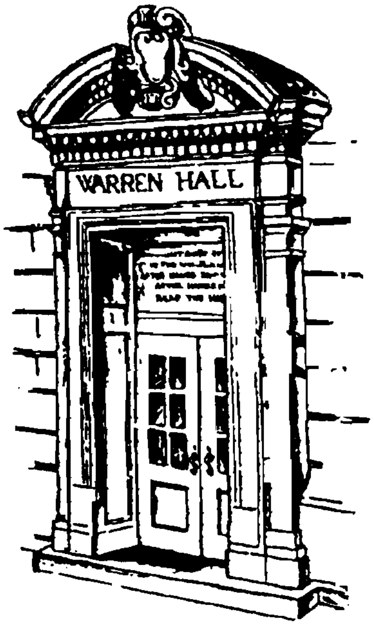

WP 97-03
March 1997

Working Paper

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ESTIMATING INDIVIDUAL FARM SUPPLY AND DEMAND ELASTICITIES USING NONPARAMETRIC PRODUCTION ANALYSIS

by

Zdenko Stefanides and Loren Tauer

Estimating Individual Farm Supply and Demand Elasticities Using Nonparametric Production Analysis

Zdenko Stefanides and Loren Tauer*

Abstract

Nonparametric production methods are used to estimate individual supply response and input demand elasticities for a group of New York dairy farm businesses. The ranges of estimates from the upper and lower bounds are extremely large, probably because only nine observations (years) are available for each farm.

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Estimating Individual Farm Supply and Demand Elasticities Using Nonparametric Production Analysis

Economic analysis of production behavior relies on the specification of the production technology, either in primal or dual form. Traditionally this specification was done by assuming some parametric functional form. The drawback of this approach is that various functional forms yield different supply-demand elasticities (Colman). Rather than assuming one particular function, an alternative approach is to specify bounds on the production response and then estimate elasticities subject to these bounds (Afriat, Varian). All possible parametric form assumptions consistent with the observed data are captured within these bounds.

Chavas and Cox used this nonparametric production analysis to estimate upper and lower bounds on aggregate output supply and input demand elasticities for US agriculture. Tiffin and Renwick also used the procedure on a cross sectional group of UK cereal producers. In the present paper we apply the framework to production analysis of NY dairy farms, and estimate individual farm supply-demand elasticities. Individual farm elasticities are useful in determining whether responses at the firm level are identical across farms and in testing various aggregation and decomposition assumptions on supply and demand. Application to individual farms is also consistent with the underlying WAPM theory.

Nonparametric Production Analysis

The profit maximization hypothesis is a necessary condition for applicability of the nonparametric production analysis. In particular, farmers solve the following decision problem (Chavas and Cox):

$$\begin{aligned} \max_{y,x} \quad & py + r'x \\ s.t. \quad & y \le f(x) \\ & y \ge 0 \\ & x = (x_0, x_1) \\ & x_0 \ge 0 \\ & x_1 \le 0 \end{aligned} \tag{1}$$

where $p>0$ denotes the market price of output y; $r'=(r_1,...,r_n)'>0$ is the (n*1) vector of market prices of the netputs x; netputs are further partitioned into any additional outputs x_0 and inputs x_1; f(x) denotes the production frontier which is assumed to be nonincreasing and concave in x.

If we observe the farmer making T production decisions then the necessary condition for his decision to be consistent with the theoretical model (1) is:

$$p_t y_t + r_t' x_t \ge p_t y_s + r_t' x_s \; ; \quad \forall \; s,t = 1,...,T \tag{2}$$

The condition (2) is termed the Weak Axiom of Profit Maximization (WAPM) by Varian. It states that profit in any given year is at least as large as the profit that could have been obtained using any other observed production decision.

The WAPM condition provides a basis for recovering a production function representing the underlying production technology. However, there is a whole set of production functions that can be recovered from the data provided the WAPM condition holds. Afriat bounded this set by two representations of the production function, the inner bound $F^i(x)$ and the outer bound $F^o(x)$. Their definitions follow.

Inner Bound $F^i(x)$

$F^i(x)$ is defined as:

$$\begin{aligned} F^i(x) &= \max_\theta \; \textstyle\sum_t y_t\theta_t \\ s.t. \quad & \textstyle\sum_t x_t\theta_t \geq x \\ & \textstyle\sum_t \theta_t = 1 \\ & \theta_t \geq 0 \; ; \\ & \forall \; t = 1,\ldots,T \end{aligned} \tag{3}$$

As proved in Chavas and Cox, $F^i(x)$ is the production function representing the underlying technology. In fact, it is the convex hull defined by the observed data points (see Figure 1). It essentially "connects the dots" of the data observation points with linear segmented production surfaces.

Outer Bound $F^{\circ}(x)$

$F^{\circ}(x)$ is defined as follows.

$$F^{o}(x) = \min_t \; y_t + \left(\frac{r_t}{p_t}\right)' [x_t - x] \; ; \qquad \forall \; t = 1, \ldots, T \tag{4}$$
$$x = (x_0, x_1), \quad x_0 \geq 0, \quad x_1 \leq 0$$

Later on we will use an alternative expression for $F^{\circ}(x)$.

$$F^{o}(x) = \max_{Y} \; Y$$
$$s.t. \qquad Y \leq y_t + \left(\frac{r_t}{p_t}\right)' [x_t - x] \; ; \qquad \forall \; t = 1, \ldots, T \tag{5}$$
$$x = (x_0, x_1), \quad x_0 \geq 0, \quad x_1 \leq 0$$

$F^{\circ}(x)$ is also the production function representing the underlying technology. In Figure 1 it is drawn as the convex set bounded by the intersection of lines going through the observed decision vectors with slopes given by the observed price ratios. For a profit maximizing firm no point is available that would produce larger profit than the points on the price line r_1/p_1 of which point 1 is a member, and also price line r_2/p_2 of which point 2 is a member. As shown in Chavas and Cox, $F^{i}(x)$ and $F^{\circ}(x)$ provide the tightest possible bounds on all possible production functions $f(x)$ that rationalize the data $\{(y_t, x_t, p_t, r_t): t=1, \ldots, T\}$.

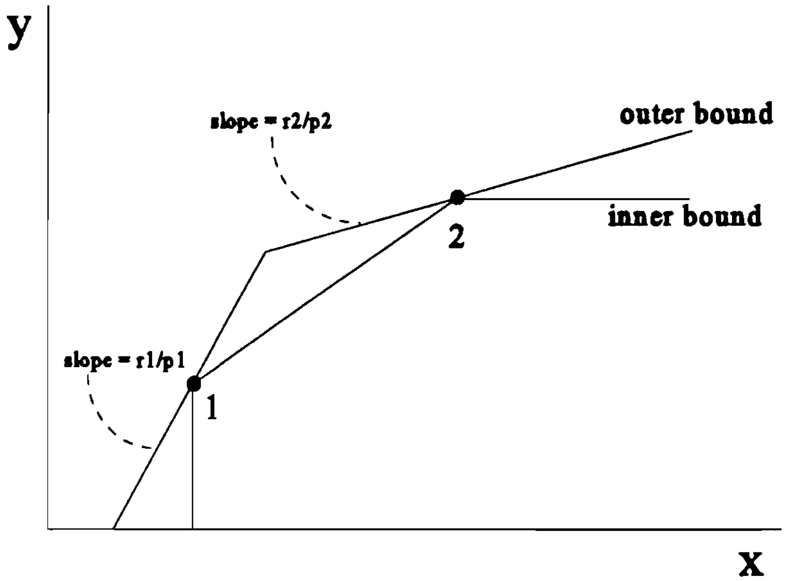

Figure 1. **Inner-bound [$F^i(x)$] and outer-bound [$F^i(x)$] representation of the technology**

Supply Response Analysis

The inner and outer bounds defined by (3) and (4), respectively, can be used for empirical production analysis as follows: Let $F^a(x)$ be a particular representation of the production function f(x). The farmers decision problem (1) then becomes:

$$\max_{y,x} \quad py + r'x$$
$$s.t. \quad y \le F^a(x), \quad y \ge 0, \quad x = (x_0, x_1), \quad x_0 \ge 0, \quad x_1 \le 0 \tag{6}$$

The solution to (6) represents outputs produced and inputs demanded at prices (r/p). When evaluated at different relative prices, this provides a basis for measuring anticipated effects of changing prices on quantities.

In order to empirically estimate program (6) we substitute the two bounds for $F^a(x)$. First, let $F^a(x)=F^i(x)$ and substitute $F^i(x)$ from equation (3) into (6). The resulting linear program takes the form:

$$\begin{aligned} \max_{y,x} \quad & py + rx \\ s.t. \quad & \textstyle\sum_t y_t\theta_t \geq y \\ & \textstyle\sum_t x_t\theta_t \geq x \\ & \textstyle\sum_t \theta_t = 1 \\ & \theta_t \geq 0 \;;\quad \forall \;\; t = 1,\ldots,T \\ & y \geq 0;\; x = (x_0, x_1);\; x_0 \geq 0;\; x_1 \leq 0; \end{aligned} \tag{7}$$

The solution to (7) gives supply-demand correspondences for the inner bound representation of the production function given the relative price vector (r/p).

Now let $F^a(x)=F^o(x)$ and substitute $F^o(x)$ from equation (5) into (6). The resulting linear program takes the form:

$$\begin{aligned} \max_{y,x} \quad & py + rx \\ s.t. \quad & y \leq y_t + \left(\frac{r_t}{p_t}\right)'[x_t - x] \;; \qquad \forall \;\; t = 1,\ldots,T \\ & y \geq 0;\; x = (x_0, x_1);\; x_0 \geq 0;\; x_1 \leq 0; \end{aligned} \tag{8}$$

The solution to (8) gives supply-demand correspondences for the outer bound representation of the production function given the relative price vector (r/p).

When the relative prices (r/p) vary, solutions to (7) and (8) allow prediction of economic behavior of farmers under alternative prices. These results can be used for computation of output supply and input demand price elasticities.

WAPM Condition Tests Under Technology Change

The above analysis assumes that the WAPM condition is satisfied for all observations t,s=1,...,T. In practice, however, this condition rarely holds. Violation under time series observations may be due to technological change, and various corrections have been proposed. Chavas and Cox presented two methods to handle data points that conflict with WAPM. We use their *effective netput approach* because the alternative approach discards data points that violate the WAPM condition and leaves us with too few observations.

Let actual netputs (y_t,x_t) and "effective netputs" (Y_t,X_t) be additively related to each other. In particular, let $y_t=A_t+Y_t$ and $x_t=B_t+X_t$, where A_t and $B_t=(B_{1t},...,B_{nt})'$ are technology indices associated with the tth observation. Substituting the effective for actual netputs in condition (2) and using the above relationships the WAPM condition reads:

$$p_t(y_t-A_t) + r_t'(x_t-B_t) \geq p_t(y_s-A_s) + r_t'(x_s-B_s) \; ; \quad \forall\, s,t = 1,...,T \qquad (9)$$

The technology indices A and B are chosen so as to make effective netputs as close as possible to the actual netputs while satisfying WAPM for all data points. The following program is used to achieve this objective:

$$\min_{A,B} \quad \sum_t \left[|A_t| + \sum_i |B_{it}| \right] \qquad s.t. \quad eq.(9) \tag{10}$$

Graphically, the point C which violates the WAPM condition is shifted to the point C′ (see Figure 2). Given equal weights on x and y adjustments in the objective function of program 10, the movement from C to C′ is perpendicular to the price line r_c/p_c. In contrast, correction for technological change using Malmquist indices brings point C up to the AB price line only.[1]

For computational purposes the program (10) is written in the linear programming form (11). Additional constraints are added to guarantee that effective netputs remain nonnegative for outputs and nonpositive for inputs.

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[1] We tried using Malmquist productivity indices computed from non-parametric methods. These indices move all interior points to the inner bound production surface ($F^i(x)$) defined by the exterior points. The result is that these interior points do not help define the production surface and thus are lost.

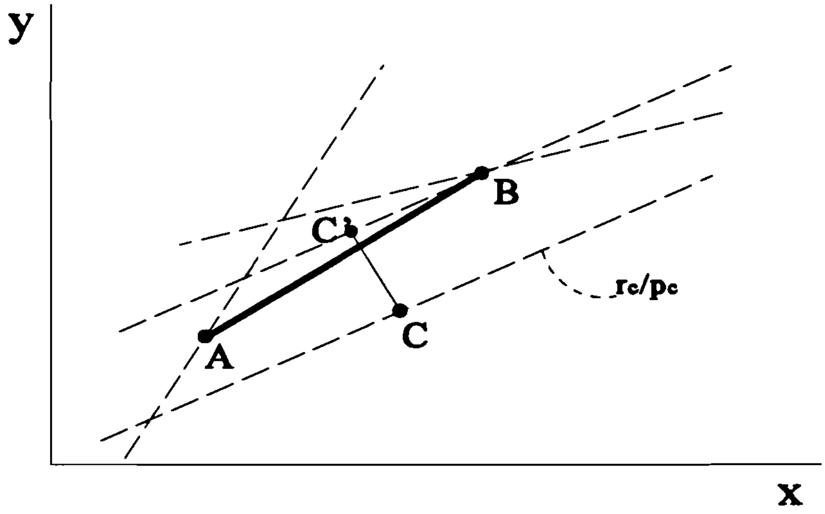

Figure 2 **Adjusting WAPM violation point C assuming violation is due to technological change**

$$
\begin{aligned}
&\min_{A^{+},A^{-},B^{+},B^{-}} \quad \sum\nolimits_t \left| A_t^{+} + A_t^{-} + \sum\nolimits_i (B_{it}^{+} + B_{it}^{-}) \right| \\
&s.t. \quad p_t Y_t + r_t^{\prime} X_t \geq p_t Y_s + r_t^{\prime} X_s \; ; \\
&\qquad \forall \; s,t = 1,\ldots,T \\
&A_t = A_t^{+} - A_t^{-} \\
&B_{it} = B_{it}^{+} - B_{it}^{-} \\
&Y_t = y_t - A_t \\
&X_t = x_t - B_t \; ; \\
&A_t^{+} \geq 0,\; A_t^{-} \geq 0,\; B_{it}^{+} \geq 0,\; B_{it}^{-} \geq 0 \\
&Y \geq 0,\; X = (X_0,\; X_1),\; X_0 \geq 0,\; X_1 \leq 0
\end{aligned} \tag{11}
$$

The effective netputs Y_t and X_t necessarily satisfy the WAPM condition (9). The effective technology Y=f(X) can be bounded by inner and outer bound representation analogous to (3) and (4). Substituting effective for actual netputs we can use programs (7) and (8) to estimate producers production responses.

Data

The data consist of seventy New York dairy farms that participated in the New York Dairy Farm Business Summary (DFBS) for each of the nine years from 1985 through 1993.

From the various expenditures and receipts that are collected on an accrual bases two outputs and six inputs were defined (see Appendix Table 1). Except for milk and labor which are collected as quantities, all expenditures and receipts were first converted into quantities by dividing by annual price indices (see Appendix Table 2). Using the same price for all farms in each year assumes that there is no regional variation across the state, nor do any farmers receive discounts. The deflated expenditures and receipts were then aggregated into the six input, two output categories (See Tauer 1996 for complete discussion of data preparation.) Prices (Appendix Table 3) were obtained by aggregating the original indices in Appendix Table 2 with 1993 average receipts and expenditure shares (Appendix Table 1) used as weights.

Results

None of the farmers pass the WAPM test for all the observations (see Tauer and Stefanides). To enable further analysis we first adjusted actual into effective netputs using program (11).

The effective netputs, which necessarily satisfy the WAPM condition, were then used for evaluating impacts on quantities from changing prices according to programs (7) and (8). As the base scenario we chose outputs supplied and inputs demanded at the average 1985-93 prices. We then increased and decreased each price individually by half a standard deviation from the respective average price. Resulting quantity changes were then used to calculate elasticities as the average elasticity from the price increase and price decrease scenario.

All programming and calculations were done in GAMS using the linear programming solver BDMLP (See appendix for the code). In table 1 we present the average estimated elasticities for all 70 farms. Vertical labels refer to changed price, horizontal labels to corresponding quantity changes. Since we are using effective netputs which conform to the underlying theoretical model (1) the elasticity matrix displays positive own-price supply elasticities and negative own-price input demand elasticities, as expected. However, the ranges of estimated elasticities are so large that they do not provide very useful information.

Table 1 Estimated Average Elasticities:
I refers to the Inner Bound Estimate
O refers to the Outer Bound Estimate.

		MILK	OTHER	LABOR	FEED	ENERGY	CROP	LIVESTOCK	REAL ESTATE
MILK	I	2.76	3.73	-0.19	5.04	2.78	2.85	3.37	5.19
	O	6.48	53.45	-34.63	11.00	-59.66	-41.96	108.32	75.49
OTHER	I	0.38	6.41	1.42	1.73	0.50	0.08	1.39	1.70
	O	-7.28	217.65	120.28	19.57	-7.13	-24.05	-0.28	-0.88
LABOR	I	0.81	-0.91	-2.31	1.38	0.97	1.33	1.33	1.54
	O	4.09	-257.55	-335.60	-4.13	-0.01	1.17	36.17	20.42
FEED	I	-1.07	-4.20	-0.26	-3.90	-1.27	-0.41	-2.10	-1.02
	O	-4.27	-39.99	15.92	-10.19	48.41	24.12	-65.60	-40.84
ENERGY	I	-0.64	-1.08	-1.02	-1.25	-3.22	-0.30	-0.25	-0.66
	O	-2.33	3.06	9.07	-3.92	-272.44	7.78	13.57	-35.33
CROP	I	-0.94	-1.08	1.02	-1.67	-0.08	-3.77	-0.39	-0.86
	O	1.64	30.61	11.37	6.03	3.51	-46.14	41.85	32.67
LIVE-	I	-0.61	-2.04	0.09	-1.49	0.04	-0.08	-3.37	-1.22
STOCK	O	-2.87	-57.69	14.62	-7.89	20.90	21.07	-69.66	-34.92
REAL	I	-1.21	-2.66	0.06	-1.90	-1.28	-1.38	-1.82	-5.66
ESTATE	O	-1.06	-16.56	18.91	9.85	11.12	29.16	-35.33	-100.99

Conclusions

The ranges of elasticities computed here using nonparametric production methods are so extreme that they would not be useful in any economic analysis. Previous attempts to estimate agricultural elasticities using either aggregate time series data (Chavas and Cox) or large cross-section data (Tiffin and Renwick) were more successful than our analysis. We think the reason for our rather disappointing results is the small number of observations (9 per farm) which does not provide very reasonable representation of individual farm technologies. Chavas and Cox used 36 observations and Tiffin and Renwick used 333 observations.

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Appendix Table 1. Data Categories

Variable	Price Index	DFBS Items Aggregated	1993 Average (in 1993 dollars)
Labor input	None	Months operator(s)	22.0
		Months hired	34.7
		Months family unpaid	2.4
Purchased feed input	Purchased feed	Dairy grain and concentrate	$133,726
		Non-dairy feed	48
	All hay	Dairy roughage	2,097
Energy input	Fuel and energy	Fuel (less gas tax refund)	10,022
		Electricity	11,658
Crop input	Fertilizer	Fertilizer and lime	10,856
	Seed	Seed and plants	7,055
	Chemicals	Spray, other crop expenses	7,385
	Machinery	Machinery depreciation (tax)	26,510
		Interest on machinery (4%)	8,761
		Machinery repairs / parts	25,154
		Machinery hire expenses	5,548
		Auto expense (farm share)	833
Livestock input	Purchased animals	Replacement livestock purchases	4,840
		Expansion livestock	16,470
		Cattle lease	144
		Interest on livestock (4%)	10,473
		Other livestock expense	23,675
	Farm services and rent	Breeding fees	5,894
		Veterinarian and medicine	12,902
		Milk marketing expenses	20,050
		Telephone	959
		Insurance	5,548
		Miscellaneous	9,447
Real estate input	Real estate	Cash rent	7,795
		Building depreciation (tax)	20,014
		Interest on real estate (4%)	21,825
	Building and fencing supplies	Building and fence repair	7,824
	Property taxes	Real estate taxes	10,357
Milk output	None	Milk production	36,837 (cwt.)
Other output	CPI	Government payments	$7,220
		Custom machine work	917
		Miscellaneous receipts	6,657
	Slaughter cows	Dairy cattle sales	50,382
		Other livestock sales	388
	Slaughter calves	Dairy calves sales	9,271
	All hay	Crop sales	9,290

Appendix Table 2. Price Indices

1984=100	1985	1986	1987	1988	1989	1990	1991	1992	1993
Purchased Feed	84	84	80	95	99	91	90	91	91
All Hay	93	87	88	93	93	94	95	108	107
Fuel and Energy	99	86	85	89	93	106	107	107	110
Fertilizer	94	89	90	98	101	99	102	98	95
Seed	100	99	98	101	107	109	111	110	113
Chemicals	100	99	97	99	103	109	117	124	129
Machinery	102	102	104	109	115	120	125	131	136
Purchased Animals	96	92	102	111	116	134	126	131	134
Farm Services and Rent	101	99	98	97	105	110	114	114	114
Real Estate	97	99	113	117	121	115	122	124	132
Building and Fencing Supplies	99	99	99	100	102	104	106	109	114
Property Taxes	109	112	118	112	116	118	118	120	124
Slaughter Cows	95	91	110	120	124	132	127	121	122
Slaughter Calves	83	82	110	132	140	148	162	145	157
CPI	104	105	109	114	119	126	131	135	139

Appendix Table 3. Prices Used in Elasticities Computations

(1984=100)

	1985	1986	1987	1988	1989	1990	1991	1992	1993
Milk	95	93	93	91	100	103	90	98	96
Other	95	92	107	117	121	129	128	125	127
Labor	107	117	123	132	140	149	158	156	164
Feed	84	84	80	95	99	91	90	91	91
Energy	99	86	85	89	93	106	107	107	110
Crop	101	100	102	107	112	116	121	125	129
Livestock	98	96	100	104	111	122	120	122	124
Real Estate	99	101	112	114	118	114	120	122	129

GAMS Code

```
OPTION LIMROW=0, LIMCOL=0, SOLPRINT=OFF;
$OFFUPPER OFFSYMXREF OFFSYMLIST OFFUELLIST OFFUELXREF

* This program solves LP's #22, #13, and #14 of Chavas and Cox (1995),
* which correspond to LP's #11, #7,  and #8  in our report.
* Data are aggregated into two outputs and six inputs.
* Quantities are defined as deflated receipts and expenditures,
* respectively. Output data are not adjusted for productivity changes.
* Prices are official price indices aggregated according to our
* input and output definitions using 1993 average shares as weights.
* (for complete description of data preparation see Tauer, 1996,
* The Productivity of New York Dairy Farms)


SETS

  K  farmers      /F1*F70/
  T  observations /T1*T9/
  N  netputs      /MILK,OTHER,
                   LABOR,FEED,ENERGY,CROP,LIVESTOCK,ESTATE/
  O  outputs      /MILK,OTHER/
  I  inputs       /LABOR,FEED,ENERGY,CROP,LIVESTOCK,ESTATE/
  SC scenarios    /1*17/
  BD bounds       /INN,OUT/;

ALIAS (T,S)
      (N,NN);

PARAMETERS
    P(O)           for individual output price changes analysis
    R(I)           for individual input price changes analysis
    YT(T,O)        for individual farmer data analysis
    XT(T,I)        for individual farmer data analysis
    YSC(SC,O,BD)   predicted farmer's output responses
    XSC(SC,I,BD)   predicted farmer's input responses
    PDEL(SC,O)     percent output price changes
    RDEL(SC,I)     percent input price changes
    NDEL(SC,N,BD)  percent netput quantity changes
    YDEL(SC,O,BD)  percent output quantity changes
    XDEL(SC,I,BD)  percent input quantity changes
    ELAST(N,NN,BD) matrix of elasticities;
```

```
TABLE  PSC(SC,O)    predicted output prices data
$INCLUDE "pscen.in"

TABLE  RSC(SC,I)    predicted input prices data
$INCLUDE "rscen.in"

PDEL(SC,O)=(PSC(SC,O)-PSC("1",O))/PSC("1",O);
RDEL(SC,I)=(RSC(SC,I)-RSC("1",I))/RSC("1",I);

TABLE  PT(T,O)      observed output price indices
$INCLUDE "pt9.in"

TABLE  RT(T,I)      observed input price indices
$INCLUDE "rt9.in"

TABLE  YKT(K,T,O)   panel data of observed real output receipts
$INCLUDE "yt9.in"

TABLE  XKT(K,T,I)   panel data of observed real input expenditures
$INCLUDE "xt9.in"

VARIABLES

    DEV            objective to be mininized in LP 22
    AP(T,O)        positive output adjustment
    AN(T,O)        negative output adjustment
    BP(T,I)        positive input adjustment
    BN(T,I)        negative input adjustment
    A(T,O)         total output adjustment
    B(T,I)         total input adjustment
    YEFF(T,O)      effective output vector
    XEFF(T,I)      effective input vector

    PROFIT         objective to be maximized  in LP's 13 and 14
    Y(O)           predicted output supplies
    X(I)           predicted input demands
    THETA(T)       weights of convex combinations

POSITIVE VARIABLES AP,AN,BP,BN,YEFF,Y,THETA
NEGATIVE VARIABLES  XEFF,X;

EQUATIONS

    MIN     defining DEV, the obj. func. in LP 22
```

```
WAPM      effective netputs are to be consistent with WAPM
EQ1       definition of total output adjustment
EQ2       definition of total input adjustment
EQ3       definition of effective output
EQ4       definition of effective input
MAX       defining PROFIT, the obj. fnc. in LP's 13 and 14
INN1      checking the outputs of inner bound
INN2      checking the inputs of inner bound
INN3      weights of convex inner bound representation sum to 1
OUT       checking the output of outer bound;


MIN..           SUM(T,SUM(O,AP(T,O) + AN(T,O))+
                      SUM(I,BP(T,I) + BN(T,I))) =E= DEV;

WAPM(T,S)..     SUM(O,PT(T,O) * YEFF(T,O)) +
                SUM(I,RT(T,I) * XEFF(T,I)) =G=
                SUM(O,PT(T,O) * YEFF(S,O)) +
                SUM(I,RT(T,I) * XEFF(S,I));

EQ1(T,O)..      A(T,O) =E= AP(T,O) - AN(T,O);
EQ2(T,I)..      B(T,I) =E= BP(T,I) - BN(T,I);

EQ3(T,O)..      YEFF(T,O) =E= YT(T,O) - A(T,O);
EQ4(T,I)..      XEFF(T,I) =E= XT(T,I) - B(T,I);

MAX..           PROFIT =E= SUM(O,P(O)*Y(O)) + SUM(I,R(I)*X(I));

INN1(O)..       SUM(T,YT(T,O)*THETA(T)) =G= Y(O);
INN2(I)..       SUM(T,XT(T,I)*THETA(T)) =G= X(I);
INN3..          SUM(T,THETA(T)) =E= 1;

OUT(T)..        SUM(O,(PT(T,O)/PT(T,"MILK"))*(YT(T,O)-Y(O))) +
                SUM(I,(RT(T,I)/PT(T,"MILK"))*(XT(T,I)-X(I))) =G= 0;


MODEL CC22      /MIN,WAPM,EQ1,EQ2,EQ3,EQ4/;
MODEL INNBOUND /MAX,INN1,INN2,INN3/;
MODEL OUTBOUND /MAX,OUT/;


FILE F1/"chavcox.out"/;
PUT F1;
F1.PC=5;
```

```
LOOP(K,

* computing adjustments over individual farm data

     YT(T,O)=YKT(K,T,O);
     XT(T,I)=XKT(K,T,I);

     SOLVE CC22 USING LP MINIMIZING DEV;

* further analysis uses only the effective netputs

     YT(T,O)=YEFF.L(T,O);
     XT(T,I)=XEFF.L(T,I);

* computing output supply and input demand changes
* corresponding to individual price change scenarios

     LOOP(SC,
          P(O)=PSC(SC,O);
          R(I)=RSC(SC,I);

          SOLVE INNBOUND USING LP MAXIMIZING PROFIT;

          YSC(SC,O,"INN")=Y.L(O);
          XSC(SC,I,"INN")=X.L(I);

          SOLVE OUTBOUND USING LP MAXIMIZING PROFIT;

          YSC(SC,O,"OUT")=Y.L(O);
          XSC(SC,I,"OUT")=X.L(I);
     );

* computation of % changes in netput quantities
* sorry for the clumsiness...

YDEL(SC,O,BD)=(YSC(SC,O,BD)-YSC("1",O,BD))/YSC("1",O,BD);
XDEL(SC,I,BD)=(XSC(SC,I,BD)-XSC("1",I,BD))/XSC("1",I,BD);

NDEL(SC,"MILK",BD)=YDEL(SC,"MILK",BD);
NDEL(SC,"OTHER",BD)=YDEL(SC,"OTHER",BD);
NDEL(SC,"LABOR",BD)=XDEL(SC,"LABOR",BD);
NDEL(SC,"FEED",BD)=XDEL(SC,"FEED",BD);
NDEL(SC,"ENERGY",BD)=XDEL(SC,"ENERGY",BD);
```

```
NDEL(SC,"CROP",BD)=XDEL(SC,"CROP",BD);
NDEL(SC,"LIVESTOCK",BD)=XDEL(SC,"LIVESTOCK",BD);
NDEL(SC,"ESTATE",BD)=XDEL(SC,"ESTATE",BD);

* computation of elasticities

ELAST("MILK",N,BD)=(NDEL("2",N,BD)/PDEL("2","MILK")+
                    NDEL("3",N,BD)/PDEL("3","MILK"))/2;
ELAST("OTHER",N,BD)=(NDEL("4",N,BD)/PDEL("4","OTHER")+
                     NDEL("5",N,BD)/PDEL("5","OTHER"))/2;
ELAST("LABOR",N,BD)=(NDEL("6",N,BD)/RDEL("6","LABOR")+
                     NDEL("7",N,BD)/RDEL("7","LABOR"))/2;
ELAST("FEED",N,BD)=(NDEL("8",N,BD)/RDEL("8","FEED")+
                    NDEL("9",N,BD)/RDEL("9","FEED"))/2;
ELAST("ENERGY",N,BD)=(NDEL("10",N,BD)/RDEL("10","ENERGY")+
                    NDEL("11",N,BD)/RDEL("11","ENERGY"))/2;
ELAST("CROP",N,BD)=(NDEL("12",N,BD)/RDEL("12","CROP")+
                    NDEL("13",N,BD)/RDEL("13","CROP"))/2;
ELAST("LIVESTOCK",N,BD)=(NDEL("14",N,BD)/RDEL("14","LIVESTOCK")+
                    NDEL("15",N,BD)/RDEL("15","LIVESTOCK"))/2;
ELAST("ESTATE",N,BD)=(NDEL("16",N,BD)/RDEL("16","ESTATE")+
                    NDEL("17",N,BD)/RDEL("17","ESTATE"))/2;


* printing the elasticities:

     PUT "Farm # ", K.TL/;
     PUT " "," ";
     LOOP(N,PUT N.TL);
     PUT /;

     LOOP(N,
          LOOP(BD,
          PUT N.TL,BD.TL;
          LOOP(NN,PUT ELAST(N,NN,BD));
          PUT /;
          );
     );

);
```

Appendix Table 4

Estimated Elasticities:

I refers to the Inner Bound Estimate

O refers to the Outer Bound Estimate.

Farm #1

		MILK	OTHER	LABOR	FEED	ENERGY	CROP	LIVEST	ESTATE
MILK	I	0	0	0	0	0	0	0	0
	O	5.4	29.78	-68.92	7.84	0	-74.03	32.35	26.77
OTHER	I	0.32	4.11	0.73	1.69	0.11	0.54	1.36	-2.53
	O	-7.46	130.61	299.27	16.01	0	-37.54	0.01	-1.38
LABOR	I	0.36	0.96	-1.97	1.3	0.41	-0.05	1.28	1.75
	O	3.28	-20.74	-117.53	-2.91	0	-0.01	10.27	9.75
FEED	I	-0.61	-7.76	-1.38	-3.19	-0.21	-1.02	-2.56	4.77
	O	-3.44	-20.26	37.72	-5.12	0	50.68	-20.87	-17.61
ENERGY	I	-0.45	1.77	1.42	-0.42	-12.81	1.53	1.85	-4.26
	O	-1.23	6.52	10.49	-1.43	0	10.49	10.49	-6.23
CROP	I	0.47	-1.84	-1.49	0.44	13.36	-1.59	-1.93	4.44
	O	1.63	14.57	14.05	3.82	0	-70.62	13.42	12.79
LIVEST	I	0.44	-1.72	-1.38	0.41	12.45	-1.48	-1.8	4.13
	O	-2.18	-26.01	26.1	-4.67	0	35.93	-18.78	-11.15
ESTATE	I	-0.55	2.16	1.74	-0.52	-15.69	1.87	2.27	-5.21
	O	-0.19	-6.19	30.48	9.35	0	58.06	-6.89	-37.07

Farm #2

		MILK	OTHER	LABOR	FEED	ENERGY	CROP	LIVEST	ESTATE
MILK	I	0	0	0	0	0	0	0	0
	O	4.65	27.6	-11.62	9.4	-52.99	-112.75	31.79	26.2
OTHER	I	0	0	0	0	0	0	0	0
	O	-7.39	107.54	83.47	22.34	-3.04	-49.95	0.01	0.01
LABOR	I	0	0	0	0	0	0	0	0
	O	3.83	-12.65	-36.11	-2.81	-0.01	-0.01	13.11	11.18
FEED	I	0	0	0	0	0	0	0	0
	O	-3.84	-16.85	8.95	-14.59	84.5	36.03	-21.83	0
ENERGY	I	0	0	0	0	0	0	0	0
	O	-2.03	7.67	9.41	-3.35	-343.19	12.01	11.38	-8.62
CROP	I	0	0	0	0	0	0	0	0
	O	2.05	13.49	9.89	8.17	6.78	-107.39	13.87	13.44
LIVEST	I	0	0	0	0	0	0	0	0
	O	-3	-21.75	13.61	-7.39	23.82	47.93	-21.29	-13.99
ESTATE	I	0	0	0	0	0	0	0	0
	O	-1.5	-10.63	15	8.53	5.44	74.43	-15.01	-35.05

Farm #3

		MILK	OTHER	LABOR	FEED	ENERGY	CROP	LIVEST	ESTATE
MILK	I	0	0	0	0	0	0	0	0
	O	6.42	19.05	-54.52	7.4	-279.77	0	29.12	27.05
OTHER	I	0.34	5.45	4.14	1.23	0.38	-0.77	-0.03	3.95
	O	-7.67	73.26	165.75	11.84	-117.57	0	0.01	0.01
LABOR	I	-0.11	-2.42	-3.89	-0.94	0.03	1.01	2.26	-4.79
	O	3.04	-27.1	-113.18	-4.09	-0.01	0	9.05	8.4
FEED	I	-0.41	-0.64	0.92	-2.82	-1.2	-1.19	-2.57	17.37
	O	-3.14	-11.33	20.25	-4.22	200.71	0	-16.65	-14.34
ENERGY	I	0	0	0	0	0	0	0	0
	O	-1.13	6.36	9.76	-0.99	-933.64	0	10.82	-4.2
CROP	I	-0.26	-0.51	4.14	0.32	-0.72	-3.8	-0.71	0.54
	O	1.73	10.94	10.94	4.43	10.94	0	10.94	10.94
LIVEST	I	-0.26	-3.09	0.49	-0.15	-0.49	-0.49	-3.09	1.94
	O	-2.61	-15.17	21.35	-4.36	121.49	0	-15.95	-10.77
ESTATE	I	0.33	0.51	-0.73	2.22	0.95	0.94	2.02	-13.69
	O	-0.3	-4.32	24.05	9.37	87.18	0	-7.78	-35.22

Farm #4

		MILK	OTHER	LABOR	FEED	ENERGY	CROP	LIVEST	ESTATE
MILK	I	0	0	0	0	0	0	0	0
	O	11.98	35.79	-40.85	26	0	-18.57	0	61.85
OTHER	I	0	0	0	0	0	0	0	0
	O	-8.03	150.73	95.04	41.06	0	-12.42	0	0.01
LABOR	I	0	0	0	0	0	0	0	0
	O	4.58	-71.05	-55.83	-21.01	0	9.75	0	5.91
FEED	I	0	0	0	0	0	0	0	0
	O	-8.17	-35.7	11.09	-28.76	0	10.73	0	-30.76
ENERGY	I	0	0	0	0	0	0	0	0
	O	-4.51	-5.08	10.49	-11.06	0	10.49	0	-27.31
CROP	I	0	0	0	0	0	0	0	0
	O	0.64	21.13	22.45	5.42	0	-20.56	0	23.66
LIVEST	I	0	0	0	0	0	0	0	0
	O	-3.3	-58.09	10.19	-18.38	0	10.19	0	-22.02
ESTATE	I	0	0	0	0	0	0	0	0
	O	3.26	-17.13	19.07	7.16	0	11.17	0	-60.03

Farm #5

		MILK	OTHER	LABOR	FEED	ENERGY	CROP	LIVEST	ESTATE
MILK	I	25.75	45.18	-7.6	21.11	20.22	-20.11	63.48	17.87
	O	5.34	118.49	-20.94	11.21	-51.03	-18.58	0	56.96
OTHER	I	0.89	18.72	0.86	4.49	1.92	-8.08	22.21	6.34
	O	-8.46	661.88	116.9	31.89	0.01	-10.49	0	-3.2
LABOR	I	-7.02	-10.02	-8.3	-6.73	-4.13	-5.83	-9.44	-8.8
	O	4.42	-142.74	-51.81	-8.13	-0.01	-0.01	0	28.93
FEED	I	-1.67	-35.25	-1.62	-8.47	-3.64	15.21	-41.82	-11.92
	O	-4.05	-97.69	12.19	-11.19	37.17	11.7	0	-34.88
ENERGY	I	10.31	8.97	8.37	8.94	6.59	12.35	10.55	12.6
	O	-2.77	-4.87	8.2	-6.14	-219.02	9.28	0	-33.09
CROP	I	1.12	23.74	1.08	5.7	2.43	-10.24	28.17	8.04
	O	1.97	64.78	6.67	5.51	7.27	-19.09	0	38.97
LIVEST	I	-0.87	-20.64	1.05	-3.8	1.52	7.73	-26.31	-9.55
	O	-2.6	-128.48	10.19	-8.91	10.19	10.19	0	-30.36
ESTATE	I	-13.91	-38.82	-11.5	-17.6	-10.9	-3.08	-45.97	-24.84
	O	-1.2	-53.68	13.67	11.34	0.03	13.99	0	-87.7

Farm #6

		MILK	OTHER	LABOR	FEED	ENERGY	CROP	LIVEST	ESTATE
MILK	I	0	0	0	0	0	0	0	0
	O	5.85	29.79	-10.47	15.86	-49.95	-41.36	51.21	41.26
OTHER	I	0.61	7.49	1.18	2.66	8.64	1.78	2.7	-3.48
	O	-2.66	32.21	27.42	11.98	-23.11	-24.6	0.7	0.01
LABOR	I	0.64	-0.63	-1.83	2.8	2.29	0.22	1.38	2.32
	O	9.55	-1895.7	-1428.3	12.45	-0.01	-0.01	22.89	18.25
FEED	I	0	0	0	0	0	0	0	0
	O	-3.84	-19.89	6.87	-10.77	35.04	28.96	-35.18	-26.9
ENERGY	I	0.15	4.73	2.77	3.17	-28.07	2.22	2.83	-3.42
	O	-3.08	7.73	8.96	-6.94	-239.7	7.53	16.12	-17.51
CROP	I	0	0	0	0	0	0	0	0
	O	2.12	17.82	9.16	13.32	4.43	-45.84	22.36	20.55
LIVEST	I	0	0	0	0	0	0	0	0
	O	-4.13	-32.55	12.26	-15.14	21.71	18.31	-41.56	-23.52
ESTATE	I	0	0	0	0	0	0	0	0
	O	-2.71	-12.72	13.86	7.97	10.19	29.37	-28.94	-52.92

Farm #7

		MILK	OTHER	LABOR	FEED	ENERGY	CROP	LIVEST	ESTATE
MILK	I	2.13	-6.72	-7.61	11.06	-3.39	7.48	-2.7	23.41
	O	6.59	23.7	-40.75	14.41	-112.16	0	30.15	24.24
OTHER	I	-0.2	1.77	1.04	-0.16	-3.86	-0.8	2.64	-7.2
	O	-7.17	96.15	107.63	24.03	-14.09	0	0.01	-0.54
LABOR	I	0.66	-2.1	-2.38	3.46	-1.06	2.34	-0.84	7.31
	O	3.53	-24.41	-63.95	-4.9	-0.01	0	10.2	8.84
FEED	I	-1.46	4.62	5.23	-7.61	2.33	-5.14	1.86	-16.09
	O	-3.92	-15.51	19.55	-9.9	77.49	0	-17.8	-14.65
ENERGY	I	-0.24	2.14	1.27	-0.2	-4.69	-0.97	3.2	-8.74
	O	-1.25	9.06	8.74	-2.17	-286.92	0	11.69	-4.32
CROP	I	-0.98	3.11	3.53	-5.12	1.57	-3.46	1.25	-10.84
	O	1.91	10.94	10.94	9.08	10.94	0	10.94	10.94
LIVEST	I	0.24	-2.08	-1.23	0.19	4.55	0.94	-3.11	8.49
	O	-2.93	-27.6	17.61	-10.2	40.9	0	-20.19	-10.83
ESTATE	I	-1.16	3.65	4.14	-6.02	1.85	-4.06	1.47	-12.73
	O	-2.27	-9.64	23.98	5.81	44.4	0	-12.78	-26.61

Farm #8

		MILK	OTHER	LABOR	FEED	ENERGY	CROP	LIVEST	ESTATE
MILK	I	0	0	0	0	0	0	0	0
	O	6.73	37.04	-32.52	12.21	-111.13	-49.25	40.83	38.13
OTHER	I	-0.1	1.65	2.75	0	8.56	-2.65	0.39	1.27
	O	-2.36	35.71	65.49	8.85	-13.35	-22.58	0.52	0.01
LABOR	I	0.46	-1.51	-6.67	0.91	-7.21	3.43	0.1	2.38
	O	4.15	-34.26	-93.66	-5.6	-0.01	-0.01	13.9	13.22
FEED	I	0	0	0	0	0	0	0	0
	O	-4.28	-24.54	19.47	-8.11	78.46	34.54	-27.52	-24.44
ENERGY	I	0.12	-2.01	-3.35	-0.01	-10.41	3.22	-0.47	-1.55
	O	-2.1	6.62	8.72	-3.23	-485.27	9.17	12.21	-11.44
CROP	I	-0.4	0.21	5.31	0.3	12.63	-4.27	-0.62	-1.34
	O	2.44	19.16	10.92	8.23	0	-41.84	17.67	17.13
LIVEST	I	0	0	0	0	0	0	0	0
	O	-3.11	-27.11	18	-7.53	47.81	22.01	-23.19	-16.76
ESTATE	I	0	0	0	0	0	0	0	0
	O	-1.35	-13.17	19.65	8.66	29.01	32.7	-15.61	-42.68

Farm #9

		MILK	OTHER	LABOR	FEED	ENERGY	CROP	LIVEST	ESTATE
MILK	I	0	0	0	0	0	0	0	0
	O	6.26	29.99	-43.89	10.79	0	-51.91	42.52	39.98
OTHER	I	0	0	0	0	0	0	0	0
	O	-7.89	135.47	138.78	17.73	0	-27.03	0.01	0.01
LABOR	I	0	0	0	0	0	0	0	0
	O	2.89	-18.4	-52.22	-2.48	0	4.2	11.51	10.52
FEED	I	0	0	0	0	0	0	0	0
	O	-3.37	-19.51	16.17	-6.06	0	35.74	-23.84	-24.13
ENERGY	I	0	0	0	0	0	0	0	0
	O	-1.77	5.59	10.49	-2.61	0	10.49	10.49	-11.41
CROP	I	0	0	0	0	0	0	0	0
	O	1.02	13.73	12.93	4.45	0	-52.16	14.78	11.88
LIVEST	I	0	0	0	0	0	0	0	0
	O	-2.48	-30.49	16.1	-6.71	0	25.79	-25.85	-16.5
ESTATE	I	0	0	0	0	0	0	0	0
	O	-0.98	-7.52	23.61	9.52	0	28.5	-12.52	-46.62

Farm #10

		MILK	OTHER	LABOR	FEED	ENERGY	CROP	LIVEST	ESTATE
MILK	I	23.74	-16.3	-23.23	6.6	23.74	12.7	-8.76	9.62
	O	6.06	17.95	-61.66	7.04	-120.26	0	32.66	22.38
OTHER	I	7.25	14.56	17.08	6.24	0.01	4.02	11.82	5.14
	O	-7.49	115.7	162.8	15.1	0.01	0	0.01	0.01
LABOR	I	1.58	-6.26	-10.75	2.65	7.25	4.97	-0.2	4.23
	O	3.07	-17.88	-59.99	-2.29	-0.01	0	10.16	8.47
FEED	I	-0.51	-0.35	2.02	-2.28	1.67	-1.45	-1.94	2.78
	O	-3.67	-12.77	27.09	-5.94	84.67	0	-17.81	-11.94
ENERGY	I	-10.16	-10.26	-11.79	-9.02	-11.56	-9.55	-9.24	-12.27
	O	-0.85	7.3	8.34	-0.86	-242.38	0	11.91	-3.34
CROP	I	-1.76	7.51	10.7	-3.04	-10.94	-5.85	4.04	-4.43
	O	1.11	10.94	10.94	2.71	10.94	0	10.94	10.94
LIVEST	I	-9.44	-9.47	-13.98	-8.64	-9.61	-6.73	-14.16	-4.39
	O	-2.19	-28.11	17.91	-5.02	36.18	0	-22.84	-9.07
ESTATE	I	-0.55	-0.63	3.17	-0.14	-2.04	-3.21	6.51	-9.48
	O	-0.68	-4.28	27.4	9.19	38.03	0	-6.92	-34.74

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