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Publication Date
1990-07-01

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WORKING PAPER NO. 545

THE USE OF COMPUTABLE GENERAL EQUILIBRIUM MODELS TO ASSESS WATER POLICIES

by

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Forthcoming chapter in A. Dinar and D. Zilberman, eds., *The Economics and Management of Water and Drainage in Agriculture*. Amsterdam: Kluwer Publishing Company.

California Agricultural Experiment Station
Giannini Foundation of Agricultural Economics
July, 1990

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Abstract

This paper discusses basic issues in project analysis and shows how these issues can be resolved in a computable general equilibrium (CGE) framework. The role of border prices and intersectoral linkages is explored. The CGE framework is compared to less comprehensive frameworks, including benefit-cost analysis, input-output models, multi-market models, and models based on social accounting matrices (SAMs). An illustrative CGE model of the southern portion of the San Joaquin Valley is constructed and is used to find the effects of reducing water inputs on aggregate Valley gross domestic product (GDP) and on sectoral output, employment, and land use. The model is also used to determine demand curves for water by the southern portion of the Valley, given alternative specifications of production technology.

1. Introduction

Drainage problems and increased urban water demands have led to serious problems for agriculture in parts of the San Joaquin Valley. The drainage problem, in its chronic form, is that the Valley is a net importer of salt. There is an extensive literature on methods of reducing this drainage problem while still engaging in agriculture. In this paper, we discuss an alternative solution: drastically curtailing agricultural use of water. We present a methodology to evaluate the effects on a region of decreased water use. We then apply this methodology in a preliminary and illustrative way to evaluate the "project" of withholding water from the southern portion of the San Joaquin Valley. The impact of this curtailment policy on regional employment, gross domestic product (GDP), crop mix, agricultural value added, and farm income should provide an upper-bound measure of the impact of less drastic policies, such as improving residuals management. The curtailment alternative also serves as a benchmark for evaluating potential government sponsored projects, such as building a master drain.

The economic evaluation of a water-curtailment policy shares all the challenges of evaluating any type of project. Our starting point is well stated by Varian (1989, p. 84):

> We start from a simple methodological premise: there is only one correct way to do cost-benefit analysis. First, formulate an economic model that determines the entire list of prices and incomes in an economy. Next, forecast the impact of some proposed change on this list of prices and incomes. Finally, use the utility functions of the individual agents to value the pre- and post-change equilibria. The resulting list of utility changes can then be summarized in various ways and presented to decision makers.

In the next section, we describe computable general equilibrium (CGE) models, which provide an empirical framework that incorporates "the entire list of prices and incomes in an economy." We next discuss the relative advantages of different partial and general equilibrium approaches to project analysis. We then describe the regional CGE model that we have developed for the southern San Joaquin Valley (including Fresno, Tulare, Kings, and Kern counties). Finally, we present the results from simulation experiments that we performed with the model to analyze the effects of removing water from the Valley. Given the level of aggregation, difficulties in specifying alternative production technologies, and the nature of the data, our empirical results must be seen as illustrative.

2. A Typical CGE Model

A CGE model is a general equilibrium model that implements the textbook description of an economy. There are utility-maximizing consumers whose decisions determine the demand for goods and supply of labor. There are profit-maximizing producers whose decisions determine the supply of goods and the demands for primary factors (labor, capital, and land) and intermediate inputs. There is international trade. There is a government which collects taxes and tariffs; may set exchange rates; and provides transfers, subsidies, and services. Finally, there are market-clearing conditions specifying supply-demand balance, which will determine equilibrium prices. The model is a "general equilibrium" because all domestic supplies, demands, prices, and incomes are determined simultaneously within the model. It is "computable" because the model solves empirically for all endogenous variables in a highly non-linear system of simultaneous equations.

Typically, CGE models have many sectors and factors of production. Equilibrium requires that, for each sector, supply (production) equals demand (consumption, investment, government, and exports) at market-clearing prices. The models often specify many household types, stratified by occupation or income level. Household expenditure on goods is specified as a function of household disposable income (the household's share of labor and distributed capital income less net taxes) and prices. For goods that are both traded and locally produced, the domestic market price is a function of international prices plus tariffs and producer prices. Sectoral output and demand for intermediates and labor is taken as a function of the capital stock and producer prices. All the usual neoclassical rules hold. In each sector, price equals marginal cost and wages equal the marginal value product of labor. Exchange rates and international trade flows are also usually taken to be endogenous.

The distribution of income is modeled, so profits and wages are first distributed to institutions (such as enterprises and labor) and then to households. This two-step distribution allows the inclusion of policy instruments (such as corporate and payroll taxes) and enterprise decisions about retained earnings, which affect the amount of factor income that actually ends up in households.

Changes in policy alter demand through changes in both income and prices. The wide scope of the model makes it especially useful for evaluating projects that have broad effects, changing incomes in many sectors through intersectoral linkages. When an investment project is large, generating many ripples in the economy, a general equilibrium framework is the appropriate tool of analysis [Bell and Devarajan (1987)].

Multi-market equilibrium models differ from CGE models by including fewer linkages [Braverman and Hammer (1988)]. In particular, final demand for goods does not depend upon endogenous household income. Sectors that are deemed unimportant to the question at hand are also not modelled. Most econometric models fall into this category. The advantage of this approach is that the analyst can pay more attention to the remaining parts of the model, focusing on the included sectors, at the cost of introducing some bias and inaccuracy by omitting sectors and feedbacks from changes in incomes. While many projects, particularly regional projects, can be well analyzed with a multi-market model, there are also many examples of policies for which feedbacks through the omitted links are very important. For example, analyzing the impact on a developing country of pursuing an agriculture-led development strategy, requires an economywide framework. Increased agricultural incomes will result in increased demand for goods produced in the urban sector, and therefore to increased urban incomes, with further indirect effects back to the agriculture sector as well. In this case, a model in which the final demand for urban goods is independent of agricultural development will miss a crucial linkage through which the policy scenario affects economic performance [Adelman (1984)].

There is also a tradition of input-output multiplier models which focus on intermediate input flows. The "semi-input-output" model improves on the standard open Leontief model by accounting for traded goods, and has been used to evaluate large regional agricultural projects.[1] This multiplier approach has been extended to include a wider view of economic linkages through the use of a Social Accounting Matrix (or SAM). The SAM extends the input-output accounts to include income flows among all agents in the economy, and also provides the database for CGE models. A SAM for the Southern San Joaquin Valley is discussed below.

We can summarize the relationships among the different types of models. The CGE framework is the most general framework in which to conduct policy analysis. Input-output analysis, SAM analysis, and multi-market analysis can all be seen as special cases of a general equilibrium model. While the CGE framework is the most general, applied CGE

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[1] See, for example, Bell and Devarajan (1985), who use a semi-input-output model to analyze the impact of a large irrigation project in the Muda valley region of Malaysia.

models tend to be more highly aggregated than models in other frameworks. A multi-market model is best seen as a subset of a CGE model, focusing on a subset of sectors and linkages. The multi-market model solves for prices in its subset of sectors and assumes all other prices are given. In particular, it assumes a fixed exchange rate. A SAM is a data framework that provides a snapshot of an economy and can easily be turned into a linear, demand-driven, multiplier model. An input-output model focuses only on intersectoral linkages and is a subset of a SAM model. Input-output and SAM-multiplier models all assume fixed prices. The price of increasing generality and economywide coverage is greatly increased demand for data and/or lowered precision.

3. Project Evaluation

There is an extensive literature on how to evaluate projects without using a full general equilibrium model. In this section we will discuss some of the general issues in project evaluation and point out how general equilibrium modelling contributes to some, but not all, of their resolution.

Benefits

Projects are considered to be good insofar as they benefit people. The concrete expression of this principle is a "social welfare" criterion. Specifying a social welfare function, one can proceed directly to evaluating projects by maximizing this function subject to the rules of the underlying economy (for example, represented by a CGE model). The problem is that this approach requires both an explicit social welfare function and a CGE model.

The standard and familiar rule of cost-benefit analysis is to accept only those projects that have benefits in excess of their costs, to whomever those benefits may accrue. This rule reflects a particular social welfare function: the marginal social benefit of a dollar is assumed the same for all citizens. Choosing such a rule does not negate the need for a model of the economy.

Manuals of project evaluation suggest using indirect approaches for specifying the welfare criteria and the way the economy operates. Little and Mirrlees (1974) (henceforth, LM), among others, suggest rules that give the same result as explicit welfare maximization in special situations and that may be more convenient to use. For example, a number of writers have argued that, when the government has sufficient policy instruments available to channel uncommitted government revenue to the most socially needy household or most worthy use, then uncommitted government income is also the appropriate maximand for project analysis and the specification of a social welfare function can be avoided.

Most American water projects are undertaken because private individuals will benefit. Water projects make farmers better off and taxpayers worse off. To apply the LM methods to these projects requires evaluation of the social value of a dollar given to a farmer relative to an uncommitted dollar in government hands. This evaluation is no easier than the direct problem of maximizing a specified social welfare function. Thus, the project manuals have no advantage over direct methods insofar as specifying benefits is concerned.

Large and Small Projects

Small projects are those that do not change many existing prices. To evaluate a small project, one needs information on the prices (or shadow prices) of its outputs and inputs at the existing equilibrium. If the project covers costs at these prices, then it should be built.

Large projects change many prices. The Aswan high dam and the California Central Valley Project were projects big enough so that one could reasonably expect that the prices of cotton, fruit, and vegetables, as well as other prices, would change after the project was built. Pre-project pricing does not (generally) solve the question about building a particular large project. The technical reason why the pricing rule may not work is that the project is taken to be a discrete alternative, which cannot be built on a smaller scale. An explicit model, such as a CGE model, which solves for market prices endogenously can resolve such problems.

Alternatives

The most difficult problem in project evaluation is the specification of alternatives. It is a problem common to all methods of project analysis. For example, the benefit-cost rule sets excess of benefits over costs as a necessary condition for the funding of a project. The rule does not guarantee that the project maximizes the difference between benefits and costs. There may well be another project (usually a smaller project when suggested by environmentalists) that has higher net benefits. In the case of a drainage project, shutting down production on some of the land would be an alternative, as would different cleanup processes. Finding these alternative projects and evaluating them is a major challenge.

In addition to physical alternatives to investment projects, there are economic alternatives. LM particularly emphasize the alternative of trade. Their border pricing rules implicitly evaluate every project against the alternative of international trade -- the "make or buy" decision. When interregional or international trade is incorporated into a CGE model, the model correctly includes trade as an alternative to every project.

Diamond and Mirrlees (1971) show that, in the presence of optimal commodity taxes, there are no distributional benefits of projects. Thus, taxes that separate producer prices from consumer prices are also important parts of any package of alternatives. These instruments are easy to incorporate into a CGE model --although it is hard to argue that current commodity taxes are optimal in the American economy, or in any other economy.

Prices

Project evaluation in a developing country always runs into the problem that domestic observed prices are not reliable indicators of value. In the case of water projects, the United States is like a developing country. Observed agricultural prices cannot be trusted as indicators of social values because they are distorted by pervasive government policies such as the loan program, deficiency payments, and export subsidies. Similarly, water prices do not reflect marginal social values because they are largely determined by government project rules rather than the operation of free markets.

The standard solution to these problems is to choose a consistent set of prices that either equal or are based on international (border) prices. Bell and Devarajan (1987) provide the exact correspondences between the LM rules and the implementation of those rules in the CGE framework. The problem with the LM rules, in practice, is that important factors (particularly, labor) are not traded in international markets. Thus, the most difficult job for the analyst is to figure out a wage that is commensurate with the border prices that the analyst uses for traded goods. It turns out that the solution of the CGE model written in a particular form will give these hard-to-calculate prices. Thus, a CGE model, which takes border prices for tradeable goods as given, generates a set of solution prices for nontraded goods which represent their LM shadow prices.

For the San Joaquin Valley, border prices are crucial. Taken from the view of the United States, the border price for cotton is the world market price, which is about 72 cents per pound. A project evaluation (done from the point of view of the United States) should not, under the LM rules, include cotton deficiency payments, which are about 10.5 cents per pound. From the point of view of California, however, the appropriate border is that with the rest of the United States. If policy makers are trying to maximize California's welfare, they should certainly take the price in the United States, which is the U. S. price plus the deficiency payment (about 82 cents per pound), as the appropriate "border" price.

Another example of the border pricing rule is water. The southern San Joaquin is an importer of water. The appropriate shadow price is the value of the next unit sold to the highest bidder. The East Bay Municipal Utilities District, for instance, is in the process of developing a high-cost, high-quality, water supply costing approximately $1,000 per acre-foot. Marin and Santa Barbara counties are both giving serious consideration to building desalinization plants, yielding water at $2,000 per acre-foot. Under these circumstances, the border price is a great deal more than the $60-$70 that the water is worth if used in the Valley or the $20-$30 that is charged by federal water projects. Both in the CGE model and following the LM project evaluation rules, water should be priced at its value in the next best alternative use.

Recent survey evidence puts the average returns (market revenues less variable costs) to growing cotton in Kern county at about $250 per acre.[2] Overhead, insurance, and such could add as much as $80 per acre, for a net return per acre of $170. A border price for water of $50 per acre-foot greater than the current cost of water would make cotton farming unprofitable. Including a deficiency payment of 10 cents per pound (about $130 per acre, given average yields) would make cotton wildly profitable. In sum, evaluating a water project in the Southern San Joaquin is very dependent upon the border pricing rules.

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[2] Personal communication from Richard Howitt.

Secondary Benefits

No area of project evaluation is more controversial than the evaluation of secondary benefits --benefits accruing to sectors purchasing from or selling to the project sector. For example, a water project raises agricultural output, which induces increased demand for agricultural inputs, such as fertilizer. Numerous practitioners double count benefits or ignore costs. For example, by counting the additional fertilizer production as a project benefit (and not counting the natural gas used to make the fertilizer as a cost), it is possible to make almost any project seem welfare increasing. An equally egregious practice is to count the increased agricultural processing activities as "stemming" benefits and then ignore their costs.

Both the CGE methodology and the LM methods provide ways of consistently and correctly accounting for changes in the economy in sectors other than those directly affected by the project. LM concentrate on finding proper prices, taking linkage effects into account, while CGE models directly compute the effects of the project on all linked sectors. Both these methodologies correctly account for project benefits and costs in linked sectors.

4. A Regional CGE Model

Our regional model is a special type of CGE model reflecting the smallness of the region at hand. For a "small" region, most sectoral exports face perfectly elastic demands at fixed prices, and the domestic price will be set by the export price. In the case of the San Joaquin Valley, it is reasonable to treat the prices of products such as grain and cotton as fixed, while a few exports (such as the fruit and nut sector) might be viewed as having an external downward-sloping demand curve. At the level of aggregation used in our model, there are exports in all sectors, so there are no pure non-traded goods in the model.

The treatment of imports and exports also differs from most economywide models. We treat all imports as "noncomparable," which means that they are not produced in the region but are consumed or used as intermediate goods. In the model, sectoral import demand, both as intermediate inputs and final demands, are given by fixed coefficients. Exports, on the other hand, are determined so as to clear the product markets in the region, given the fixed prices. For each sector, supply and demand is calculated given the fixed price. Then, net exports are determined residually to balance supply and demand. While net exports could be negative (i.e., becoming net imports), all sectors in the San Joaquin Valley are large net exporters in the base data.

In the Valley model, we assume that capital is sectorally fixed and immobile. On the other hand, we assume that the aggregate supply of labor in the Valley is fixed and let the model solve for the market-clearing wage and the sectoral allocation of labor. Alternatively, we could have specified the average wage as fixed and let the model solve for net labor migration into the Valley. In the event, the difference between these two specifications was irrelevant, given the policy changes we modelled. Even our most extreme experiments yielded virtually no change in the average wage in the Valley, and hence, no change in the aggregate demand for labor.

In the regional model, the exchange rate is, by definition, fixed and set to one. This rules out problems faced in a country model of specifying how the foreign-exchange market clears. In a regional model, the capital account always adjusts to offset any balance of trade that the model yields in equilibrium. It is traditional, in the LM rules, to evaluate projects in terms of uncommitted government expenditure in local currency at international prices. Obviously, in terms of the United States, U. S. dollars will do just fine.

Hanemann *et al.* (1987) focuses on constraints of soil type. We have been able to model such constraints crudely, as discussed below. Similarly, the quota constraints on dairy are modeled. Our major source of data is a regional SAM for the aggregate of counties provided by the U. S. Forest Service.[3] Data on water coefficients by crop were provided by the Department of Water Resources. Production parameters are estimated using 1976 data on water usage, 1982 acreage data, and intermediate use from 1977 input-output data updated to 1982.

The model has 14 sectors, with 6 agricultural sectors [dairy, grazing (livestock), cotton, grains, fruits and nuts, and other agriculture], two processing sectors (one for dairy and one for all other agriculture), one other manufacturing sector, a mining sector, and four service sectors (trade, freight, banking, and other services).

There are five factors of production in our model: land, water, labor, capital, and intermediate inputs. Land and water are only used in the agricultural sectors. Land is taken to be in fixed aggregate supply, and there are three different types of land. Land currently growing cotton is assumed to be able to be converted to field crops or grazing, but not vice versa. Similarly, land currently growing fruits and nuts can be moved to field crops or to grazing, but not vice versa. Thus, grazing is the residual use, with land able to be converted from crops to grazing, but not vice versa. This specification captures the notion that there is a hierarchy of land qualities. Good land can be converted to less-good uses, but not vice versa.

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[3] Alward *et al.* (1989) describes the method for constructing regional SAMs.

Water is taken as having a fixed aggregate supply, and our experiment is simply to decrease this supply. Water coefficients are assumed fixed by sector and, hence, by crop. However, water is assumed to be freely mobile across sectors. That is, one can convert land from one crop to another (according to the hierarchy) and can also convert the water use at the same time.

Laborers are modeled as mobile between sectors within the Valley and immobile between the Valley and the rest of the world. Capital is taken as sectorally fixed. Thus, the model will solve for a single average wage which clears the labor market but will yield sectorally differentiated profit rates.

Production Technology

In Figure 1 we describe the production technology for the agricultural sectors. Sectoral production is given by a nested multi-level function. We specify two variants of this function: (1) a "high elasticity" variant and (2) a "low elasticity" variant. In both variants, domestic and imported intermediate inputs are demanded according to fixed input-output coefficients and land consists of a combination of acreage and water, with the water to land ratio given by a fixed coefficient (which differs across agricultural sectors). In the high elasticity variant, which is shown in Figure 1, real value added is a Cobb-Douglas aggregation of land, labor, and capital. In the low elasticity variant, capital and land are used in fixed proportions, and labor is combined with the capital-land aggregate according to a Cobb-Douglas function.[4] In effect, capital is moved to the bottom level in Figure 1.

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[4] In the low elasticity variant, sectoral capital in the agricultural sectors varies with land use. In the high elasticity variant, sectoral capital stocks are fixed.

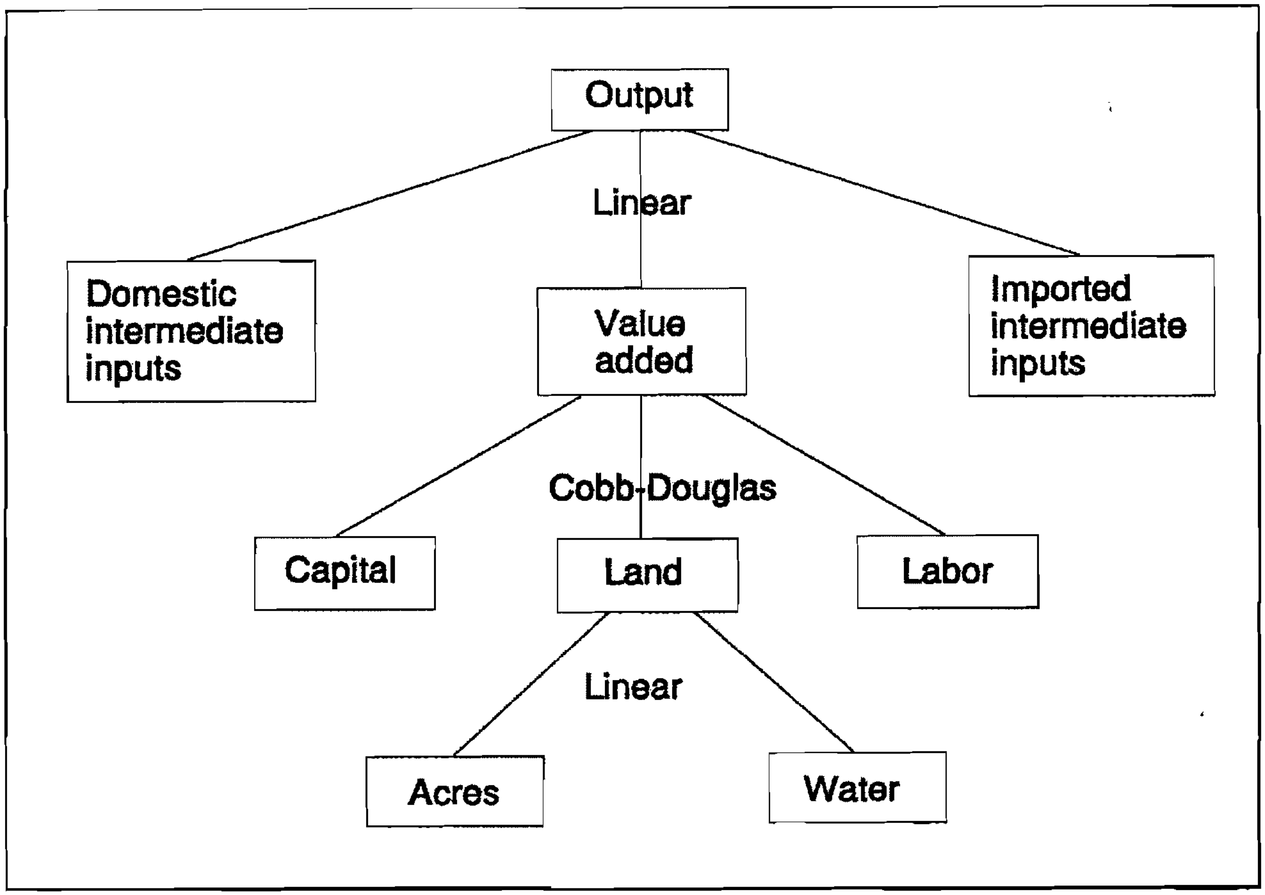

Figure 1: Production Technology, High Elasticity Variant

This specification of technology severely limits substitution possibilities in sectoral production. Water, land, and (in the low elasticity variant) capital are used with fixed coefficients, and there is no direct substitution between land and intermediate inputs such as fertilizer and pesticides. There are, however, substitution possibilities between land, labor, and (in the high elasticity variant) capital, with a substitution elasticity of one.[5] Thus, in response to changes in water availability and relative factor prices, yields can be changed but only by changing sectoral employment. In sum, the model probably understates substitution

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[5] In the high elasticity variant, even though there are substitution possibilities between land and capital, capital is sectorally fixed. The responsiveness of output to changes in land use, however, differ between the two variants.

possibilities in sectoral production, certainly in the low-elasticity variant, although it allows adjustment by changing the cropping pattern through changes in the sectoral structure of land use and production. Given the specification of technology, one would expect the model to yield results that provide an upper bound on the impact of changes in water availability on the agricultural sectors.

The non-agricultural sectors do not use land. Thus, their technology is described by the first two-aggregation levels in Figure 1, with land omitted from the value-added aggregation. The treatment of the non-agricultural sectors follows that in standard CGE models, given the assumption that all imports are non-competitive.

Solution Techniques

Solving CGE models numerically involves finding a general equilibrium solution with supply-demand balance in all markets.[6] In a standard model, these supply and demand equations are all written out explicitly, reflecting first-order conditions for maximization of profits by producers and utility by consumers. In our model, the specification of the technology for the agricultural sectors involves inequality constraints, so it is not possible to write out the factor demand equations explicitly. Instead, we write out the explicit programming problem for maximizing proprietor income (profits plus return to land) for the agricultural sectors and solve it as a subproblem, thus determining product supply and factor demands for the agricultural sectors numerically. One advantage of this procedure is that the model generates the shadow price of water to the agricultural sectors, enabling us to

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[6] For a survey of solution techniques used in applied models, see Ginsburgh and Waelbroeck (1981) and Dervis, de Melo, and Robinson (1982). We use a software package called General Algebraic Modelling System (GAMS), which is described in Brooke, Kendrick, and Meeraus (1988).

determine the demand curve for water by running a number of experiments varying the aggregate supply of water.

A Social Accounting Matrix

The primary data for our illustrative model comes from a SAM for Fresno, Tulare, Kings, and Kern counties. The SAM used here was produced by the U.S. Forest Service's IMPLAN system.[7] The SAM shows the flow of income and expenditure in the four-county region.[8] Table 1 is an aggregate version of the SAM. The model distinguishes 14 sectors but, for presentation purposes, Table 1 shows only two: agriculture and non-agriculture.

The entries in the SAM are 1982 production, factor payments, transfer, trade, and final demand in dollar flows. The first sector in the aggregate SAM is agriculture. The entries down the column indicate expenditures by the agricultural sector. The first entry is intermediate purchases by agriculture of agricultural products as intermediate inputs. The second entry is purchases of non-agricultural intermediates, followed by payments to factors of production (e.g., wages and profits). In the SAM, producing sectors make no direct payments to households. Finally, there are entries for purchase of intermediate inputs from the "rest of the world," which represents imports from the rest of the United States and other countries. The first row of the SAM is sales of the agricultural sector and describes the market for agricultural goods. Demand categories include intermediates, consumption by households, government and investment demand, and exports to the rest of the world. The corresponding row and column sums must be equal, since we require that sales equal disbursements in every account.

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[7] See Alward *et al.* (1989). The data start from a 1977 input-output table, updated to 1982.

[8] Pyatt and Round (1985) provide a complete description of the SAM methodology.

Table 1: A Social Accounting Matrix for the Lower San Joaquin Valley, 1982

						Expenditures:				
Millions of dollars	1	2	3	4	5	6	7	8	9	
Receipts	Agric.	Non-ag.	Wages	Profits/ Rent/Tax	Enterprises	Households	Government	Investment	Rest of World	Total
1 Agricultural	401	577				86	14	19	4,009	5,106
2 Non-agricultural	1,303	6,824				6,721	1,637	1,084	12,117	29,686
3 Wages	645	8,575								9,220
4 Profits/Rent/Tax	1,463	6,084								7,547
5 Enterprises				4,269						4,269
6 Households			7,791		3,182		2,035			13,008
7 Government			1,200	1,369	932	2,174				5,675
8 Investment				1,909	155	-90	846		-14	2,806
9 Rest of World	1,294	7,626	229			4,117	1,143	1,703		16,112
Total	5,106	29,686	9,220	7,547	4,269	13,008	5,675	2,806	16,112	

The SAM treats sectors like agriculture and institutions like households symmetrically. The column for households shows their purchase of goods (domestic and imported), savings, and payments of taxes. The row for households shows that household income comes from wages, distributed profits, and transfers. The SAM captures the entire flow of funds in the Valley economy.

The SAM gives a good picture of the Valley economy. Agriculture, while important, provides only 13 percent of total value added in the Valley. Agricultural purchases of non-agricultural goods produced in the Valley are only 8 percent of Valley value added, so the "backward linkages" from agriculture through intermediate inputs produced in the Valley are not very large. Their major links are to the non-Valley economy, with intermediate imports (both agricultural and non-agricultural) equalling 53 percent of value added and exports equalling 46 percent of total sales. This underlying structure is captured in the model and largely drives the empirical results described below.

Data from the SAM provide many of the parameter estimates of the CGE model. On the production side, all the linear coefficients are taken from the SAM, while the cost shares are used as estimates of the Cobb-Douglas parameters. The demand and distributional parameters are also taken directly from the SAM. Thus the base-year solution of the CGE model exactly replicates the SAM.

5. Results

Starting from the base run, our simulation experiments are designed to explore the impact of removing water from agricultural use. We ran two sets of five experiments. In each set, the experiments remove water in 10 percent increments, with the last experiment forcing agriculture to use half the base-year water allocation. The two sets of experiments differ in the factor substitution elasticities assumed in the four agricultural sectors.

Figures 2 and 3 indicate the changes in water use by major crops under different assumptions about the elasticity of substitution amongst factors of production. In the high elasticity case, where factors are relatively more substitutable, water is first removed from cotton and other agriculture, and then from grains. As the cut in water use approaches 50 percent, grain acreage nearly disappears. In the low elasticity case, grains decline first, followed by other agriculture and cotton. Grain acreage nearly disappears when the cut in water reaches 30 percent. Neither dairy nor fruits and vegetables are affected at all in either case. The changes in the high elasticity case are much more gradual, with smoother changes in cropping mix than in the low elasticity case.

Agricultural sectoral production results are shown in Figures 4 and 5. They closely follow the results for water. High value agriculture (such as fruits and vegetables and dairy) are not cut back as water is removed. There is increasing livestock output as irrigated crop land is diverted to dry land pasture. The decline in the output of grains actually leads to the region becoming a grain importer in the extreme experiments.

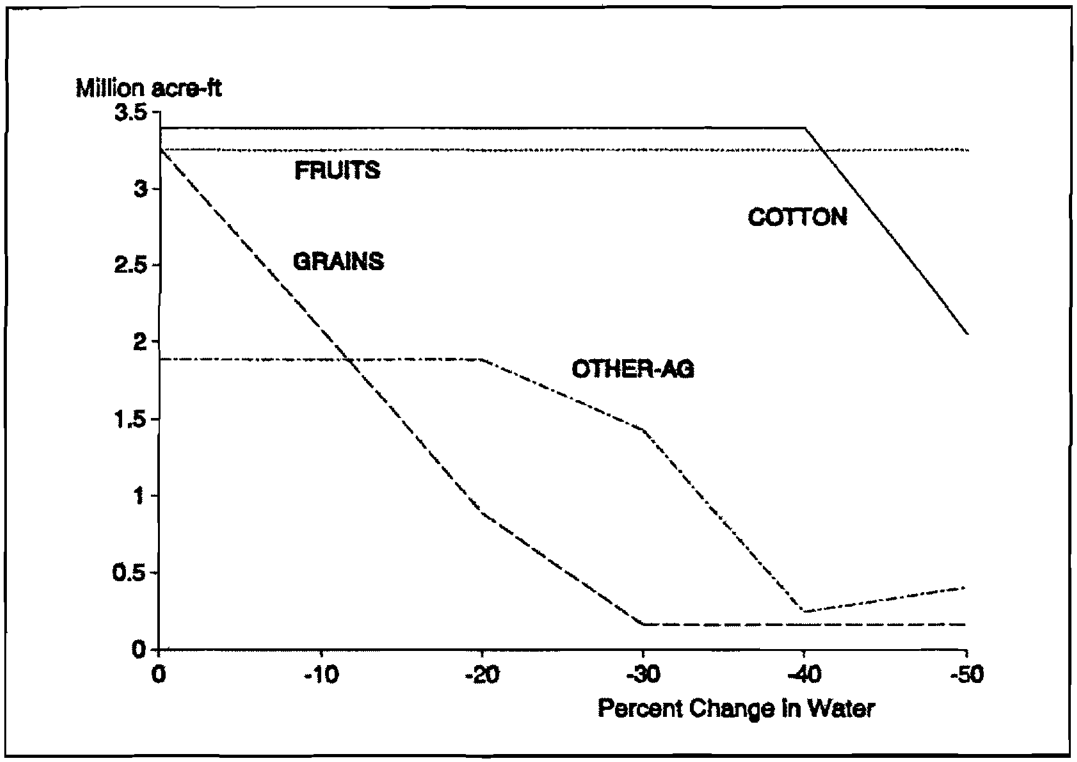

Figure 2: Water Use, Low Substitution Elasticities

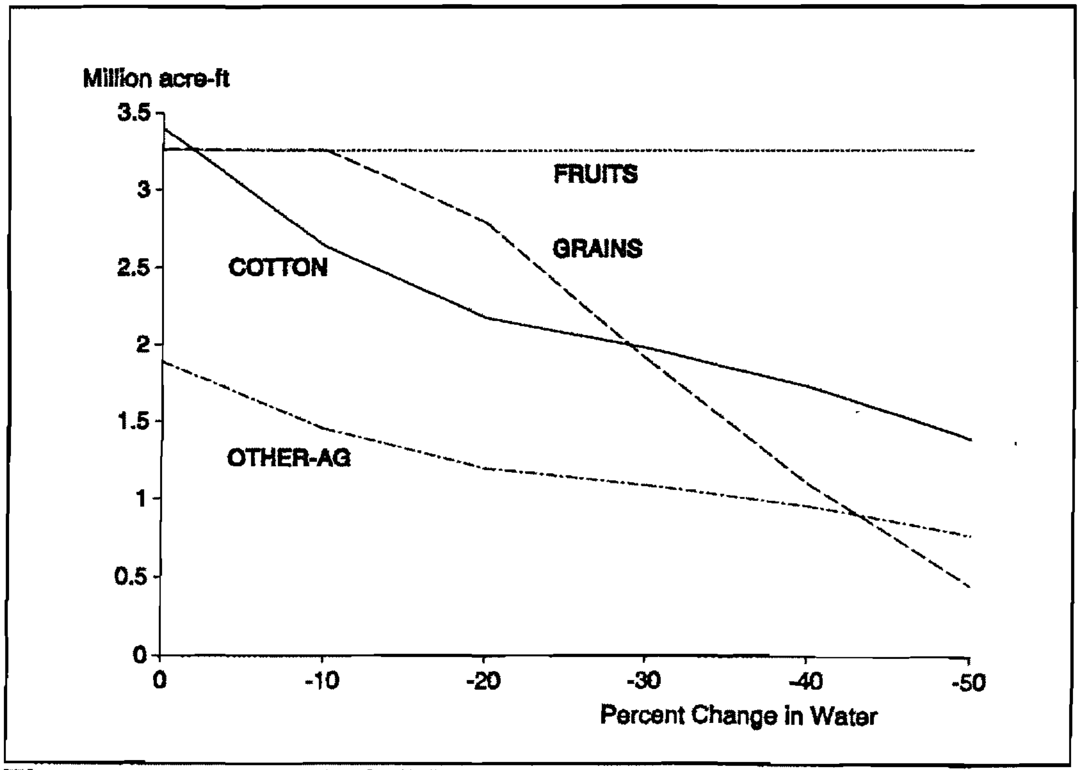

Figure 3: Water Use, High Substitution Elasticities

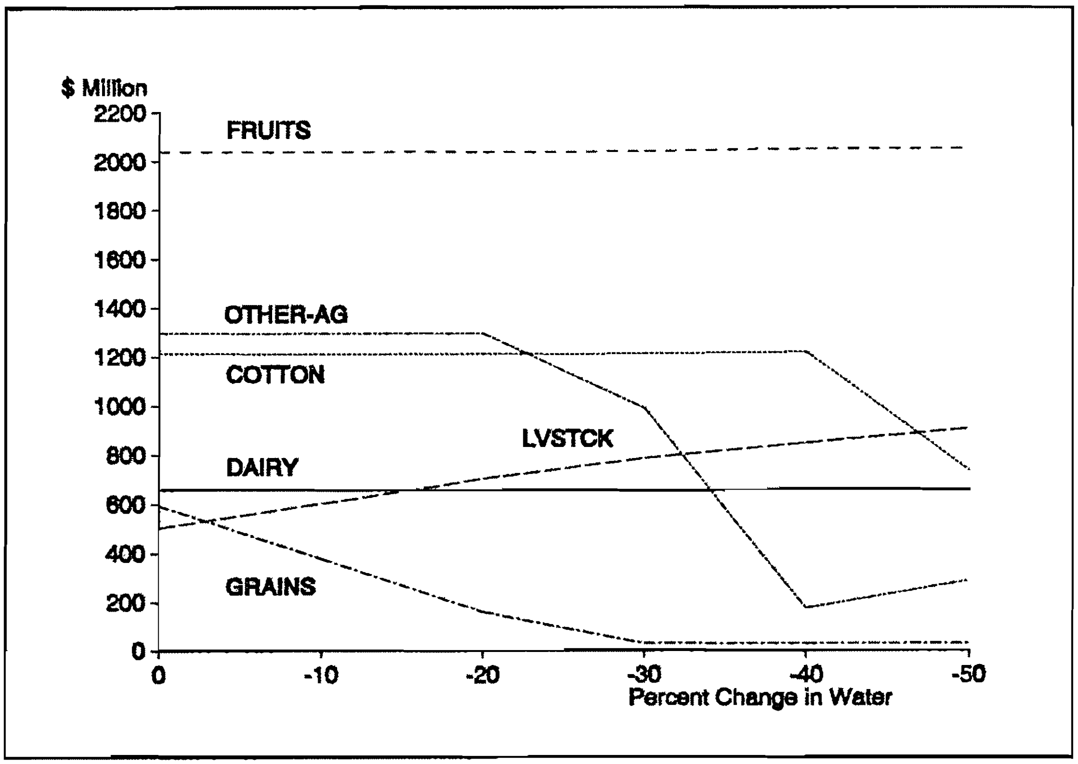

Figure 4: Output, Low Substitution Elasticities

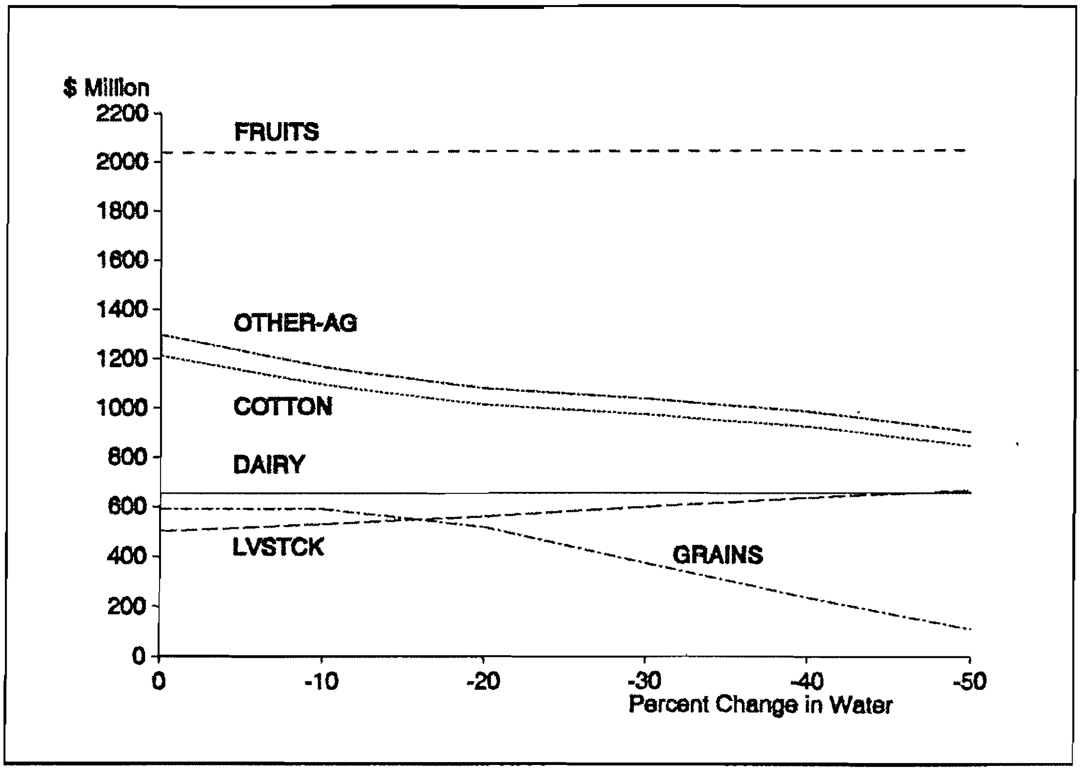

Figure 5: Output, High Substitution Elasticities

The effect of water restrictions on Valley GDP, agricultural value added, and returns-to-agricultural proprietors are given in Table 2. In the most extreme case, with a 50 percent cut in water and low elasticities of factor substitution, agricultural value added falls by $758 million and proprietor income falls by $401 million. Valley GDP, however, only falls by $305 million, which represents 3 percent of initial Valley GDP.

Table 2: Aggregate Results

		Percent Change in Water				
	Base	-10%	-20%	-30%	-40%	-50%
Low Elasticities						
Valley GDP	9,803	9,755	9,706	9,649	9,577	9,498
Agricultural value added	2,538	2,475	2,413	2,248	1,910	1,780
Proprietor income	1,515	1,454	1,394	1,319	1,218	1,114
High Elasticities						
Valley GDP	9,803	9,770	9,729	9,685	9,638	9,586
Agricultural value added	2,538	2,442	2,353	2,278	2,192	2,088
Proprietor income	1,515	1,470	1,418	1,363	1,303	1,237

Note: All figures are millions of 1982 dollars.

Agricultural value added includes the value of agricultural labor. When the agricultural sectors contract, labor is released to work in other sectors, thus ameliorating the impact of the water reductions on Valley GDP. The difference between the $758 million loss in agricultural value added and the $305 million loss in GDP equals $453 million, which represents the earnings of the resources shifted out of agriculture. Most of this offset is accounted for by the transfer of 22,000 laborers into other sectors (not tabulated). The losses are less extreme in the high elasticities of substitution experiments.

In the experiments, landowners are not compensated for their lost water. In the most extreme case discussed above (low elasticities, 50 percent cut in water), a payment of $67 per acre-foot of water removed per year would leave proprietor income unchanged from its base value.

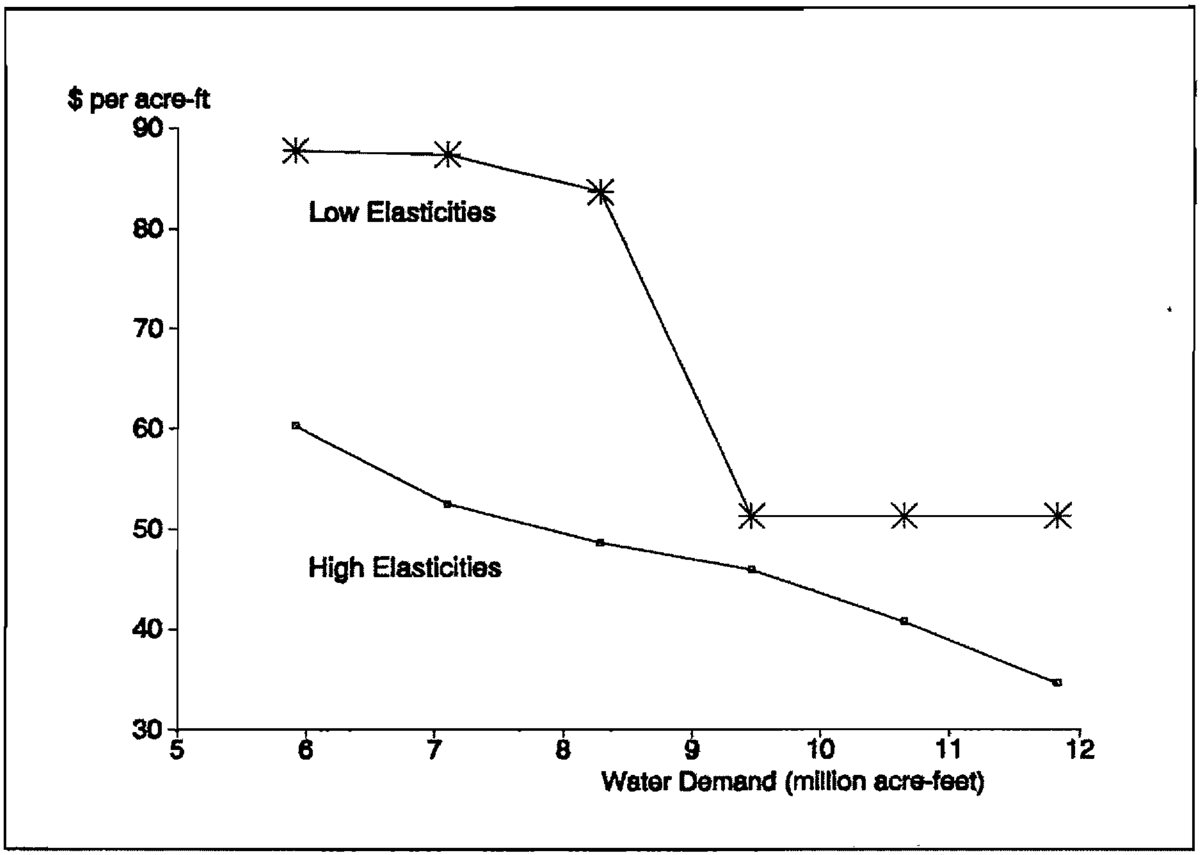

Figure 6: Demand Curves for Water, Low and High Substitution Elasticities.

The marginal value of water to proprietors (the shadow price generated by the model solution) reflects the demand for water by the agricultural sector as a whole. Plotting these marginal values against total water usage represents the demand curve for water by the agricultural sector. Figure ~~8~~ 6 shows these demand curves for the low and high substitution elasticities cases. As expected, the demand curve is much steeper in the low substitution case. In the extreme case, the competitive price of water would rise to $88 per acre-foot, from a value of $51 in the base. In both cases, the price elasticity of demand rises above one after a 30 to 40 percent cut in water usage.

Table 3 presents results for multipliers with respect to changes in water usage. In the high elasticity case, the GDP multiplier for the first 10 percent cut in water usage is $28 per acre-foot. The corresponding multipliers for agricultural value added and proprietor income are $81 and $38 per acre-foot. The low elasticity multipliers are uniformly higher for proprietor income, as one would expect. The less able farmers are to adjust farming techniques, the more the withdrawal of water hurts them. There is no necessary relationship for the other multipliers between the low and high elasticity cases, and they, in fact, vary widely.

The labor multipliers show particularly wide variation, depending on the nature of the changes in cropping patterns as water is withdrawn. The largest is 13,000 workers withdrawn per million acre-feet of water withdrawn, which occurs in the low elasticity case when other agriculture is affected (see Figure 6). All the labor multipliers in the high-elasticity case, and three of the five multipliers in the low-elasticity case, are under 3,000 workers per million acre-feet withdrawn.

6. Conclusion

In this paper, we have laid out a methodology for evaluating the economic impact of withdrawing water from agricultural use. The model we presented is fairly aggregated, highly stylized, and is designed to illustrate the methodology. Two versions of the model were presented with production specifications that probably bracket the actual substitut-

Table 3: Water Multipliers

	Percent Change in Water				
	-10%	-20%	-30%	-40%	-50%
Low elasticities					
Dollars per acre-foot					
Valley GDP	41	41	48	61	67
Agricultural value added	53	53	139	286	110
Proprietor income	51	51	63	85	88
Workers per million acre-ft					
Agricultural labor	118	118	4,684	12,509	1,387
High elasticities					
Dollars per acre-foot					
Valley GDP	28	34	38	40	44
Agricultural value added	81	75	64	72	88
Proprietor income	38	44	47	51	56
Workers per million acre-ft					
Agricultural labor	2,676	1,934	1,036	1,355	1,982

Notes: Values are dollars (or workers) lost per acre-foot (or million acre-feet) of water removed from agricultural use. Values calculated from successive 10 percent reductions in water use.

ability of labor and capital for water. Both versions are extreme in that they assume no substitution possibilities between other intermediate inputs (such as fertilizers and pesticides) and water. In the end, we believe that our aggregate results will prove to be robust and that the results from our two models will probably bracket those from a more detailed model.

Our experiments indicate that removing water from the Southern San Joaquin Valley results in a rapid decline in cotton and/or grain acreage and in an increase in acreage devoted to livestock. Coincident with this acreage shift is a decrease in Valley GDP, employment, and agricultural income. These decreases in macroeconomic indicators are much less pronounced than the acreage shift, because the released resources find alternative employment. Given that the crops withdrawn have relatively low labor intensities, the net effect of water withdrawal on agricultural employment is small. For example, the effect of withdrawing 20 percent of the water supply leads to the displacement of only 5,000 agricultural workers.

Similarly, the net effect of withdrawing 20 percent of the water supply on economic activity in the Valley as a whole is small, although it decreases proprietor incomes in agriculture by around $100-120 million. With a market in water rights, payments for water would offset these income losses. Even in the most extreme case, a payment of $67 per acre-foot of water withdrawn would compensate proprietors for their loss of income.

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