New Technologies and Innovations in Agricultural Economics Instruction

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Analysis of Economic Effects of Government Policies: An Interactive Computer Model

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The importance of personal computers has been recognized in the businesses and academic institutions. Teachers and students understand this new reality. Computer graphics, spreadsheets, programming and simulation models, and computer oriented video projections contribute significantly in agricultural economics curriculum. New information delivery technologies using personal computers have been developed and adopted by universities, businesses, local and national governments, international organizations, and agricultural extension educators. The dramatic growth for markets for personal computers, data storage and retrieval using compact disks and color projection monitors and screens indicate the acceptance of the high-tech media and their success.

More recently, computer skills have become basic requirements for white collar jobs in private companies, academic institutions, and government. In response to this change in emphasis of job skills, academic institutions rapidly modify the curricula. Computer oriented economic curricula have become increasingly expensive and resource base to the academic institutions are limited. Federal, state and local governments face severe budget constraints in recent years, and allocation of resources to universities are further strained. Universities are reluctant to allocate resources for development of computer models for class room adoption. Alternatively, it is feasible and cost-effective for academic institutions to look for adoptable computer models developed by business, government and international organizations. This paper illustrate one such computer model for potential application for class room teaching.

This interactive menu driven comparative statics model is developed for analyzing the economic effects of government policies. The program is developed using Lotus 123. The requirements to use the model are minimal and they include: (1) IBM PC or compatible computer with at least 512K memory with a hard-drive or two floppies and a monochrome monitor, and (2) Lotus 2.1 or other compatible spreadsheet programs such as QUATTRO. This paper describes an economic model to analyze the economic effects of tax/subsidy policy on a single commodity. This computer model estimates changes in price and quantity, consumer and producer surplus, resource costs, tax revenue and subsidy burden to the government, and net welfare. An empirical example is presented using the U.S. Corn data and hypothetical tax/subsidy, and elasticity values.

Analytical Methodology

Economic models utilize theory and establish relationships between economic variables such as prices and quantities. This paper employs a comparative statics model to conduct the policy analysis. A comparative statics model predicts values of economic variables from one point to another point. Comparative statics means that a snapshot is presented of an affected market in the pre-policy condition. It is then compared to another snapshot of the same market after all of the adjustments have taken place in response to the policy. Comparative statics analysis have been extensively applied for policy evaluations. In this paper, we apply the fundamental microeconomic principle that consumers/producers maximize utility/profit to

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determine market price and quantity. Our model assumes that consumers and producers have complete knowledge of the market they participate.

Development of Policy Model

The model is derived using utility/profit maximizing behavior of consumers/producers. Equations (1) and (2) are final outcome of the derivations.

(1) Demand Function for Product Q:
$Q_D = Q_D(P,\phi)$

(2) Supply Function for Product Q:
$Q_S = Q_S(P,\mu)$

where Q_D is the quantity demanded, Q_S is the quantity supplied, P is the price, ϕ is the policy shifter for the demand function and μ is the policy shifter for the supply function.

Taking total differentials of equations (1) and (2), and after appropriate mathematical manipulations, an operational comparative statics model is developed. Equations (3) and (4) define an operational model:

(3) Demand Equation: $E(P) = (1/\eta)\ E(Q) + \delta$

(4) Supply Equation: $E(P) = (1/\epsilon)\ E(Q) + \sigma$

Operators E(P) and E(Q) represent logarithmic differentials of price and quantity (proportional changes in P and Q). Shifter variable δ and σ represents the proportional shift of supply and demand function respectively. Demand and supply elasticities are designated by η and ϵ. The price elasticity of demand is the percentage change in quantity demanded due to a given percentage change in price. The price elasticity of demand is negative because quantity and price are related inversely. An elasticity value of less than -1 corresponds to elastic demand where as and elasticity value of greater than -1 implies inelastic demand. Similarly, the price elasticity of supply is the percentage change in quantity demanded due to a given percentage change in price. Supply elasticity is always positive because price and quantity are positively related. When the elasticity value is greater than 1, supply is elastic and supply is inelastic if elasticity value is less than 1. Equations (5) and (6) define demand and supply elasticities:

(5) Price Elasticity of Demand:
$\eta = (dQ_D/Q_D)\ /\ (dP/P)$

(6) Price Elasticity of Supply:
$\epsilon = (dQ_S/Q_S)\ /\ (dP/P)$

Equations (3) and (4) determine pre-policy and post-policy market equilibrium price and quantity. When ϕ=0 and σ=0, the solutions to (3) and (4) will determine the pre-policy market equilibrium. Post-policy market will correspond to ϕ>0 and/or σ>o. Equations (3) and (4) contain two unknown (endogenous) economic variables and will have unique solutions for P and Q. A matrix representation of equations (5) and (6) is given by (7). Equation (8), the solution of equation (7) is established using matrix algebra.

(7) System of Equations: $Z * X = M$

(8) Solution to the System: $X = Z^{-1} * M$

where matrix Z, vectors X and M are defined by:

$$Z=\begin{bmatrix}1 & -1/\eta \\ 1 & -1/\epsilon\end{bmatrix}$$

$$X=\begin{bmatrix}E(P) \\ E(Q)\end{bmatrix}$$

$$M=\begin{bmatrix}\delta \\ \sigma\end{bmatrix}$$

Our spread sheet computer model is developed using equations (7) and (8) in matrix form. The matrix Z, and vectors X and M are defined using appropriate range names. The solutions are obtained using matrix inversion and multiplication facilities available in Lotus. The economic and computer model can be extended to n markets. The Z-matrix will have 2n rows and 2n columns, X vector will have 2n endogenous variables (n prices and n quantities) and shifter vector M will have 2n shift variables. The mathematics of extending Z-matrix from one market to many markets is direct. However, the development of elasticities of supply, demand and cross-price elasticities is complex.

Illustration of Analytical Methodology

Two scenarios are generated here to explain the economic consequences of tax/subsidy policies. Scenario 1 outlines the economic effects of an excise tax on producers. In Scenario 2, effects of government subsidy to consumers is synthesized. Figures 1 and 2 sketches pre-policy and post-policy market outcomes of tax and subsidy policies. To simplify the presentation, a linear demand and supply functions are used. Scenarios 1 and 2 are similar and analytical details are presented in greater details for scenario 1 and omitted for scenario 2. Summary details of results for scenario 2 is presented at the end.

Pre-tax market equilibrium is established at the intersection of supply (S) and demand (D) curves. Pre-tax price and quantity are represented by P_0 and Q_0 respectively. P_1 is post-tax price and Q_1 is post-tax quantity. A tax levy equivalent to P_1P_2 to producers of commodity Q has induced marginal cost of production to increase. This is shown by the shifted post-tax supply curve S_1. A new post-tax equilibrium is established at the intersection of S_1 and D. Post-tax price P_1 is greater than pre-tax price P_0 and post-tax quantity Q_1 smaller than pre-tax quantity Q_0. Consumers pay higher price (P_1), producers receive lower price (P_2), and government receives tax revenue equal to the area ABP_2P_1 (Q_1 multiplied by P_1P_2).

An amount of tax burden equivalent to area ABP_2P_1 is shared both by producers and consumers. The tax burden to consumers and producers depend on their ability to cope with increased costs. Responsiveness of consumers and producers are reflected by magnitudes of demand and supply elasticities. In addition to price and quantity, other key variables affected by the tax policy include sales revenue, consumer surplus, producer surplus, resource costs, and social welfare. Measurement of consumer and producer surplus, assumptions and their limitations are discussed in greater details in intermediate price theory and public finance text books. A brief discussion on consumer and producer surplus and geometry of their measurement are presented in next paragraph.

Demand curve represents marginal value of benefit to consumer (price consumer willing to pay for product). Price line represents the price that consumer actually paid for that product. Area between price line and demand curve represents surplus benefits accrued to consumer. Consumer surplus is defined by this area. Supply curve, similarly represents marginal cost of production of product. Revenue to producer is equal to equilibrium price multiplied by equilibrium quantity, the area below price line. The area between price line and supply curve represents surplus revenue collected by producer. Producer surplus (also known as economic rent) is measured by this area. Social welfare is the sum of consumer and producer surplus. In figure 1, area CP_0F defines consumer surplus and area LCP_0 determines producer surplus. Area LCF represents value of social welfare and is the sum of area CP_0P and area LCP_0. Total cost of resources to produce Q_0 is determined by area $OLCQ_0$. Total sales revenue is price multiplied by quantity (area P_0Q_0).

Economic Effects of Excise Tax

The excise tax causes an increase to the price of the output as shown in figure 1 by post-tax supply curve S^1. Post-tax price and quantity is P_1 and Q_1 respectively. Area FAP_1, area MAP_1, area $BLOQ_1$, and area MAF corresponds to post-tax values of consumer surplus, producer surplus, resource costs, and social welfare respectively. Area ABP_2P_1 represents value of tax revenue to the government. Algebra of computation of key economics effects using figure 1 is described by equations (9) to (14):

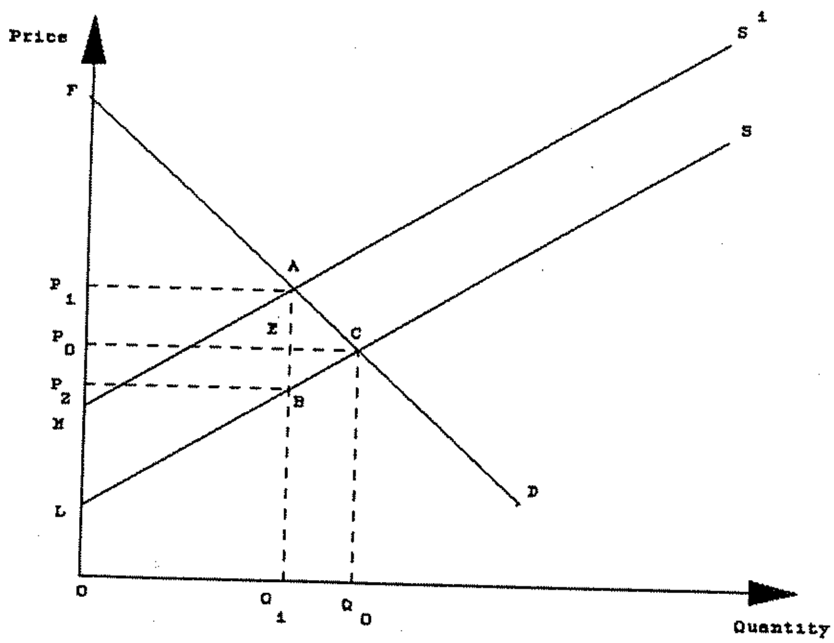


Figure 1. Economic Effects of Excise Tax on Producers

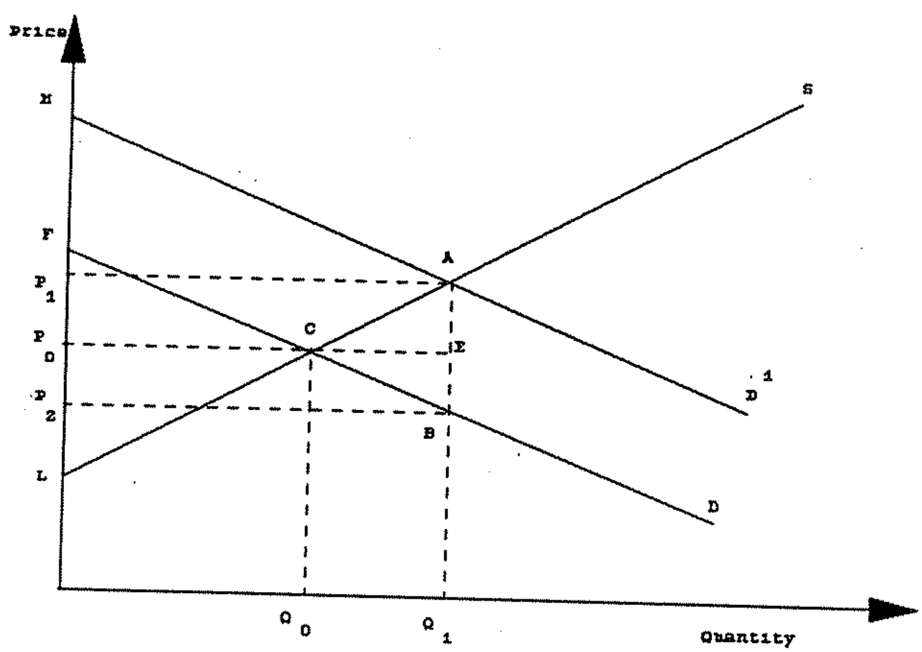


Figure 2. Economic Effects of Tax Subsidies to Consumers

(9)	Change in Price	$= (P_1 - P_0)$
(10)	Change in Quantity	$= (Q_1 - Q_0)$
(11)	Change in Consumer Surplus	$=$ (Area FAP_1 - Area FCP_0)
(12)	Change in Producer Surplus	$=$ (Area MAP_1 - Area LCP_0)
(13)	Change in Resource Cost	$=$ (Area $OLCQ_0$ - Area $OLBQ_1$) $=$ - Area BCQ_1Q_0
(14)	Change in Social Welfare	$= \{(11) + (12)\}$ $=$ (Area FAM - Area FCL) $=$ - Area MACL $=$ - Area MABL - Area ABC

Equations (13) and (14) require additional explanations. Resource cost: Area BCQ_1Q_0 in equation (13) represents opportunity cost of resources used to produce $(Q_0 - Q_1)$. Change in social welfare (equation (14)) has two components: (a) tax burden equal to area MABL and (b) net welfare loss (deadweight loss) equal to area ABC. Using geometry, it can be shown that area MABL (tax burden of consumers and producers) is identical to area ABP_2P_1 (tax revenue to government). Areas AEC and BEC represents net loss to the consumer and producer respectively.

Scenario 2 analysis in figure 2 are analogous to Scenario 1. Government subsidy to consumers induced upward shift of demand (shift equal to P_1P_2). Post-subsidy price P_1 and post-subsidy quantity Q_1 are greater than the pre-subsidy price P_0 and pre-subsidy quantity Q_0 respectively. Consumers pay higher price (P_1), producers receive higher price (P_2) and incurs higher cost of production. Government's payment for subsidy is equal to area ABP_2P_1 (Q_1 multiplied by P_1P_2). Net welfare loss to society is again represented by area ABC. Aggregate price and quantity effects and distribution effects are in general different for tax and subsidy policies. Our analytical model do not capture distribution effects across consumers or producers. Our approach here is to establish the macroeconomic effects of potential government policies. This model is applicable for analyzing pollution control strategies, quotas, and trade restrictions. For example, cost increases to meet regulatory requirements can be used to compute the initial supply shifts.

Empirical Results

Appendix A contains a two page manual to operate the computer model. Reported corn production and price data are taken from Agricultural Outlook (ERS, USDA, January-February 1992) for conducting the empirical study. To simplify our presentation, consumption is assumed equal to production. Data and results of the computer run are presented in table 1. Our computer model constructs linear demand and supply curves (figures 3 and 4) using market equilibrium price and quantity and assumed supply and demand elasticities. Pre-policy price per bushel of corn was \$2.30 and pre-policy quantity was 7,933 million bushels. Estimates of market revenue, consumer surplus, producer surplus and resource cost are 18,246, 6,082, 4,561, and 13,684 million dollars respectively. A ten percent tax on the producers of corn is considered for scenario 1. In order to compare difference between tax and subsidy policies, a subsidy of 23 cents per bushel (equal to 10 percent price subsidy) is hypothesized in scenario 2. The results of the analysis are shown in table 1. In either scenarios, society suffers a deadweight (net-welfare) loss of 78 million dollars. Tax policy reduces consumption and increases price. Subsidy policy increases consumption and price. Tax policy will transfer a revenue of 1.668 billion dollars from producers and consumers to Government. Subsidy policy will cost government (and consequently tax payers of economy) an amount of 1.981 billion dollars.

Extension of Policy Model

A computer model based on one-product and two inputs is adopted for policy analysis. This model uses the derived demand conditions developed by Allen and Hicks. The computer model predicts the effects of a regulation on input/product markets on the market prices and quantities of input and product markets. Computation of welfare effects are excluded due to complexity. To predict post-policy prices and quantities, the user should provide pre-policy values of: price and quantity of input 1, price and quantity of inputs, the supply elasticities of two inputs and demand elasticity of product. The computer model is developed using Lotus 2.1 and it is interactive and menu driven. The software with documentation is available for interested user.

References

Allen, R. G. D. *Mathematical Analysis For Economists*. London: Macmillan & Co., 1938.

Bingham, Tayler H., Ram V. Chandran, and Terry M. Dinan. "The Old Newspaper Problem: Benefit-Cost Analysis of a Marketable Permit Policy" North Carolina State University, Natural Resources Economics Workshop. May 1, 1990.

Bohm, Peter. *Social Efficiency: A Concise Introduction to Welfare Economics*. London: Macmillan & Co 1973.

Chandran, Ram V. and Tayler Bingham, "Economic Impact of Air Emissions Regulations: Hazardous Waste Management", Report Prepared for the Office of Air Quality Planning and Standards, U. S. Environmental Protection Agency, July 1989.

Friedman, Milton. *Price Theory*. Chicago: Aldine Publishing Co., 1962.

Hicks, J. R. *The Theory of Wages*, Gloucester, Mass.; Peter Smith 1957.

Samuelson, p. 1964. "The Pure Theory of Public Expenditure." In Collected Scientific Papers of Paul A. Samuelson, ed. J. Stiglitz. Cambridge, Mass.: MIT Press, 1966.

U. S. Department of Agriculture. "Agricultural Outlook" Jan-Feb 1992.

Willig, R. 1976. "Consumer Surplus without Apology". American Economic Review 66: 589-597

Table 1: Economic Effects of Due to Tax/Subsidy Policy on Corn Producers/Consumers.

Pre-Policy Values of Economic Variables[1]

Economic Variable	Before Tax/Policy
Quantity of Corn (Millions of Bushel)	7,933
Price of Corn ($/Bushel)	2.30
Market Revenue	18,246
Consumer Surplus	6,082
Producer Surplus	4,561
Resource Cost	13,684
Assumed Elasticity of Demand	-1.50
Assumed Elasticity of Supply	2.00

Post-Policy Values of Economic Variables[1]

Economic Variable	Scenario 1 Tax Policy	Scenario 2 Subsidy Policy
Quantity of Corn (Millions of Bushels)	7,253	8,613
Price of Corn ($/Bushel)	2.43	2.40
Market Revenue	17,635	20,659
Consumer Surplus	5,084	7,169
Producer Surplus	3,813	5,377
Resource Cost	12,154	15,282
Tax Revenue to Government	1,668	0
Subsidy Payment to the Consumer	0	-1,981

Effects of Policy on Key Economic Variables[1]

Economic Variable	Scenario 1 Tax Policy	Scenario 2 Subsidy Policy
Quantity (%)	-8.60	8.60
Price (%)	5.71	4.29
Consumer Surplus	-998	1087
Producer Surplus	-748	815
Net Welfare Loss	-78	-78
Resource Cost	-1,530	1597
Market Revenue	-611	2413
Tax Revenue	1,668	0
Subsidy Payment	0	1981
Net Welfare Loss	-78	-78

[1] Except for price and quantity, all values are in millions of $

APPENDIX

USER MANUAL FOR THE

COMPUTER MODEL

MODEL CHARACTERISTICS

ECONOMIC VARIABLES: **PRICE AND QUANTITY, CONSUMER & PRODUCER SURPLUS, SOCIAL WELFARE, RESOURCE COSTS**

ESTIMATED ELASTICITIES:SUPPLY AND DEMAND ELASTICITIES

POLICY VARIABLES: **TAXES AND SUBSIDIES**

MODEL FEATURES

MODEL IS MENU DRIVEN WITH HELP SCREENS

MODEL IS INTERACTIVE

ONLY BASIC PC & SPREADSHEETS SKILLS ARE REQUIRED

MODEL PRESENTS GRAPHS OF THE ECONOMIC EFFECTS OF POLICIES

MODEL PERMITS TO DEVELOP SCENARIOS OF TAX AND SUBSIDY POLICIES

MODEL ENABLES CHANGING ELASTICITY TO CONDUCT SENSITIVITY ANALYSIS

MODEL COMPUTES AND TABULATES ECONOMIC EFFECTS

COMPUTATION IS QUICK & EASY TO UNDERSTAND

POTENTIAL EXPANSION OF THE MODEL FOR MORE PRODUCTS

COMPUTER SCREENS AND MODEL INSTRUCTIONS

1. FIRST RETRIEVE THE FILE BASIC.WK1 IN TO THE SPREADSHEET.
2. COMPUTER SCREENS 1 & 2 SHOWN BELOW WILL POP UP.
3. THE MENUS OPERATE EXACTLY LIKE THE SPREADSHEET MENUS.
4. IF AND WHEN NECESSARY USE MACRO <ALT-S> AND SAVE YOUR COMPUTATIONS.
5. USE MACROS <ALT-M>, <ALT-H> TO REACTIVATE THE MODEL IF AND WHEN YOU QUIT THE INTERACTIVE MODE.
6. TO LEAVE FROM INTERACTIVE MODE USE OPTION <u>EXIT</u> OR PRESS <ESC>.

POPPED UP COMPUTER SCREEN 1

OPTION_1 OPTION_2

INTERACTIVE SPREADSHEET ECONOMIC POLICY MODEL

CHOOSE ONE OF THE FOLLOWING TWO OPTIONS

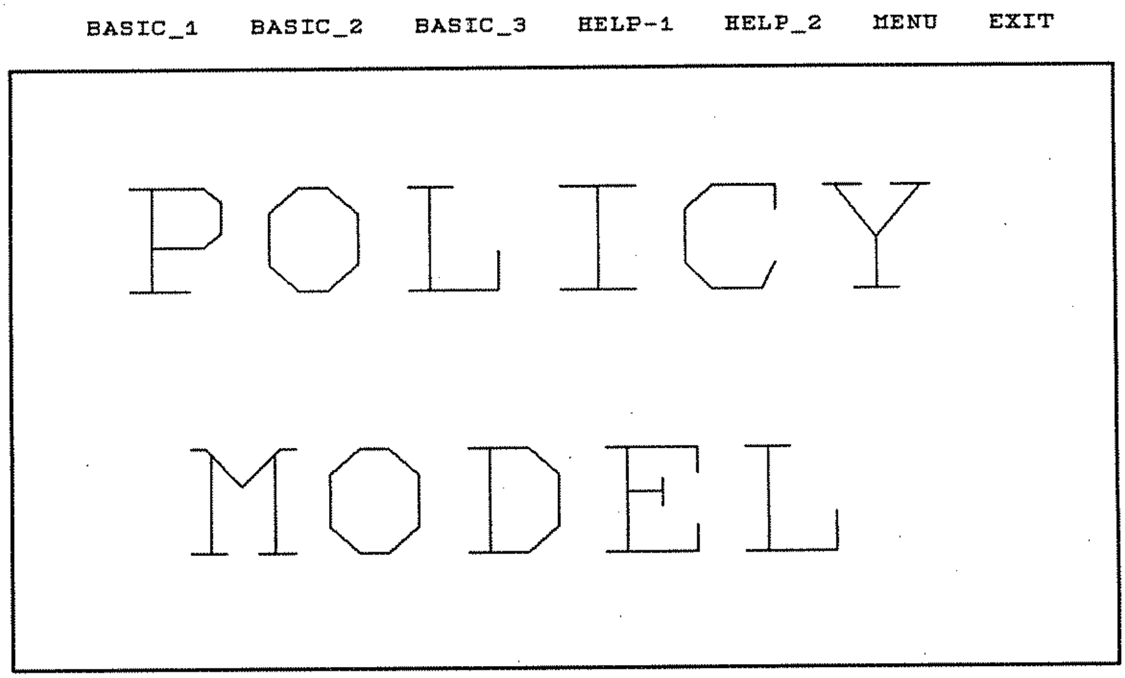
OPTION_1: TO INITIALIZE POLICY VALUES AND START A NEW PROBLEM

OPTION_2: TO CONTINUE WITH AN EXISTING PROBLEM (NO INITIALIZATION)

MOVE THE CURSOR TO OPTION_1 OR OPTION-2 AND PRESS <ENTER>

IF YOU CHOOSE OPTION_1 OR OPTION_2, THE COMPUTER SCREEN SHOWN BELOW POPS UP. AVAILABLE MENU OPTIONS ARE BASIC_1, BASIC_2, BASIC_3, HELP_1, HELP_2, MENU.

POPPED UP COMPUTER SCREEN 2



OPTIONS BASIC_1, BASIC_2, BASIC_3 OUTLINES MODEL FEATURES

OPTIONS HELP_1 & HELP_2 WILL ASSIST WITH APPROPRIATE HELP SCREENS

CHOOSE THE OPTION "MENU" TO OPERATE THE ECONOMIC MODEL INTERACTIVELY

CHOOSE THE OPTION "EXIT" TO LEAVE INTERACTIVE MODE.