)^{-t} \tag{1}$$

$$C = \sum_{t=1}^{41} \sum_{k=1}^{4} C_{kt}(1 + r)^{-t} \tag{2}$$

$$N = B - C \tag{3}$$

$$BCR = B/C \tag{4}$$

$$IRR = [r: B = C] \tag{5}$$

where t is each year of the time horizon from the beginning of design and construction to the end of production and liquidation of salvageable assets; B is present value of benefits at beginning of year 1; C is the same for costs; N is the net present value of benefits and costs; BCR is the benefit-cost ratio; r is the social discount rate; IRR is the internal rate of return (the social discount rate such that the present value of benefits exactly equals the present value of costs); B_1 is export sales increased by 15 percent premium; B_2 is import substitution sales increased by 15 percent premium; B_3 is other domestic sales; B_4 is domestic wages; C_1 is import purchases of capital goods adjusted by price index and increased by foreign exchange penalty; C_2 is import purchases of operating supplies in-

[6] See [21; 12, pp. 31–41]. This view is taken in unpublished research by C. Nader and N. A. Sherbiny. A partly contradictory view is held by Hansen [9].

Table 6. Benefit-cost analysis summary

Social discount rate	Present value of benefits	Present value of costs	Net benefits	Benefit cost ratio
percent	million dollars			
10	364.5	494.2	−129.7	0.74
15	187.2	342.2	−555.0	0.55
5	826.5	801.4	25.1	1.03
5.45	762	762	0	1.00

creased by penalty; and C_3 and C_4 are domestic capital and operating expenses.

Since gross national product is the sum of value added, net present value can be interpreted here as the present value of direct GNP changes adjusted for foreign exchange premiums and penalties.

The first row of Table 6 shows the results, which are clearly uncomplimentary; net benefits indicate a loss of $130 million, and the benefit-cost ratio is less than one. The social discount rate of 10 percent can be bracketed by computing net present values for rates of 5 percent and 15 percent (see rows 2 and 3). The 15 percent rate lowers the *BCR* to 0.55, and the 5 percent rate has a small positive net benefit. If 15 percent is more likely to be correct than 5 percent, the implication of this bracketing is negative. The social internal rate of return is 5.45 percent.

Difficulty in determining the national income employment gain has been noted. Alternatively, it can be postulated that the 9,000 man project labor force would not be otherwise unemployed, and the domestic wages for operation and construction are not a national income benefit. In this case the present value of the net benefit loss becomes −$173 million at a 10 percent social discount rate, −$185 million at 15 percent, and −$46 million at 5 percent.

Conclusions

Within the context of the assumptions employed here, the nuclear powered agro-industrial complex utilizing desalinated seawater would be unable to be self-sufficient financially and would retard national income growth in the United Arab Republic.

Project employment has been an important U. S. policy goal. This, in turn, has been related to expectations for refugee settlement. For example, Senate Resolution 155 stated:

> Whereas the greatest bar to a long-term settlement of the differences between the Arab and Israeli people is the chronic shortage of fresh water, useful work, and an adequate food supply; . . . Resolved, That it is the sense of the Senate that the prompt design, construction, and operation of nuclear desalting plants will provide large quantities of fresh water to both Arab and Israeli territories and, thereby, will result in—(1) new jobs for the many refugees; (2) an enormous increase in the agricultural productivity of existing wastelands; (3) a broad base for cooperation between the Israeli and Arab governments . . . . [20, p. 1]

There were about 1.35 million refugees prior to the 1967 war and perhaps 1.7 million afterwards [2]. With an assumed labor participation ratio similar to Egypt's [12, p. 33], a maximum employment goal would be 510,000 man-years. With a third of this assumed as a specific goal, 57 projects identical to this design would be required. Investment capital would be $22.5 billion, and the present value of national income benefit loss (from Table 6) would be $7.4 billion.

Fried and Edlund have suggested that desalination agriculture in the Middle East is feasible if it can be assumed that crude oil is donated "at a price that would cover its production and transportation costs" [7, p. 163]. The UAR produces some oil but also has substantial imports. Simply selling the same crude oil abroad would make a greater contribution to UAR national income.

Roger Woodworth [24] estimated that efficient irrigation agriculture in the UAR would be feasible at a water price as high as 3.6 cents per thousand gallons with a 10 percent interest rate and 10.9 cents per thousand gallons with a 5 percent interest rate. Both figures are significantly below the cost of the most efficient large-scale desalination plants being designed.[7]

It is concluded here that joint production of electricity, salts, and agriculture based upon

[7] A. D. K. Laird summarizes the state of the art in engineering economics in this way [23, pp. 1–5]: (1) current design plants of one to five MGD capacity may desalt water at 50 to 80 cents per 1000 gallons; (2) larger plants to be built in five to 15 years may produce water at 20 to 40 cents per 1000 gallons; (3) very large plants built after 1985 may produce water at 10 to 15 cents per 1000 gallons. Laird's estimates are apparently in 1970 dollars with a 5 percent interest rate. Similar views are expressed in [22]. Juxtaposing Woodworth's agricultural analysis with Laird's desalting estimates suggests financial feasibility is at least 15 years away and positive project net benefits are further into the future. But this juxtaposition of Laird-Woodworth estimates is partially misleading since any large-scale desalination agriculture would be part of a larger project analogous to that analyzed here. Joint production of power and water is less costly than the separate production of each.

seawater desalination with either nuclear power or oil is not economically feasible in the United Arab Republic in the foreseeable future. Such production appears to require deficit financing, provide little employment, retard national income growth compared to other investment opportunities, increase the foreign exchange deficit, and require substantial capital.

However, it is not correct to conclude that large-scale agro-industrial projects are inherently infeasible in the UAR or elsewhere in the Middle East.[8] Naiem Sherbiny [17] has suggested that a suitable project would (a) utilize indigenously profitable industries such as glass and glass products, paper products, pesticides, herbicides, fertilizers, clothing, and processing of agricultural products; (b) produce agricultural commodities for import substitution and export such as grains, fruits, and vegetables; and (c) use oil and/or hydropower as energy sources and ground water and/or reservoirs as irrigation sources [18]. These suggestions can be contrasted with this project's design emphasis on power-intensive industry, water-efficient crops, nuclear power, and desalination.

In retrospect, the process of analysis suffers from what might be termed "problem reversal." That is, it began with a presumed solution and attempted to relate it to the problem. To the extent that these difficulties characterize other power and water development projects, it is of general interest to economists in developing and developed countries.

[8] It would also be incorrect to conclude that desalination is infeasible in other uses now. World desalination capacity now exceeds 300 MGD [23, p. 1] and is expected to reach 1 billion gallons per day in 1975 [22, p. iii].

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APPENDIX

The following relations define the basic elements of the program used in the financial and benefit-cost analyses. The variable subscript corresponds to the column number in Table 4; 1971 is year 1 (i.e., $t=1$). Nominal prices are assumed actual future prices.

1–6. Domestic capital investment (X_1), foreign capital investment (X_2), domestic operating costs (X_3), foreign operating costs (X_4), domestic sales (X_5), and export sales (X_6) are taken from [4] and are in 1969 prices.

7. Domestic tax, first repayment analysis

$$X_{7,t} = .0488 \sum_{t=1}^{7} (X_{1,t} + X_{2,t}).$$

8. Basic cost and revenue price index, 1969 = 1.00

$$X_{8,t} = (1.029)^{t+1}.$$

9. Foreign capital price index, 1969 = 1.00

$$\begin{aligned} X_{9,t} &= (1.08)^{t+1} \quad \text{for} \quad t = 1 \text{ through } 8 \\ &= (1.08 - .05(t-8))X_{9,t-1} \\ &\qquad \text{for} \quad t = 9 \text{ through } 18 \\ &= 1.029X_{9,t-1} \quad \text{for} \quad t = 19 \text{ through } 41. \end{aligned}$$

10. Actual net domestic revenues, nominal prices

$$X_{10,t} = (X_{5,t} - X_{3,t} - X_{1,t} - X_{7,t})X_{8,t}.$$

11. Actual net foreign revenues, nominal prices

$$X_{11,t} = (X_{6,t} - X_{4,t})X_{8,t} - X_{2,t}X_{9,t}.$$

12. Domestic interest earnings or charges, nominal prices

$$\begin{aligned} X_{12,t} &= .05(X_{14,t-1} + X_{10,t}) \text{ if } X_{10,t} < 0 \\ &= .05X_{14,t-1} \quad \text{if} \quad X_{10,t} \geq 0. \end{aligned}$$

13. Foreign interest earnings or charges, nominal prices

$$\begin{aligned} X_{13,t} &= .05(X_{15,t-1} + X_{11,t}) \text{ if } X_{11,t} < 0 \\ &= .05X_{15,t-1} \quad \text{if} \quad X_{11,t} \geq 0. \end{aligned}$$

14. Domestic debt or surplus at year's end, nominal prices (S represents the sum of domestic debt, interest, and revenues to be used either in the domestic or foreign account; see text.)

$$\begin{aligned} S_t &= X_{14,t-1} + X_{12,t} + X_{10,t} \\ X_{14,t} &= S_t \quad \text{if} \quad S_t \leq 0 \quad \text{or} \quad X_{15,t-1} \geq 0 \\ &= 0 \quad \text{if} \quad X_{15,t-1} < 0 \quad \text{and} \quad S_t > 0. \end{aligned}$$

15. Foreign debt or surplus at year's end, nominal prices

$$\begin{aligned} X_{15,t} &= X_{15,t-1} + X_{13,t} + X_{11,t} + .87S_t \\ &\qquad \text{if} \quad X_{15,t-1} < 0 \quad \text{and} \quad S_t > 0 \\ &= X_{15,t-1} + X_{13,t} + X_{11,t} \\ &\qquad \text{if} \quad X_{15,t-1} \geq 0 \quad \text{or} \quad S_t \leq 0. \end{aligned}$$

For the 22.9 percent value added tax case, domestic wages (X_{16}) are \$3.053 million each year from 1978 through 2007, value added (X_{17}) is $X_{16}+X_5+X_6-X_4-X_3-X_2-X_1$. The domestic tax ($X_7$) is now 0.229 X_{17}. Calculations proceed as in the previous case.

With the tax at 5 percent of gross revenues, $X_7=.05(X_5+X_6)$.

When the foreign nuclear and electrical investment is donated and the then-official exchange rate is used, foreign capital investment (X_2) is reduced about 50 percent (see Table 1). In X_{15}, 0.87 is replaced by 1.0.

In the analysis for no interest on foreign accounts, $X_{13}=0$.

For the benefit-cost analyses, the social benefit and cost variables are derived from the X variables as indicated in the text.