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The Value of Models in Policy Analysis

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A Model as a Simplification of Reality

There is no single model of an economic system. In general, a model is a simplified approximation of reality, and there must surely be many such approximations. Therefore, we have large and small models, real and nominal models, sector and aggregative models, dynamic and static models, long- and short-run models, and so on. The model being used at any one time is undoubtedly chosen, in part at least, according to the objectives for its use. Some models are very general in design, in order to be available for a variety of applications, but no economic model, in a very practical sense, stands apart from its end use. Special purpose models, to the extent that they can be made available, are the best for difficult problems.

Among the many classes of models, I am going to be concerned, in this paper, exclusively with econometric models. Accounting models, mathematical programming models, systems-dynamic models, general equilibrium models and other types are not going to be considered or implicitly assumed. I shall work exclusively in this essay with mainstream econometric models, typified by those of Wharton Econometric Forecasting Associates, Data Resources, Inc., the Federal Reserve Model, the Michigan Model, and similar systems.

These mainstream models are used in many ways, the most visible of which is in forecasting the macro economy or significant parts of it. The forecasting application is important and must continue to occupy a great deal of the model builder/operator's time, but surely the largest single use of econometric models is for study of economic alternatives. This is how they are best used in the policy process.

Once a model has been specified, i.e., given a parametric structure, and estimated on the basis of available data, it is ready for application. The most important single tool for use of a model is analysis. Whether it is a pure forecast simulation or a hypothetical policy simulation or a stylized scenario, it is always a simulation of some kind that underlies any application of the system.

The mathematics, statistics, and numerical analysis of simulation are straightforward. A simulation is a ***solution*** of an economic model. This solution is an integral (in finite terms, usually) of a dynamic system, starting from fixed initial conditions. The generating of solutions is at the base of using models in the policy process.

Formal Political Economy

The variables of an econometric model can be classified in a variety of ways, but the most revealing classifications are into:

endogenous variables
exogenous variables
target variables
instrument variables

Endogenous variables are variables that are generated, or explained, by the model. They are the objectives of model building.

Exogenous variables are external to the system. They have impact on the endogenous variables, but there is no feedback from the economy (or the model of it) to the exogenous variables. Other expressions for these same two classes of variables — endogenous and exogenous — are jointly ***dependent*** variables (endogenous) and ***independent*** (exogenous) variables. The independent variables "drive" the model, apart from initial conditions and functional form.

For purposes of policy analysis, the other split is very helpful. The concepts of targets and instruments are due to J. Tinbergen.[1] A target is a policy-set value (or group of values) for an endogenous variable. Four percent inflation, low (4.0 percent) unemployment. high (4.5 to 5.0 percent) growth, budget balance, a strong dollar, and other pertinent magnitudes are target objectives for public

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1 J Tinbergen, ***Economic Policy: Principles and Design***, Amsterdam North-Holland. 1956.

authorities who need to try to reach certain goals for the economy.

Not all endogenous variables are targets — only those with a deep meaning and commitment for the policy maker. At the macro level, comprehension, appreciation, meaningfulness for the electorate, and manageability are criteria that limit the number of targets, certainly fewer than ten magnitudes, and possibly no more than five are practical limits at the present time. If there are hundreds or thousands of endogenous variables, it is clear that a tiny minority of such variables are used as targets at any one time. The remaining hundreds are not ineffectual; they are simply having a passive transition phase.

By the same token, not all exogenous variables are ***instruments.*** They are controllable magnitudes that are set by public authorities in order to achieve certain results. Among the thousands of exogenous variables in economic systems only a few (fewer than ten) are selected for policy control purposes. Most exogenous variables are not terribly concerned with contemporary policy control, in order to achieve stated aims, or targets.

In the formal design of an econometric model system for policy analysis we note that there are two types of endogenous variables — targets and other — and that there are two types of exogenous variables — instruments and other. In abstract terms we write:

$$F(y_t', y_{t-1}', \ldots, x_t', x_{t-1}', \ldots, z_t', z_{t-1}', \ldots, w_t', w_{t-1}', \ldots, \theta') = e_t$$

$$F = \begin{matrix} f_1 \\ f_2 \\ \vdots \\ f_n \end{matrix}$$

y_t is a column of target endogenous variables at time t.

$$y_t = \begin{matrix} y_{1t} \\ y_{2t} \\ \vdots \\ y_{n_1t} \end{matrix}$$

x_t is a column of non-targeted endogenous variables at time t.

$$x_t = \begin{matrix} x_{1t} \\ x_{2t} \\ \vdots \\ x_{n_2t} \end{matrix} \qquad n_1 + n_2 = n$$

z, is a column of instrumental exogenous variables at time t

$$z_t = \begin{pmatrix} z_{1t} \\ z_{2t} \\ \vdots \\ z_{m_1 t} \end{pmatrix}$$

w, is a column of non-instrumental exogenous variables at time t.

$$w_t = \begin{pmatrix} w_{1t} \\ w_{2t} \\ \vdots \\ w_{m_2 t} \end{pmatrix} \qquad m_1 + m_2 = m$$

e, is a column of random variables.

$$e, = \begin{pmatrix} e_{1t} \\ e_{2t} \\ \vdots \\ e_{nt} \end{pmatrix}$$

0 is a column of parameters.

$$8, = \begin{pmatrix} \theta_1 \\ \theta_2 \\ \vdots \\ \theta_r \end{pmatrix}$$

The formal approach is clear enough. The parameters 0 are estimated from historical sample data. They are denoted $\hat{\mathbf{0}}$. Given $\hat{\theta}$, initial conditions — lag values of x_t, y_t, z_t, w_t — and values of exogenous variables over a projection or solution period, estimate y_t and x_t. This is a dynamic solution. using lags as initial conditions but generating values of y_t and **x,** as carryover initial conditions for the next period of solution. It is a non-stochastic simulation if ***e,*** is put at its mean (zero) value or at some a priori non-zero value. If the values of e_t used in the simulation are drawn by a random process we obtain a stochastic simulation.

In the first instance. a *baseline* solution is computed. This would be with standard or best judgmental values for the exogenous variables. When it comes to policy analysis, however, we estimate deviations from the baseline simulation by changing exogenous inputs or by changing parameters of the system, if they are policy controlled.

Policy has goals; these are expressed by the target values y_t. The policy maker attempts to hit these targets by changing values for z_t. If there are equal numbers of elements in y_t and z_t, then the econometrician simply reclassifies the two. Target values become exogenous, because they are given by the policymaker. Instruments become endogenous, because they are to be computed for the policymaker.

This simple ***inversion*** of the simulation problem is not generally possible when the number of targets exceeds the number of instruments. We would then try to come "as close as possible," in some well defined sense, to the target values by judicious choice of instruments. The procedures for doing this fell under the heading of ***optimal economic policy methods*** or ***optimal control*** theory, as that subject is known in the engineering literature.

Although some elements of the exogenous vector, w_t, are not controllable as instruments, the policymaker can try to become aware of various alternative consequences of changed values by altering the inputs for w_t and computing corresponding estimates of the solution. Possible responses to oil price shocks or harvest failures are typical examples of policy simulation in preparation for adverse circumstances.

One way to use models in the policy process would be to follow the techniques of optimal control and allow in a probability sense for error by using the extensions of the methods, known as stochastic control. Another approach, by far the most prevalent, is to proceed by search and experimentation. We have learned to overcome the most serious computational problems in the application of control theory methods to large scale economic systems, consisting of hundreds or even thousands, of equations. Yet there is a feeling that public authorities are not yet ready for the automatic approach of control theory and prefer to proceed with models, among other devices, by search and experimentation.

Alternative assignments of values to the elements of z_t and, in some cases, to $\hat{\theta}$ with simulation of each set of values gives the policy analyst a large menu of possible economic developments from which to choose. Also, ***scenario*** analysis of different choices for the elements of w_t, together with choices for z_t and $\hat{\theta}$, enable one to think in an analytical way about possible alternative futures. When policymakers find combinations of input values that lead to desirable model solutions, they choose the configuration that they like. In actual practice, models will not be used alone in this search/experimentation mode, but will be combined with informational analyses from other sources, but model results are almost certain to be one of the most serious sources of information in reaching ultimate policy conclusions.

It is useful to think how agricultural models fit into this frame of analysis. A model of the agricultural sector is like a model of any other major part of the economy. In the abstract, it is an equation system, dependent on enodgenous and exogenous variables, with both targets and policy instruments. They are also dynamic and stochastic equation systems.

There are, however, a few distinctive features about an agricultural sector model that are worth noting in relation to its applicability for policy analysis. First, it is a sector model and in that respect is an incomplete system when looked upon from a substantive point of view. In the United States, agriculture is an important sector, but it does not dominate the economy as it does in other countries, mainly large developing countries where population pressure imposes a burden on available food supplies. To a large extent, agriculture depends on the industrial economy in the United States and not vice versa, but agriculture does play a major role in determining a most sensitive component of the price level. It is also a major supportive factor in our net trade position; and it is important for regional politico-economic patterns. Either agriculture can be modeled as a satellite system with linkages to the non-agricultural base of the economy, with some degree of feedback, or agriculture can be modeled as one among several distinctive sectors in a large multi-sectoral system held together by some such device as an input-output system. The disadvantage of this latter approach is that it limits the amount of agricultural detail that can be included in an already large system of a few thousand equations. In a stand-alone mode, a complete agricultural model like the Wharton Model of ***the*** Agricultural Sector would have as many as 388 equations by itself. This would be the type of satellite system that would be used with linkages to the nonagricultural sector if the first approach is to be used.

The second distinctive aspect of agricultural model specification is the incorporation of a major uncertainty factor caused by the influence of weather variation. Agricultural supply responds to price and other economic factors in a systematic way, but it is also strongly affected by natural growing conditions, the most volatile of which is weather. General climate, crop disease (or health), and other natural factors have significant effects but such weather variables as rainfall, soil moisture, wind, temperature, storm, and similar phenomena are all highly relevant.

While the application of fertilizer, insecticide, and irrigation are all man-made decisions that attempt to modify or change natural factors, many of the effects of weather, climate, and other natural factors cannot be dealt with by human decisions. The z and w variables both occur in agricultural sector models. The z variables are the input levels of fertilizer, insecticide, and irrigation, but the natural factors are w variables. They cannot be controlled effectively. At one time, it appeared that cloud seeding might enable man to have a significant impact on rainfall, but an effective degree of control is not visible in the near future. The distinctive features of agricultural sector models can be succinctly described in terms of the relative variance of the z and w variables. As compared with model structure for other sectors of the economy, the relative variance of w relative to that of z is large.

If we cannot control important w variables, what can we do about them? First, it is important, at the estimation stage of model building to have the best attainable values for the quantitative effects of w variables, even if they cannot be controlled. This is so because we need to know how much to expect from w variation, and we do not want to bias the estimated effects of the other variables. Within the realm of scientific modeling, econometric models of all types, whether agricultural or other, have comparatively large noise-to-signal ratios, and we have no more control over "noise" than over the w variables of an agricultural sector model. The difference between the two kinds of variables is that w variables are directly measurable, while the noise variables are not. The latter are generated by the laws of probability (assumed), while the generating process of w variables may or may no be known.

In the most favorable case, the laws governing the w variables are the subject of investigation of another branch of science, either meteorology or climatology. Short run weather factors are estimated by meteorologists for the economist. While, in principle, we can use meteorological estimates of rainfall, temperature, and other weather indicators, the trouble is that they are useable in terms of degree of accuracy, over only a very brief horizon. Short term meteorological forecasts of a few days have use and accuracy that are similar to those found in projections from economic models, but month-ahead or year-ahead weather projections are very unreliable.

The usual way of taking this aspect of uncertainty into account in applications of economic models is to prepare, first, an economic projection on the basis of normal weather patterns and then to consider deviations above and below normal. It is possible that meteorological data could be used to estimate probabilities of departure from normal; in this way an expected projection could be made, as from

$$P_o \hat{Y} + \sum_{i=1}^{n} P_i^- \hat{Y}_i^- + \sum_{i=1}^{n} P_i^+ \hat{Y}_i^+$$

where $\hat{Y}$ is the solution of the economic model using normal inputs, occurring with a relative frequency or probability of P_o; Y_i^- is the solution for the i-th level input below normal, occurring with relative frequency P_i^-; and Y_i^+ is the solution for the i-th level input above normal, occurring with relative frequency P_i^+.

In the calculation of standard error of forecast from a linear model we construct a quadratic form in terms of departures of exogenous variables from their average values, the weights (coefficients) being covariances of the estimated coefficients. We could add a quadratic form to that having as coefficients the covariance of exogenous variables — in this case, the meteorological variables.

By drawing on the expertise of meteorology, and combining that with economic interrelationships, we can use models in a way that takes account, in a quantitative sense, of the uncertainty involved even though we cannot make a precise point estimate of the variable representing the uncertain magnitude.

Some Examples of Policy Analysis

The discussion thus far has been quite general. It is time to take a look at some specific examples of what is meant by policy analysis, using an economic model. I shall begin with a macro analysis of the most relevant and discussed national issues contained in President Reagan's economic program. There are four main categories of action that have significant impact on exogenous variables of a model, in this case the Wharton Quarterly Model of the U.S. Economy.

1. Increases in defense spending.
2. Reductions in non-defense (federal) spending.
3. Reductions in personal federal taxes in three installments (10/1/81, 7/1/82, 7/1/83). Guideline lives for industrial capital are also shortened, for tax purposes.
4. Monetary policy is to be kept restrictive, in order to achieve specific targets for M1-B and M2 growth.

Each of these policy assumptions has been factored into the Wharton Model for latest projections; some of the assumptions are statutory and some are our own interpretations of budgetary or stated committments.

Defense Spending. Increases in military compensation of 14.4, 8.9, and 7.9 percent are introduced on October 1 of 1981, 1982, and 1983, together with corresponding civilian raises of 4.8, 7.0, and 7.0 percent, respectively. By the middle of fiscal 1982, military manpower is assumed to increase by 50,000 persons and by another 25,000 afterwards. For FY 1982, the defense spending total is $172.8 billion, representing an increment of about 17 percent in nominal terms and about 7.0 percent in real terms. For 1983, the real growth is increased to about 9.0 percent.

Non-Defense Spending. For goods and services, this figure is put at $77.4 billion for FY 1982. This total includes pay increases of 4.8 percent, 7.0 percent, and 7.0 percent at the start of the next three fiscal years. Also, purchases of 250,000 barrels per day for the strategic petroleum reserve are included. In real terms, spending for goods and services is practically unchanged or falling slightly for the next year. In 1983, there are significant real cutbacks of some 9 percent. This allows nominal increases of about 7.0 percent in FY 1982, but hardly any change in 1983. Transfer payments depend on the level of economic performance. We have assumed that the administration's targets for foodstuffs, medicare, and other programs will prevail. Also, interest costs will depend on behavior and results in financial markets. In total, the Wharton budget assumptions for FY 1982 come to $715 billion, while the administration's estimate is $705 billion. In FY 1983, the Wharton total is $788 billion.

Taxation. Personal taxes have been reduced, in line with the administration's program (approved by Congress) for a reduction of 5 percent in rates on October 1981, followed by 10 percent reductions on July 1, 1982, and July 1, 1983. The Wharton forecast also allowed for the reduction of the maximum rate on investment income, the elimination of the marriage penalty, the deductions for income earned abroad, and the new deductions on estates and gifts. Some other minor tax reductions were also factored into the forecast.

The reduction in guideline lives for corporate depreciation allowances has been estimated at about **40** percent, effective January 1, **1981.** Some miscellaneous indirect taxes have been increased.

Monetary Policy. The guidelines of the administration made known publicly are simply to show restraint in expansion of money supply and to follow monetarist practices, i.e., to hold monetary aggregates to target ranges, while letting interest rates follow a course determined by market supplies and demands for funds. In a more formal sense, the Federal Reserve System has fixed guideline limits for **M1-B** and M2. For **M1-B** (adjusted for NOW and ATS accounts) the target range is **3.5-6** percent, and for **M2** it is **6-9.** The main instrument for control in the Wharton Model is nonborrowed reserves. This variable is fixed to a path that produces a solution for **MI-B** growth between 5 and **6** percent on average in **1981-83,** and **M2** growth between **8** and 11 percent. The later drifts above the range at the end of the solution path in late **1982** and **1983.** Nevertheless, we judge this as an overall restrained monetary policy.

The principal policy assumptions for the projection of the model being discussed are covered under the four heading listed above. There are two other important assumptions that must be dealt with in order to plan these political assumptions in the context of a meaningful result. These two exogenous areas are energy and agriculture. With respect to energy, the main assumption is that OPEC will make no price increases during the second half of **1981**. During **1982,** prices are increased quarterly at annual rates of 10 percent. During **1983,** this figure is raised to **11** percent.

The assumptions about weather, plantings, and main crop yields (wheat, corn, soybeans), lead to increases of the food CPI of 8 percent for **1981**, **9.6** percent for **1982,** and **9.4** percent for 1983.[2]

Given these policy and other exogenous assumptions for the next three years, how do we interpret the outcome and the success of the

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2. The excellent crop reports (mid-August) for the United States would probably lower these estimates of the food CPI, especially in 1982, back to the estimate of food price inflation prevailing in 1981.

policies? In general, the Wharton Model estimates that the administration will move toward most of the targets that it has set, namely lower inflation, stronger growth, and lower interest rates. These are only some of the main targets. But it does not appear, from the Wharton calculations, that it will achieve one other important target — a balanced budget by 1984.

TABLE 1

Wharton Model Forecasts and Administration Targets

	1980	1981		1982		1983	
	(observed)	Model	Administration	Model	Administration	Model	Administration
Change in real GNP (%)	-0.16	2 3	2 6	3 1	3 4	4 4	5 0
Change in GNP deflator (%)	9 0	8.8	9 6	8 4	8 0	8 1	7.0
Treasury bill rate (%)	11 4	15 2	13.6	15 4	10 5	12.7	7 5
Deficit (fiscal year, $billions)	54 9	54.3	55 6	80 0	42 5	98 6	22 9

Source The Wharton Model forecast of July 29, 1981 and the Mid Session Review of the U S. Government The Review was released prior to the report of the 2nd quarter GNP data of July 20

1980 was a recessionary year, and the Wharton forecast is for a continuing recovery during 1981-1983. The administration also looks for a recovery, but one that is considerably stronger than the Wharton estimate. Similarly, they look for a better inflation performance (after a worse estimate for 1981) and much lower interest rates. The Wharton Model, however, sees a basic contradiction in the administration position, and this is a main use of models: to examine internal consistency. The model estimates that interest rates will be higher as a consequence of the internal deficit and the restrictive monetary policy. Since interest costs are now more than $70 billion for the federal government, this is an item that can knock deficit estimates askew. Other aspects are higher transfers and reduced revenues associated with a softer real economy. These are the reasons why the model gives a message to policy makers that their plans will not achieve their targets.

In order to avoid the range of $100 billion deficits what policies might the authorities undertake?

- They could rescind part of the three year tax cut program.
- They could make more expenditure cuts in the budget, defense or non-defense.
- They could increase indirect taxes.
- They could adopt an easier monetary policy, with lower interest rates.

Each of these policies could make significant contributions to lowering the deficits. It would undoubtedly take some combination of all together in order to account for some $100 billion of estimated deficit, but it is a matter of quantitative magnitude — how much of a rescaling in the tax cut program, how much in expenditure cuts, etc.?

If the entire tax reduction plan for individuals were to be eliminated — in other words, if tax provisions that prevailed prior to August 13th were kept in place — the budget balance target would be met, but at the expense of higher unemployment and slower real GNP growth; therein lies the contradictory nature of the policy program, as estimated by the model.

Some of the individual options have been examined one at a time, in model simulations. The results are:

	Deficit Reduction (NIPA basis)
Rescind the 1983 round of personal tax cuts	$30.0 billion
Tax gasoline by $0.50/gal.	$45.0
Easier money (reduce short rates 100-150 basis pts.)	$ 9.0

These have not been estimated on a cumulative basis, and they all have differential impacts on other performance variables, but they do indicate the magnitude of the problem and the amounts that would be left for additional spending cuts if that were to be the residual item to make up the shortfall in achieving budget balance.

All these forecasts, including the baseline cases (both of the model and of the policymakers) are subject to error: therefore, one should not try to aim for pinpoint precision in policy formation. It should be pointed out, however, that projections in which a policy-induced simulation is compared with a baseline simulation are likely to benefit from error cancellation; i.e., the errors are correlated between two solutions being compared. This makes for better precision in comparative policy evaluation than in absolute forecasting.

Models have been used in more specific policy analysis than in this example of overall macro management of the economy. International models, comprising separate models for individual countries, have been simulated together, in project LINK, to study oil interruptions, oil pricing, and harvest failures, as well as general policy coordination among countries. By contrast, a specific policy application of models that is more related to the interests of this conference is a case worked out for U.S. agriculture, using the Wharton Agricultural Model, together with the Wharton Quarterly Model of the economy as a whole. The case to be considered is one of "parity pricing," which became a national issue in the spring of 1978.

During 1977 favorable crops in the United States and elsewhere contributed to low inflation rates but also to relatively poor farm income. Costs continued to rise for farmers, and they lobbied for full parity pricing of agricultural products in 1978, by setting targets at projected parity levels of October 1978 on a 1910-14 base. Increases from that date were to be based on changes in production costs. The figures under discussion are outlined in Table 2.

TABLE 2
Prevailing Market Prices and Parity Projections, May 24, 1978 (dollars per bushel)

	Prevailing Prices May 24. 1981	Projected Parity Price (October, 1978)	Parity Projected by Production Cost Increases (Oct. 1979)
Wheat	3.24	5.17	5.36
Corn	2.67	3.62	3.75
Soybeans	7.08	8.55	8.85

The effect of these parity price projections on the national and agricultural economy were estimated by joint simulation of two Wharton Models.[3]

The Wharton Agricultural Model was simulated, using inputs from the Wharton Quarterly Model (general inflation, national income performance, world trade, and related magnitudes). The agricultural model solution also used the parity price values for 19 commodities (16 others, in addition to those important ones in table 2). The results were so different from. previous solutions, of the agricultural model that the Wharton Quarterly Model, had to be re-solved, with the higher food prices, changed trade values, and related magnitudes. National economic variables were then fed back into the agricultural model for a new solution. The iteration process

3. In the policy context, these kinds of simulation results were used by Dr. Dean Chen in his testimony before the Senate Committee on Agriculture, Nutrition, and Forestry, March 2, 1978.

was halted at this stage, because, in a practical sense, convergence was attained. Table 3 shows the results of two simulations for 1979, with and without full parity pricing.

The parity requests were not granted. This model scenario showed that it would have been quite inflationary and very expensive to the federal government — more expensive than a $20 billion tax cut that would eventually serve a much broader segment of the national population. Agriculture would have suffered significantly. The political choice was unacceptable, and full parity was rejected.

TABLE 3
Parity Pricing Estimates of the Wharton Agricultural Model and Baseline Forecasts, 1979

	Parity Pricing	Baseline Forecast
Index of prices received by farmers, (1981-14 = 100)	731.6	462.1
Consumer Price Index for food (1967 = 100)	239.5	211.5
Net Farm Income ($ billion)	69.8	21.9
Wheat (bu. million)		
domestic disappearance	766.3	806.3
exports	959.9	1127.3
Corn* (bu., million)		
domestic disappearance	4544.3	4486.6
exports	1579.7	1728.0
Soybeans* (bu., million)		
domestic disappearance	937.9	966.4
exports	458.1	597.5
Cattle and calves on feed (head, million)	11.5	11.8
Pig crop (head, million)	43.2	44.8
GNP ($1972, billion)	1443.2	1455.7
GNP deflator (1972 = 100)	163.6	159.7

*Crop year estimates, 1978-79.

Overall Assessment

It could be argued plausibly that the examples cited could have been adequately dealt with by non econometric methods. That is undoubtedly true, but some kind of model, explicit or implicit would be needed to reach intelligent conclusions. All such policies