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THE ECONOMIC EFFECTS OF PETROLEUM- SUPPLY SHORTFALLS ON THE U.S. ECONOMY: ALTERNATIVES TO THE SCAM METHODOLOGY

G. Anandalingam

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ABSTRACT

The DRI Quarterly Macro Model is used to forecast final demands and simulate the base case for the Supply Constrained Analysis Modeling (SCAM) system. As in other commercially available macroeconomic forecasting models, the only expectations formulation used in the DRI Macro Model is adaptive in nature and is estimated with historical data. This is inadequate in modeling short-term major changes in consumption behavior, for example, panic buying of gasoline, when there is a supply shortfall in petroleum. This report describes alternatives to using the DRI Macro Model to estimate the macroeconomic impacts in the SCAM system. The possibility of using models that incorporate the rational expectations formulation was investigated, as was the possibility of modifying the DRI model to better capture short-run consumption behavior. It is suggested that in the absence a good commercially available rational expectations macroeconomic model, the modification of the DRI Macro Model would have the lowest resource cost in terms of person- and computer-hours spent.

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1 INTRODUCTION

Since the beginning of the seventies, one of the main problems for the U.S. and other oil consuming countries has been - and over the indefinite future will continue to be - the instability of the world oil market. In the winter of 1973-74, the Organization of Arab Petroleum Exporting Countries (OAPEC) instituted an oil embargo to curtail the exports of oil to the U.S. as a policy measure. More recently, in 1979, the political changes in Iran and the resulting turmoil drastically reduced Iranian production. In 1981 and beyond, the possibility is not remote that such incidents, both deliberate actions and unanticipated accidents, will occur from time to time. In 1980, roughly 18 out of the 30 million barrels per day of oil in world trade came through the unstable Persian Gulf and "an even higher proportion is produced in very politically [volatile] areas".¹ Thus, about 60% of the oil traded in the world market is subject to both supply and price instabilities.

Since the OAPEC embargo in 1973-74, a wide range of studies have been undertaken to assess the economic effects of petroleum supply interruptions.* Each of the studies has, in some fashion, modelled the petroleum sector and the U.S. economy. However, while the previous studies (such as those of the Institute of Defense Analysis-INFORUM (1977), the Congressional Budget Office-Wharton (1979), the Austin/DOE-DRI (1979) etc.)** were quite good at analyzing energy issues related to short-term price changes and federal policy changes, they were inadequate in handling supply constrained situations.

To provide a tool which addressed these shortcomings, the Management Technology Division of MTSC Inc., a Washington, D.C. based consulting firm, developed the Supply Constrained Analysis Modeling System (SCAM) under the management of Edward R. Novicky. SCAM is not a single model per se but a set of econometric and linear programming models which are capable of analyzing issues related to supply constraints and price changes. SCAM is composed of three principal models:

- A macroeconomic model which is used to analyze the implications of price changes (especially energy prices) and of foreign trade on the economy. The model currently in use is the DRI Quarterly Macroeconomic Model of the U.S. Economy.

*For a detailed review see Novicky.²

**Ibid, pp. 67-84.

- An allocation model which is used to estimate how any specified allocation plan would allocate available energy supplies to various economic sectors. This was developed by MTSC Inc. and is called the SCAM Allocation Model
- A linear programming model which is used to estimate the effects on the economy of constrained energy supplies while minimizing the loss in consumer surplus. This was also developed by MTSC Inc. and is called the SCAM-LP Model.

The SCAM system outlined above* is used by the Office of Contingency Planning at DOE as a tool for simulating the effects of short-term petroleum supply shortfalls. SCAM is designed to analyze such issues as (i) domestic petroleum price controls, (ii) alternative allocation plans, (iii) conservation contingency plans and (iv) Strategic Petroleum Reserve drawdown strategies. For each shortfall scenario and U.S. government policy measure, the SCAM system produces quarterly forecasts of major economic variables (GNP, prices, employment levels) and sectoral details over a four- to eight-quarter forecast horizon. Thus with the use of this system, an integrated assessment of contingency plans is possible.

Although the SCAM methodology is adequate as a tool for analyzing petroleum supply shortfall scenarios, it is deficient on two counts. It is inadequate in gaming situations, and it does not take into account the future expectations of households and firms. International reactions, both from the International Energy Association (IEA) countries and the OAPC, will affect the relative attractiveness and effectiveness of different U.S. policy options. Whether the U.S. reevaluates its policies after the revelation of a "threat" from other countries, or indeed takes into account such international reactions when deciding on its policy options in the first place, such situations are best analyzed in the format of a Non-cooperative Game⁴. Since these "games" would be played in a short time span, a game theory analysis requires that the model for analyzing petroleum shortfalls be sensitive to policy reversals in the short run. The SCAM system, and the DRI Macro Model in particular, do not allow for such a response.⁵ The inclusion of adaptive lagged consumption functions in the DRI macroeconomic model makes the consumption very sluggish to changes in the variables that determine it, and is partly responsible for the insensitivity of SCAM to sudden policy changes.

*For more details see the report by Novicky and Strauss³ and Figure 1.

Figure 1. Overview of the Supply Constrained Analysis Modeling System

The anticipation of households and firms has played a central role in the thinking of macroeconomic theorists for some time. These expectations are particularly relevant to situations of supply shortfalls in petroleum. The summer of 1979 saw sudden increases in the purchase of gasoline by consumers who expected the petroleum shortfall to continue.¹ Such short-run behavior cannot be captured by conventional models in which all the economic relationships are estimated by econometric techniques using historical data. Past data would hardly be representative of the future especially during periods of turmoil. The DRI Quarterly Macro Model that is used to set up the base case and also the vector of final demands that are fed to the SCAM allocation and linear programming models would not be able to capture fully the behavior of consumers during petroleum supply shortfalls. Thus the outcome of the solution of SCAM could not be expected a priori to be good. Recent developments in Rational Expectations theory⁶ and its use in policy models⁷ could prove to be a better alternative.

This paper describes possible alternatives to using the DRI Macro Model as it is presently constituted. Two main alternatives are considered: (i) modifying the DRI Macro Model and (ii) using another macroeconomic model that better captures the short-run changes in the households consumption behavior due to a sudden shortfall in petroleum supply.

The SCAM allocation model is quite straightforward and has few problems if any. The SCAM linear programming model, although containing some indirect and not well explained methods for estimating some of its parameters, is basically sound. The SCAM system has a very basic problem in its interaction with the users. The documentation, especially those sections that direct the users on how to use the computer routines, could be improved a great deal. However, the focus of any modifications to be made in the SCAM system should be on changing the macroeconomic model.

2 ALTERNATIVES TO DRI QUARTERLY MACRO MODEL

All the macro-economic models available commercially (such as Wharton, the Federal Reserve Board and Chase Econometrics macro models) have the same inadequacy as the DRI model in that they all use historical data to estimate parameters and do not take into account the "rational" anticipation of consumers. They take into account the anticipation of consumers in an adaptive sense. There are major differences between adaptive and rational expectation. The models designed to analyze business cycles involved expectational variables. The effort to estimate these quantitative models involving expectational variables "forced acceptance of the idea of anticipation functions formed on observable data, because without them such models could not be estimated and empirically tested".⁸ The assumption most often used was that the expectation of some variable, say price P , equalled the weighted average of past values of P with higher weights applied to the recent past than to the distant past. These models were classified as adaptive expectation models because the anticipation adapted to recent experience. The rational expectations concept introduced by Muth⁹ goes well beyond adaptive expectation and, as Buiter¹⁰ has pointed out, even the concept of a "Bayesian" predictor derived from explicit optimizing behavior. Muth hypothesized that the mean expectation of firms (and households) with respect to some variable, say price P , was the same as that made by the "relevant" economic theory⁺:

$${}_{t+1}P_t^* = E_t P_{t+1}$$

where ${}_{t+1}P_t^*$ are the subjective expectations of the price level and $E_t P_{t+1}$ is the mathematically optimum forecast of the price level at time $t+1$ conditional on all that is known about the determination of prices.

The incorporation of rational expectations into large macroeconomic models is still at the infancy stage. Indeed no rational expectation model that has been used to date either commercially or in academic institutions has any sectoral detail.⁺⁺ Economists are still in the process of

⁺It is not clear who picks the "relevant" economic theory. The idea is that firms and households will look at the world with the eyes of a neo-classical economist who believes in clearing markets, etc.¹⁰

⁺⁺This was confirmed by conversations with Professors Dennis Apple (Carnegie-Mellon), Lester Lave (Carnegie-Mellon, now with Brookings Institute), Robert Litterman (M.I.T.) and Douglas Lee (Data Resources Inc.) and by unofficial representatives of Chase Econometrics and the Federal Reserve Board [April, 1981].

understanding the effects on economic theory of including the assumption of rational expectations. For this purpose, and to understand the underlying assumptions of rational expectations theory, most models are formulated in very simple terms.¹¹

None of the commercially available quarterly macro-models incorporate rational expectations (RE) of the firms and households in a comprehensive way. Some work on incorporating RE is under way at both the Federal Reserve Board and Data Resources Inc.¹² The only commercially available model that incorporates rational expectations, built by Claremont Economics Institute, a small California based consulting firm, (13,14) concentrates on the financial and monetary side of the economy. This model was used by the Office of Management and Budget for forecasting the effects of President Reagan's budget. This rational expectations model is quite controversial and makes startling predictions (such as the rate of inflation falling to 5% in 1982) which "many in the economic and financial communities may find hard to swallow."¹⁴ Indeed one of Claremont's first major forecast was that the interest rates would be falling fast by late May 1981, with commercial paper as low as 10%. This has turned out to be "miles off target."¹⁵

The Claremont model primarily focused on forecasting interest rates and financial accounts. The model lacks sectoral details; consumption goods are divided into durables, non-durables and services.¹³ Documentation on the model has not been released for public circulation,¹³ and thus, it is difficult to make a more in-depth study of the structural equations. It is unclear at present (i) whether the model captures international linkages, at least through the monetary side, (ii) whether the model results could be disaggregated to be useful for linking with the SCAM allocation and linear programming models and (iii) whether the model is computer intensive, requiring large resource costs and long turnaround time. What is clear however is that the Claremont model has neither the sectoral detail that is used in the SCAM for present assessment of the economic effects of a petroleum supply shortfall nor a proven "track record" in solving other problems.

It is interesting to note that DRI and Claremont Economic Institute have been "negotiating a commercial arrangement whereby Claremont's monetarist/rational expectation model would be offered on DRI's time-sharing network."¹⁶ With DRI's interest in incorporating rational expectations in the quarterly

macro-economic model, it would not be surprising if a model that synthesizes the Claremont and DRI models were forthcoming.

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3 MODIFICATION OF DRI MACRO MODEL

The DRI Macro Model could be modified to reflect the consumption behavior that is rational when sudden shortfalls occur in the supply of petroleum. The consumption equation can be modified in three important ways. The equations describing the consumption of those goods that show sluggish response could be dropped altogether. These would be replaced by new equations estimated by using only the historical data collected during adverse times, like the period after the 1973-74 oil embargo and the 1979 Iran crisis. The new equations will capture more accurately the behavior of consumers during petroleum supply crises. The time-series for these selected periods could prove too short for any reasonable use of econometric techniques for parameter estimation.

Conversely, only the lagged structure of the consumption equations which is primarily responsible for the slow consumer response to adverse events could be replaced either selectively or totally. This adjustment is not straightforward and in some cases could result in equations that do not make any sense. Consider, for example, the consumption of Automobiles - Motor Vehicles and Parts. Figure 2 shows the independent variables that explain the consumption of Motor Vehicles and Parts by households. In the estimated equation all variables except for Disposable Income (in 1972 dollars), Cost of Car Operation, Consumer Sentiment and Dummy for Strikes in automobile factories are lagged by at least one quarter.^{17a} In other words, the consumption of automobiles is explained by the position a quarter back of the Consumer Installment Debt Liquidity, Stock of Cars, (private and commercial) and Household Financial Assets Outstanding, all important variables. Dropping these variables would reduce the explaining power of the equation and could also make the results of the parameter estimation statistically insignificant.

Both of the above methods would also present another major problem, that of model validation. When partial adjustments are made in a large macro-economic model, there is always the danger of the model being inadequate in tracking historical data. This may not seem a problem when the situation being analyzed is new and adverse, e.g., petroleum supply shortfall. However, a model's credibility depends on its ability to reproduce events that have occurred. A model that needs to be changed for every new situation would not be attractive.

Figure 2: Automobile Consumption and Scrappage, From DR17.

The third method of modifying the DRI consumption equations seems to be better than the others. The variable termed Consumer Sentiment Index (CSI) appears in most consumption equations. (Figures 2 and 3) The consumption levels of those goods that depend on the CSI are very sensitive to changes in this variable.¹² C.S.I. is an endogenous variable in the DRI Macro Model and is explained by the function:

$$CSI = f \left\{ [GNP (1972 \text{ dollars})/GNP\text{-Full Employment (1972 dollars)}]^+, [Average \text{ Market Yield on U.S. Govt. 3-month bills}]^-, [Rate \text{ of Employment over 4 quarters}]^+, [Rate \text{ of change of the Wholesale Price Index over 4 quarters}]^-, [Rate \text{ of change of the Implicit Price Deflator over 4 quarters}]^-, [Standard \text{ and Poor's composite index of Common Stock Prices}]^+, [Rate \text{ of change of Average Refiner's Acquisition Price for domestic crude oil}]^-, [The \text{ change of the Effective Tax Rate}]^-, [Time \text{ Trend}]^- \right\}$$

where the superscript on each variable gives the sign of the estimated equation.* Of these variables, the Average Market Yield on the Government 3 month-bills, the Refiners Acquisition Price for Domestic Crude Oil and the Effective Tax Rate are all exogenous variables that can be changed to reflect the adverse situation. Alternatively, the CSI can be made exogenous so that it can be changed directly and the above equation can be dropped from the model. In either case, some sensitivity analysis needs to be done before changes in the CSI can represent the petroleum supply shortfall scenario with any credibility.

The theoretical basis for the proposed changes in the Consumer Sentiment Index is very good. It can be argued that the consumers' perception of the effect of a shortfall in the supply of petroleum, although not strictly explained by the variables given above, is contained in this Index. Use of the CSI to capture short term reactions in the consumption functions is also attractive for other reasons: (i) the information available in the model results would be as detailed as before and (ii) not much extra time (person-hours) would be tied up in setting up the alternative.

The above method however presents one major problem. The Consumer Sentiment Index does not directly explain the consumption of Gasoline, one of the more important of the final demand variables (Figure 3). The relative

*See the Users Manual of the DRI Macro Model for the exact values of these parameters.

Figure 3: Consumption of Nondurables. From DRI¹⁷

Figure 4: Consumption of Durables excluding Automobiles. From DRI¹⁷

price of gasoline is an important variable that is taken into account when deciding on consumption levels.* The price elasticity of gasoline is relatively small, - 0.43 for each quarter.^{17b} However the price variable can be replaced by a pseudo price variable that takes into account future price expectations and leads to changes in the consumption patterns. For this, a price-expectations equation would have to be modelled outside the SCAM system for each final demand variable. Such price-expectations models are readily available in the literature [see Shiller¹¹, Buiter¹⁰ et al.] and one of these could be used. What has to be kept clearly in mind is how the price-expectation equations would interact with the DRI Macro Model. For example, if the consumers expect the price of gasoline to increase drastically in the future, then it would be rational for them to buy up as much gasoline now as possible and even to hoard it. This behavior would be shown in the DRI consumption functions if the pseudo price of gasoline decreased. Thus what is needed is a price-expectation model in which a pseudo price (the input into DRI) would decrease (increase) whenever major increases (decreases) are anticipated in the commodity price in the future.

Strictly speaking, the parameters in the DRI consumption equations should be changed when price expectations are taken into account. Use of the pseudo-price in the existing DRI consumption functions could be explained by the assumption that the pseudo-price was the same as the current price for the historical period that is used for parameter estimation. Although the choice of the "correct" price expectations model would involve additional simulation, the resource cost (in terms of person- and computer-hours) involved would not be very great. The price expectation model could also increase the international linkage of the present system by including within the equation the various strategies of the other players (IEA countries and OAPEC) during a petroleum shortfall scenario.

*Indeed the relative price is an important variable that explains the consumption of both non-durable (Figure 3) and durables (Figure 4) goods.

4 CONCLUSIONS

The Supply Constrained Analysis Modeling (SCAM) system is basically sound in what it is intended for: analysis of the economic impacts of a petroleum supply shortfalls on the U.S. economy. However, the DRI Quarterly Macro Model used by the SCAM system to forecast the effects of price changes and to simulate the base case could not be expected to produce useful results when handling short-run consumption behavior. This paper explored the possibility of either using a new macro model incorporating rational expectations in the SCAM system or modifying the DRI Macro Model to better capture the behavior of consumers towards anticipated changes in the economy.

Very few macro models were found that explicitly included rational expectations in their formulation. Considerable interest in such a model has arisen and some work is being done both at the Federal Reserve Board and at Data Resources, Inc. but neither of these will be available for at least a year. The only commercially available macroeconomic model that incorporates rational expectation is the Claremont Model constructed by the Claremont Economic Institute, a California based consulting firm. Although the Claremont model has been used by the Office of Management and Budget for forecasting the financial effects of the Reagan administration budget it has neither an adequate sectoral breakdown for the purposes of the DOE Office of Contingency Planning nor a proven track-record. Also large resource costs (in terms of person- and computer-hours) would probably be needed to adapt the Claremont Model to the SCAM system and to the analysis of petroleum supply shortfalls.

The recommended procedure therefore is to modify the DRI Macro Model for adequately capturing short-run behavior. The lag structure of the consumption functions could be changed to give unlagged equations that will react faster to changes due to external shocks, such as price increases or supply shortfalls. This could lead to problems of model validation and in many cases to equations that do not capture causality with any rationale.

The most suitable modification should be one of two:

- (i) manipulating the Consumer Sentiment Index (CSI) to reflect short-run consumer reactions to petroleum supply shortfalls.

(ii) using a "pseudo" price instead of the price of the final goods and price-expectations equations external to the DRI model that adequately capture consumption behavior.

Either of these methods, while being theoretically attractive and containing the desired sectoral detail, would also impose the lowest resource costs.

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