GOVERNMENT PAYMENTS TO FARMERS AND REAL AGRICULTURAL ASSET VALUES IN THE 1980s

Charles B. Moss, J.S. Shonkwiler, and John E. Reynolds

Abstract

This study determines the effect of government payments on real agricultural asset values using Bayesian vector autoregression. In developing the empirical model, special attention is focused on the informational content of government payments. The results indicate that government payments to farmers have little effect on real asset values in the long run. In the short run, an increase in government payments to farmers may be associated with decline in asset values.

Key words: informational content, Bayesian vector autoregression, real asset values, government payments to farmers.

Real agricultural asset values declined rapidly in the 1980s. In December 1980, real asset values in agriculture stood at $1.26 trillion in 1986 dollars. By the end of December 1986, real agricultural asset values had fallen to $0.70 trillion in 1986 dollars, or 58.8 percent of their December 1980 level (Melichar). This decline in asset values contributed to the increased financial stress in agriculture in the 1980s as farmers were forced to sell capital assets to meet financial obligations incurred in times of greater prosperity.

During the period of falling asset values, government expenditures on agriculture increased rapidly and farm income fell. Over the 1970s, real government payments to farmers averaged $4.75 billion (1986 dollars) per year, while government payments to farmers in the 1980s averaged $6.68 billion (1986 dollars) per year. From 1970 to 1979, real returns to agricultural assets averaged $31.64 billion (1986 dollars), while in the 1980s average real net income to farm assets fell to $23.72 billion (USDA).

Recent studies attempting to explain the decline in asset values in the 1980s have primarily focused on the decline in income-to-asset ratios and the increase in real interest rates. Alston found that most of the growth in real land prices could be attributed to changes in real rents. Burt used a time series model to show the reaction of land prices through time as a function of rent. Finally, Featherstone and Baker specified a dynamic model for assets and estimated real asset values as a function of lagged real interest rates, income-to-asset ratios, and real asset values.

This study extends the framework of Featherstone and Baker by examining how farm asset values are related to government payments to agriculture. Specifically, this study defines market income as that portion of the rate of return to agricultural assets arising from market transactions, not from government payments, or net farm income excluding government payments. Thus, the effect of government payments to farmers on real asset values can be separated from the effect of market income, real interest rates, and lagged changes in asset values. It is hypothesized that government payments to farmers may have a different effect on real asset values from that of market-generated income. For example, because of uncertainty surrounding the political process, government payments may have little effect on asset values. That is, they may be regarded as transient income. Alternatively, because government payments increase when market-generated income declines, government farm payments could indicate decreasing future profitability in agriculture.

The next section sketches the theory used to develop a dynamic model of real asset values. The following section presents the procedure used to estimate real asset values followed by an explanation of the data. Finally,

Charles B. Moss is an Assistant Professor, J.S. Shonkwiler is a Professor, and John E. Reynolds is a Professor, Department of Food and Resource Economics, University of Florida.

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the study presents the results of the empirical procedure and conclusions based on those results.

THE PRICE OF AGRICULTURAL ASSETS

The value of a capital asset is determined by the discounted stream of future revenues arising from the purchase of the asset. An asset is desirable or should be purchased if the net present value of that investment is greater than zero. Therefore, if the world were riskless and all agents in the economy had the same discount rate, the price for a capital asset conditional on the series of future returns $\{R_t\}_{t=1}^n$ and the real interest rate $\{r_t\}_{t=1}^n$, where t denotes time periods t=l, . . . n, would be

$$(1)\ V\left[\{R_t\}_{t=1}^n, \{r_t\}_{t=1}^n\right] = \sum_{s=t+1}^{n} \frac{R_s}{(1+r_s)^s},$$

where V[•] is the market price of the asset.

Of course, the world is not certain. Thus, $\{R_t\}_{t=1}^n$ and $\{r_t\}_{t=1}^n$ are not known at time t=0 and must be projected by the investor. The assumption that the investor can project the revenue and discount rate in period s given only values observable in period t ($t < s$) would require little modification to equation (1). Specifically, if investors were risk neutral and their expectations about future income and discount rates could be represented by the projected series $\{P[R_s|I_t]\}_{s=t}^n$ and $\{P[r_s|I_t]\}_{s=t}^n$, where I_t is the information available in period t, then the only change in equation (1) would be the substitution of the projected series of returns and discount rates for $\{R_t\}_{t=1}^n$ and $\{r_t\}_{t=1}^n$, respectively. Finally, if investors were risk averse, then the equality in equation (1) could be replaced with a proportionality operator. Thus, the general direction of the effect would remain unchanged, but the exact effect could be dampened or magnified by risk aversion.

COMPONENTS OF FARM INCOME

For the purpose of this study, farm income is divided into two components, market income and income from government program payments. Different processes generate each component. Market income is generated by the interaction of environmental factors, technology, and individuals' utility functions. Income from government programs is generated through a political process. As a result, an increase in income from each component may have different implications for asset values through time.

An increase in the market value component of farm income indicates that a potential change in the "real economy" has occurred. Increased real agricultural income could result from an alternative use of agricultural commodities, such as synthetic fuels, becoming economically feasible or from increased growth in developing nations. These shocks would probably be perceived as fairly permanent, causing an upward shift in the entire future stream of asset returns. On the other hand, the market increase in income may be attributable to a short-lived phenomenon such as the 1988 drought in the Midwest. In the case of weather, the increased income would probably be viewed as transitory and, hence, would not affect asset values in the long run.

Farm income from government payments occurs because society makes a normative decision to redistribute wealth.[1] An increase in farm income through program payments may be attributed to either a change in society's definition of an "equitable" distribution of wealth or variations in the market's definition of "equitable" returns such that society's preferences are held fixed. The permanence of this income component is obviously much different from the permanence of the market component.

From the earliest history of the United States, some form of agricultural policy has existed. Initially, the focus was on land distribution, but by the Civil War the focus partially shifted to education and research. During the Depression, the focus had shifted to transfers to farmers. From this historical perspective, the government payments component would appear to be as permanent as shifts in market income. However, because of shifts in population from rural to urban since the 1940s, the uncertainty regarding agriculture's ability to maintain preferential government treatment in the future has increased. As a result, government payments may be increasingly viewed as transitory.

Investors may also derive information about future market returns from the level of government involvement. A large government

[1]The typical focus of agricultural commodity programs has been income enhancement. Government transfer payments have been made to farmers because market returns were deemed unsatisfactory. Typically, farm lobbies have argued for various reasons that these programs did not represent wealth redistribution in the same way as other transfers such as various welfare programs. The purpose of this study is not to add to this debate. The only necessary argument is that government programs for agriculture represent a redistribution of wealth in society.

involvement may be interpreted by investors as indicative of low market returns for agriculture in the future. A classic example of this is the accumulation of Commodity Credit Corporation (CCC) stocks. Government actions to support prices through CCC loans cause an accumulation of government stocks. These increased stocks may have the effect of depressing future prices for commodities. Further price distortions may allow marginal producers to remain in the sector.

Theoretically, the investor uses current information to project future returns and interest rates in deriving the value of agricultural assets. An important component of the information set is the composition of farm income between market returns and government payments.[2]

PROCEDURE

The stylized model developed in the preceding section is not directly quantifiable. The expectation function for each variable is not theoretically well defined. Therefore, this study uses an approach similar to that adopted by Featherstone and Baker.

The unrestricted vector autoregression used by Featherstone and Baker involves estimating a reduced form, autoregressive representation of a vector of theoretically related variables. The reduced form equations can then be used to examine the relationships between endogenous variables over time. In the macroeconomics literature, vector autoregression mitigates the specification error arising from inadequately developed macroeconomic theory and poor specification of the system dynamics or expectations process (Sims; Moss et al.; Featherstone and Baker). Likewise, in this study, the time series approach is adopted due to inadequate theory regarding the specification of the expectations process. Thus, the technique attempts to discover the regularities (Bessler) of the dynamic system through time.

The estimation procedure in this study differs from Featherstone and Baker by the use of a Litterman prior in estimation. A Litterman prior or Bayesian Vector Autoregression (BVAR) represents a compromise between a structural econometric approach and unconstrained vector autoregression. Prior beliefs are imposed on the model through the selection of endogenous variables and a weak prior on the time series process. The Litterman prior is a random walk with a matrix of tightness coefficients determining the information required to change the estimates (Bessler and Kling; Litterman and Wiess; Litterman). The prior mean is unity on the first lag and zero for all other coefficients. The tightness parameter on each lag includes a specific term and an overall tightness term. The specific term can be used to impose a prior belief about the effect of one variable on another. A tight prior or a specific parameter close to zero implies that a large amount of information will be required to change the coefficient from the random walk prior.

Mechanically, this study applies the Litterman prior using Theil's mixed estimator. Theil's mixed estimator can be defined as a generalized least squares (GLS) estimator which combines the observed data with other information about the parameters of interest. This nonsample or prior information is weighted relative to the observed data via the use of tightness parameters. After constructing the weighting matrix, GLS is applied in a fairly straightforward manner. A more detailed explanation can be found in Theil.

In this study, an autoregressive representation of the model outlined in the preceding section is used. Specifically, the current values of real interest rates (INT), the rate of return to assets from market income (INC), the rate of return to assets from government payments (PAY), and the real growth in asset values (VAL) are estimated as functions of their lagged values, a vector of constants, and the supply reduction due to government programs (SREDUCT),

$$(2)\quad \begin{bmatrix} \text{INT} \\ \text{INC} \\ \text{PAY} \\ \text{VAL} \end{bmatrix}_t = \alpha + \sum_{i=1}^{n} \beta_i \begin{bmatrix} \text{INT} \\ \text{INC} \\ \text{PAY} \\ \text{VAL} \end{bmatrix}_{t-i} + \gamma \ \text{SREDUCT}_t ,$$

where α is a 4 dimension vector of constants, β_i are 4*4 matrices, and γ is a 4 dimension vector of constants. SREDUCT is an estimate of the number of acres removed from production under the farm program (Ericksen and Collins). This variable is included to remove potential noise from the supply reduction programs typically associated with government payments by isolating the pure transfer payment effect of government programs.

The specific components of the priors used in this study are given in Table 1. The overall

[2]Feldstein suggested that inflationary speculation may also influence land prices. However, Burt dismisses this formulation, preferring instead a model where real asset values are driven by real returns. This study follows Burt's formulation, arguing that inflationary gains are transient.

TABLE 1. LITTERMAN PRIOR FOR BAYESIAN VECTOR AUTOREGRESSION

Dependent Variable	Lagged Endogenous Variables			
	Interest Rate	Market Income	Government Payments	Total Assets
Interest Rate	1.000	0.001	0.001	0.001
Market Income	0.250	1.000	0.900	0.750
Government Payments	0.250	0.900	1.000	0.750
Total Assets	0.900	0.900	0.900	1.000

tightness coefficient was set at .3, and a harmonic decay with a decay parameter of .75 was used. Further, the study uses the five-period lag length from Featherstone and Baker. One particular prior imposes a very tight distribution for the effect of agricultural variables on the real interest rate. Thus, a relatively large amount of evidence will be required for agricultural variables to affect the real interest rate. Similarly the priors for the effect of the real interest rate on market income and government payments are fairly tight, suggesting that the real interest rate has little effect on market income or government payments.[3] The remainder of the specific priors are fairly loose.

Due to the reduced form nature of vector autoregressions, alternative methods of interpreting their results have been developed. To examine the effect of one variable on another through time, impulse response functions are used. The impulse response function shows the response of an endogenous variable to a shock or innovation in an endogenous variable. This study uses orthogonal shocks; thus, the initial shock has been adjusted for contemporaneous correlations between endogenous variables (Bessler). Therefore, the impulse response function gives the anticipated effect of an innovation in an endogenous variable.

Another way to examine the implications of the time series model is by the decomposition of variance. The decomposition of variance indicates the portion of the variance explained by each endogenous variable over a given period of time (Bessler). The process involves forecasting an endogenous variable k periods in the future based on current data and computing the variance. Information is then added for all k periods on a particular variable. The change in variance due to the additional information is the portion of variance explained by that variable. The portion explained is averaged over all possible k forecast periods in the sample.

A related method of interpreting the results of the vector autoregression is the historical decomposition of forecast error. The historical decomposition of forecast error depicts the effect of the endogenous variables on a specific endogenous variable over a given period (Featherstone and Baker, Burbidge and Harrison). The procedure is actually a counterfactual simulation. The system of endogenous variables is simulated over a given period using only initial conditions and exogenous data. Then the information for one of the endogenous variables is added, and the system is simulated again. The change in projection is attributed to the most recently added variable. Alternatively, the change in forecast due to information on the endogenous factor is taken to be the effect of that factor on the variable of interest. For more information on these techniques see Appendix I.

Finally, the Granger causality statistic shows the statistical significance of endogenous variables in predicting the current value of a particular endogenous variable (Sims). In the strictest sense of the word, the Granger statistic does not test causality. It merely indicates the ability of one variable to predict changes in another.

DATA

The farm income and value of total assets for the period 1945 to 1986 along with the Personal Consumption Expenditure component of the implicit GNP deflator (PCE) are from Melichar. The farm income used in this study is the annual return to farm assets before interest, and the measure of total assets is the total assets in agriculture on December 31 of each year (Melichar). The interest rate for the same period was derived from the average

[3]The increased use of debt in agriculture may seem inconsistent with this prior. However, as Table 1 indicates, the priors on the effect of interest rates on market income and government payments are much looser than the priors for agricultural variables on real interest rates. In this way, it's possible that the sample information will reveal a stronger effect from the prior postulates.

annual interest rate on 3-month treasury bills (U.S. Department of Commerce *Business Statistics* augmented in recent years by the U.S. Department of Commerce *Survey of Current Business*). This interest rate was suggested in Featherstone and Baker as the riskless opportunity cost of capital. The treasury bill rate is adjusted for inflation using the average annual PCE from Melichar. Finally, real government payments to farmers are derived from USDA figures adjusted with the average annual PCE. The income from market factors is derived by subtracting the government payment to farmers from the annual income. The supply reduction variable (SREDUCT) is from Ericksen and Collins. The data used in this study are presented in Appendix II.

RESULTS

This section presents the results of the Bayesian vector autoregression described above. As indicated in the procedure section, the results of this time series technique are somewhat more complex than typical econometric procedures. Basic results of the estimation are presented first, followed by the results of the interpretive procedures.

Coefficient Estimates

The estimated coefficients presented in Table 2 indicate that the real interest rate is best described by lagged real interest rates. Further, the effects of lagged real interest rates on current real interest rates decline as the length of lag increases. The Ljung-Box statistic[4] implies that little information remains in the residuals, but the R-square indicates that significant deviations in the real interest rate remain unexplained by the current model.

The results for the market income equation indicate that the autoregressive representation explains a little more than half of the total variation in market income over the sample period. The Ljung-Box statistic shows that little information remains in the residuals. Thus, the relatively low R-square is probably due to factors not explicitly modeled, such as consumer income and trade variables. Apparently, the current level of income is highly affected by the first lag on market income and the first lag on government payments.

The autoregressive representation explains the vector of government payments well. The R-square of this equation is .9360. Further, the Ljung-Box statistic indicates that the residuals cannot be distinguished from white noise at any conventional level of significance. An examination of the individual parameters shows that government payments are significantly affected by supply reduction measures. Further, the results indicate that increased supply reduction entails greater government payments to farmers. An examination of the individual lags suggests that current government payments are primarily determined by the rate of government payments last year. However, high capital gains last year also decrease the current rate of government payments.

Finally, the results in Table 2 show that the autoregressive representation explains two-thirds of the variation in the total assets. The Ljung-Box statistic indicates that little information remains in the residuals. Thus, the model explains a large amount of the movement in total asset values during the sample. However, the results leave room for other significant factors such as inflation. Individually, current total assets appear to be mostly attributable to capital gains last year.

References to the significance of individual lags on an endogenous variable in the previous discussion should be tempered with a healthy skepticism. Sims noted that the significance or insignificance of an individual lag was not appropriate in this time series approach. Instead, he proposed the Granger statistic to jointly test the statistical significance of all lags of a particular variable. The Granger causality statistics for this study are presented in Table 3. In a Granger causal sense, real interest rates, market income, and total asset values are due to lagged values of each variable.[5] Government payments to farmers, however, are predicted by lagged innovations in government payments and total asset values. Thus, the policy process may move in response to observed capital losses.

[4]The Ljung-Box statistic provides a measure of information or explanatory power remaining in the residuals of a time series estimation. Specifically, the Ljung-Box statistic measures the amount of current residual explained by past residuals. Failing to reject the Ljung-Box hypothesis implies that the residuals are white-noise. The goal of time series analysis is to reduce the residuals to white-noise so that all systematic information from the data series has been incorporated. For further details see Harvey (pp. 209–212).

[5]Granger causality does not necessarily coincide with economic causality. Granger causality primarily refers to predictive power. If one variable is Granger causal of another, that variable can be used to predict the second or caused variable. Economically, this result does not rule out the possibility that both variables are strongly influenced by a common factor.

TABLE 2. ESTIMATED COEFFICIENTS FROM THE BAYESIAN VECTOR AUTOREGRESSION

	Dependent Variable			
	Interest Rate	Market Income	Government Payments	Total Assets
Explanatory Variables				
Intercept	.00661	.007941	.000355	-.019015
	(.00448)	(.006156)	(.000921)	(.029948)
SREDUCT	.00000	.000000	.000001***	.000000
	(.00000)	(.000000)	(.000000)	(.000000)
Interest (t-1)	.83375***	-.019122	.001890	-.323986
	(.13103)	(.036575)	(.005388)	(.391880)
Interest (t-2)	-.10641	-.002649	.000736	-.183706
	(.13041)	(.02702)	(.003347)	(.303641)
Interest (t-3)	.07715	.006106	.000304	-.165113
	(.10283)	(.016876)	(.002498)	(.235211)
Interest (t-4)	.06854	.000154	.000317	-.076772
	(.08573)	(.013670)	(.002016)	(.196571)
Interest (t-5)	-.00296	-.002780	.000284	.069774
	(.07352)	(.011561)	(.001704)	(.164845)
Income (t-1)	-.00000	.646703***	-.016343	-1.072600*
	(.00052)	(.132199)	(.018939)	(.578096)
Income (t-2)	-.00001	-.070042	.010876	.534788
	(.00031)	(.114559)	(.015896)	(.486136)
Income (t-3)	-.000000	.009984	.007674	.336002
	(.00023)	(.089227)	(.012298)	(.380608)
Income (t-4)	-.000000	-.003946	.011831	.054250
	(.00081)	(.073587)	(.010434)	(.319325)
Income (t-5)	.000000	.004365	.002449	.093422
	(.00016)	(.066558)	(.009067)	(.280304)
Gov't. Pay. (t-1)	-.000087	1.400206**	.612682***	-2.253283
	(.003334)	(.666782)	(.101633)	(3.045752)
Gov't. Pay. (t-2)	-.001982	-.775944	-.041578	-1.640348
	(.001982)	(.630675)	(.098865)	(2.828328)
Gov't. Pay. (t-3)	-.000036	.311440	.066883	2.777338
	(.001463)	(.504308)	(.079927)	(2.265941)
Gov't. Pay. (t-4)	-.000039	.149034	-.033965	.875936
	(.001179)	(.425234)	(.067849)	(1.906260)
Gov't. Pay. (t-5)	-.000028	.001942	-.015363	1.348156
	(.000997)	(.351511)	(.055642)	(1.580150)
Total Assets (t-1)	.000000	-.002852	-.009718**	.569258***
	(.000112)	(.024929)	(.003676)	(.150262)
Total Assets (t-2)	.000000	-.003818	-.003195	-.051360
	(.000066)	(.020174)	(.002972)	(.113095)
Total Assets (t-3)	.000000	-.007511	-.001005	.043423
	(.000049)	(.016433)	(.002423)	(.093648)
Total Assets (t-4)	.000000	-.007899	-.000659	-.037585
	(.000030)	(.013764)	(.002029)	(.079258)
Total Assets (t-5)	-.000000	.004854	-.000025	.014657
	(.000033)	(.003623)	(.000530)	(.017936)
	Equation Statistics			
R-Square	.5901	.5580	.9360	.6678
Ljung-Box Q-Statistic	15.55[a]	13.25[a]	17.04[a]	17.09[a]

[a]Ljung-Box statistic fails to reject the hypothesis that the residuals are white-noise at the .05 confidence level given a $\chi 2$ distribution with 18 degrees of freedom.

*** Denotes statistical significance at the .01 level of confidence.

** Denotes statistical significance at the .05 level of confidence.

* Denotes statistical significance at the .10 level of confidence.

Numbers in parentheses are standard deviations for the estimated parameter.

TABLE 3. GRANGER CAUSALITY RESULTS

	Lagged Endogenous Variables[a]			
Equation	**Interest Rate**	**Market Income**	**Government Payments**	**Total Assets**
Interest Rate	1	—	—	—
Market Income	—	1	—	—
Government Payment	—	—	1	10
Total Assets	—	—	—	5

[a]1 denotes statistical significance at the .01 level of confidence, 5 denotes statistical significance at the .05 level of confidence, and 10 denotes the statistical significance at the .10 level of confidence.

TABLE 4. CONTEMPORANEOUS CORRELATION MATRIX

Equation	**Interest Rate**	**Market Income**	**Government Payments**	**Total Assets**
Interest Rate	1.0000	-.0941	.0460	-.6197
Market Income		1.0000	-.1785	.366
Government Payments			1.0000	-.1423
Total Assets				1.0000

TABLE 5. PERCENT OF FORECAST VARIANCE FOR GROWTH IN REAL AGRICULTURAL ASSETS ATTRIBUTABLE TO EACH ENDOGENOUS VARIABLE

Year	**Real Interest**	**Market Income**	**Government Payments**	**Growth in Assets**
1	38.40	9.59	0.37	51.64
2	43.47	6.98	1.08	48.47
3	48.09	5.84	3.40	42.67
4	54.29	5.27	3.28	37.16
5	59.63	4.82	2.83	32.71
6	63.09	4.50	2.63	29.78
7	65.34	4.22	2.62	27.83
8	66.81	4.02	2.68	26.50
9	67.74	3.88	2.78	25.60
10	68.30	3.79	2.89	25.02
11	68.61	3.74	2.97	24.68
12	68.78	3.70	3.03	24.49
13	68.86	3.68	3.06	24.39
14	68.91	3.67	3.08	24.34
15	68.94	3.67	3.08	24.31
16	68.96	3.66	3.08	24.30
17	68.97	3.66	3.08	24.29
18	68.98	3.66	3.08	24.28
19	68.99	3.66	3.08	24.27
20	69.00	3.65	3.08	24.27
21	69.01	3.65	3.08	24.26
22	69.02	3.65	3.08	24.25
23	69.02	3.65	3.08	24.25
24	69.03	3.65	3.08	24.24

Interpreting the Autoregressive Representation

As indicated in the procedure section, interpretation of vector autoregression results typically involves post-estimation techniques not common in other econometric methods. These techniques are akin to multiplier analysis and simulation analysis. The techniques allow the researcher to examine the interaction between variables over time. This section presents the results of these techniques.

A starting point for most of these post-estimation procedures is the residual correlation matrix, which indicates contemporaneous interactions in the model. Table 4 indicates that a positive innovation[6] in the real interest rate is associated with a decline in the market income, an increase in government payments, and a decline in the growth of asset values. An increase in market income is contemporaneously correlated with a reduction in government payments and an increase in the growth of real asset values. Lastly, an increase in government payments is associated with a decline in real asset values. Therefore, the contemporaneous correlations are fairly consistent with the capitalization formula and the informational content of government support price payments.

Figure 1 shows the impulse response function for the rate of government payments to farmers. The figure indicates that an innovation in the rate of government payments results in future rates of government payments being consistently higher than the trend. Thus, government payments persist over time. Also, growth in real asset values tend to depress government payments. Therefore, if capital gains above trends are experienced in agriculture, the rate of government payments declines over time. Increases in the real interest rate lead to increased government payments. Hence, the political process may recognize the capital requirements of agriculture and attempt to compensate as the real interest rate increases. Alternatively, an increase in the real interest rate is highly correlated with declines in real asset values. Thus, Congress may observe and react to information on real asset values that is correlated with changes in the real interest rate. Finally, an increase in market income leads to lower government payments through time as might be expected.

Figure 2 depicts the response of the growth in real asset values to endogenous variables.

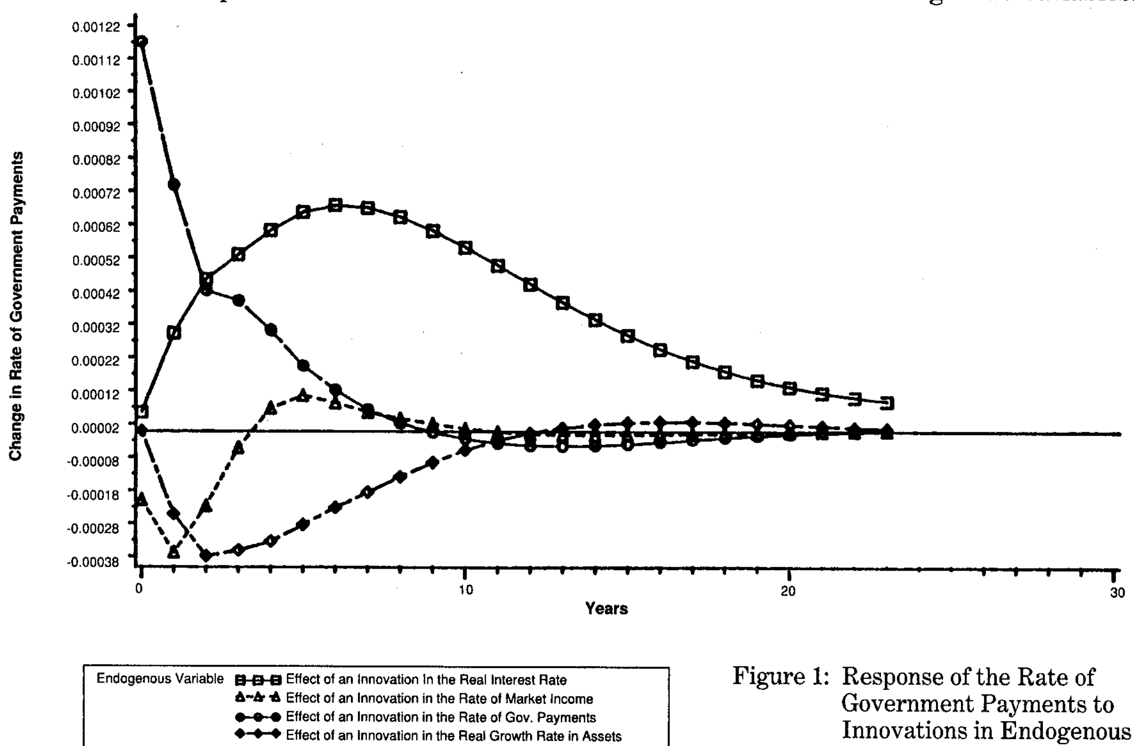

Figure 1: Response of the Rate of Government Payments to Innovations in Endogenous Variables.

[6]The word innovation is used in time series analysis to mean a change not explained by the model. The correlation matrix can then be used to describe a standard innovation. However, as Bessler explains, the typical innovations used in past-estimation procedure come from a Cholesky decomposition of the variance matrix. This matrix is used in the remainder of the paper, but the correlation matrix is used here for explanatory purposes.

The figure shows that innovations in market income are quickly assimilated into asset values. In the first and second year, there appears to be a slight over-adjustment as real asset values decline slightly in response to an increase in market income. The effect of the real interest rate also conforms to a priori expectations. Growth in real asset values declines in response to an innovation in the real interest rate. The immediate effect of a shock in government payments is a decline in the growth rate of real asset values. This is consistent with the informational content of government payments.

Table 5 gives the historical decomposition of variance over the entire sample. The results indicate that initially information on lagged growth in real asset values explains most of the forecast variance. However, as the length of lag increases, lagged real interest rates explain a majority of the forecast variance. After 24 years, lagged real interest rates explain 69.03 percent of the forecast variance while lagged growth in real asset values explains only 24.24 percent of the forecast variance. The rate of market income initially explains 9.59 percent of the variation, but the amount of forecast variance explained by the rate of market income declines to 3.65 by the 24th year. The explanatory power of the rate of government payments, on the other hand, starts at 0.37 percent and increases to 3.08 percent.

In general, the growth in real land prices has been lower in the 1980s than would have been projected using 1977 data (Figure 3). The historical decomposition of variance shows that a large portion of this shortfall can be attributed to changes in the real interest rate.

In October 1979, the Federal Reserve Board made a policy decision to reduce inflation.[7] This change in monetary policy caused a significant increase in the real interest rate throughout the 1980s. Therefore, the large negative effect of the real interest rate on growth in real asset values is consistent with the capitalization formula. The next largest factor in explaining growth in real asset values is innovations not explained by the autoregressive model. At the beginning of the forecast period, own factors caused the real growth in asset values to be higher than forecast. An explanation for this result may involve speculative bubbles (for a discussion on asset bubbles, see Featherstone

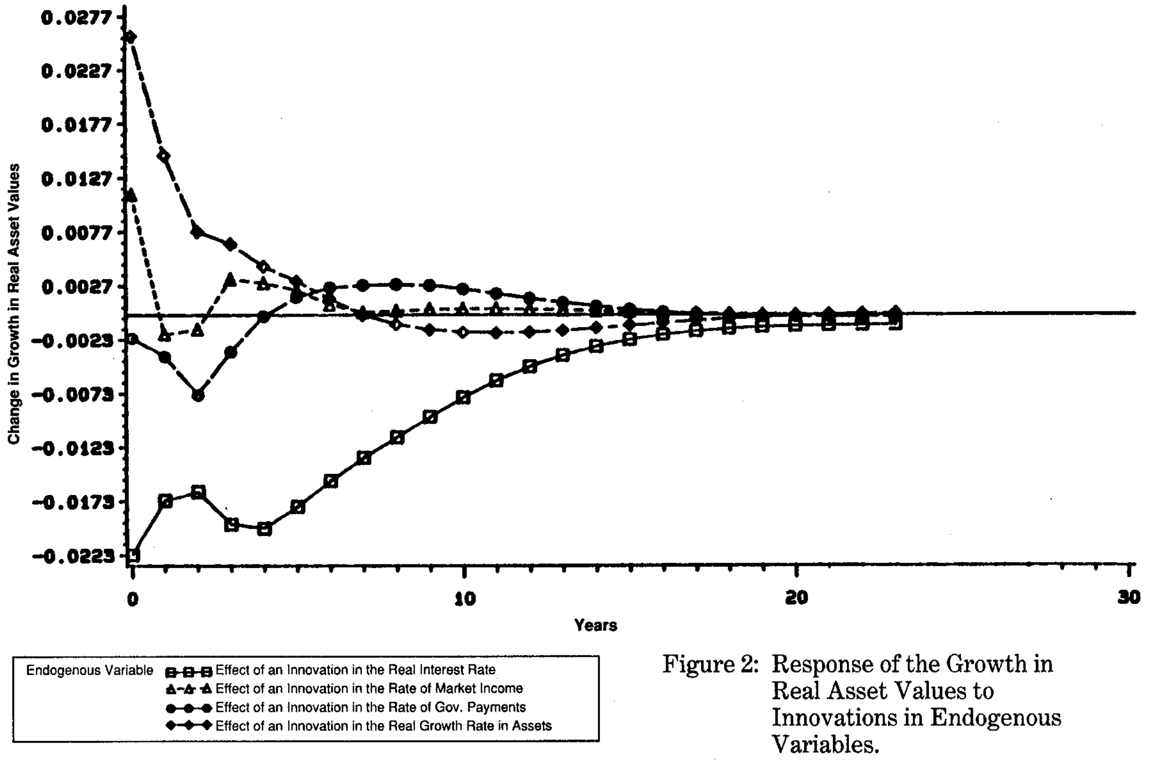

Figure 2: Response of the Growth in Real Asset Values to Innovations in Endogenous Variables.

[7]Technically, the Federal Reserve made a decision to change from targeting the federal funds rate to controlling growth in monetary aggregates. However, the policy of targeting the federal funds rate during the 1970s to counter recessionary tendencies in the economy was inflationary. Thus, the move had the primary effect of slowing inflation.

and Baker). During the 1970s, real estate including farm land tended to increase more rapidly than inflation because investors bid the price up attempting to hedge against inflation. Thus, even after the reduction in inflation of the early 1980s, real estate values continued their climb through momentum. Figure 3 also indicates that the rate of market income and the rate of government payments have had little effect on the growth in real asset values in the 1980s.

CONCLUSIONS AND DISCUSSION

The autoregressive analysis indicates that government payments were positively affected by lagged government payments and supply reduction measures. Lagged total asset values negatively affected government payments. This autoregressive representation explained about 94 percent of the variation in government payments. The autoregressive analysis explained two-thirds of the variation in total assets with lagged total assets being the only significant variable. The residual correlation matrix indicates that an increase in government payments is associated with a decline in real asset values.

The impulse response function for growth in real agricultural asset values indicates that real asset values decline in response to an increase in the rate of government payments in the short run. An innovation in the rate of government payments appears to have little long-term effect on real asset values in agriculture. In addition, the decomposition of variance over the entire sample and the decomposition of forecast error suggest that the rate of government payments does not significantly affect growth in real asset values over the sample or in the 1980s. However, our technique is not suited for studying certain interactions between government policies and asset values. For example, if a new administration made a commitment to improving returns to agriculture over four years, the step change in government policy might be confused with own variation in asset prices.

The real interest rate and lagged asset values exert the greatest influence on real growth in asset values. Further, the rate of market income explains only a small portion of changes in the growth of real asset values. These results are consistent with those of Featherstone and Baker.

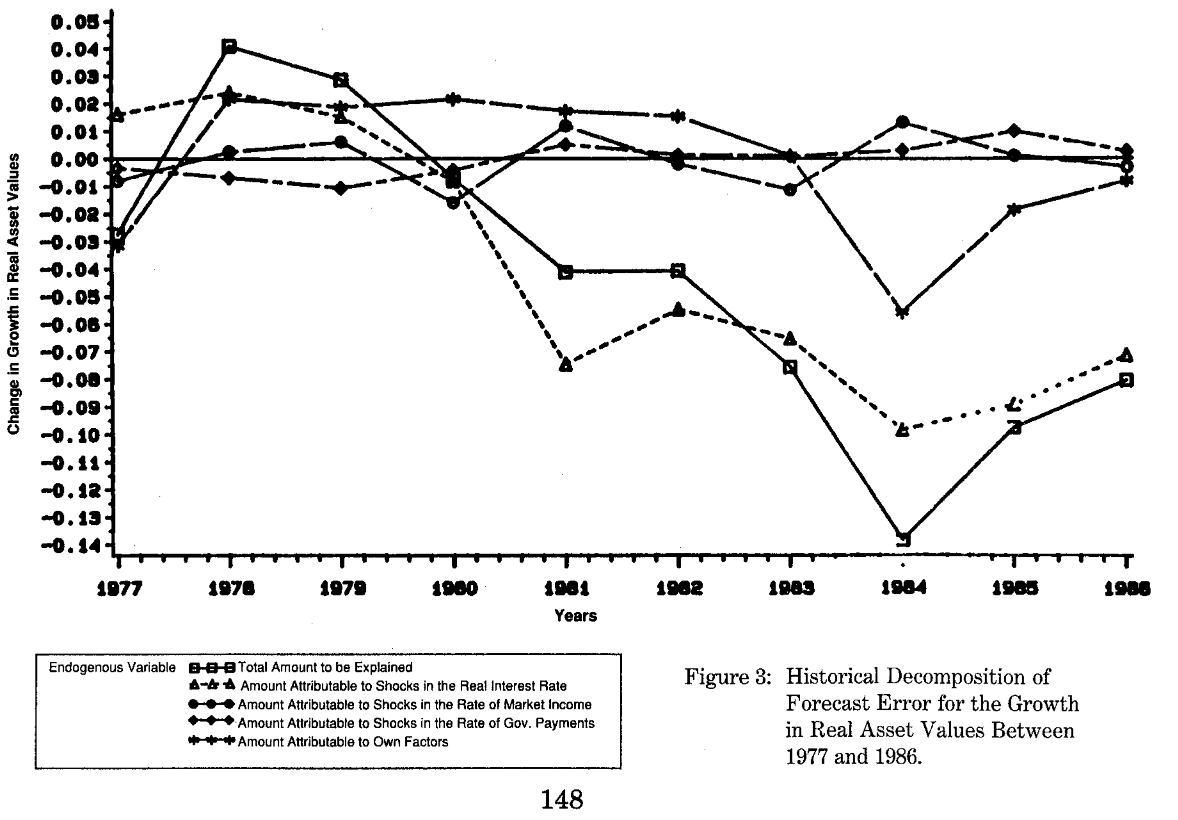

Figure 3: Historical Decomposition of Forecast Error for the Growth in Real Asset Values Between 1977 and 1986.

The results indicate that the effect of the rate of government payments on the growth in real asset values is transitory. An increase in the rate of government payments cannot be used as a tool to control agricultural asset values over time. Further, in the short run increased government payments to agriculture may even cause real asset values to fall. One reason for this decline may be investors using increased government involvement as a signal of future problems in agriculture.

One facet of agricultural stress in the 1980s was declining agricultural asset values. As asset values declined, some farmers found that their assets, primarily land, were insufficient to liquidate their liabilities. This increased the level of stress in agriculture and adversely affected agricultural lenders. One option was to simply increase the government payments to agriculture to stabilize or increase real agricultural asset values. However, the results indicate that a more effective method of increasing agricultural asset values is to reduce the real interest rate. A large portion of the decline in real asset values over the 1980s can be attributed to the increase in the real interest rate following the action of the Federal Reserve Board in 1979. Also, the results indicate that asset bubbles (Featherstone and Baker) may explain the change in asset values over time. Therefore, investors may heavily rely on the current level of asset values in predicting future asset values.

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Appendix I: A Mathematical Description of Post Estimation Procedures Used In Vector Autoregression

This appendix is intended to briefly outline the post-estimation procedures used in this study to interpret the results of the vector autoregression. The treatment, however, may be insufficient for those wishing to duplicate the results of this study. Doan and Litterman's documentation for RATs and other literature cited in the text would be helpful in that endeavor.

IMPULSE RESPONSE FUNCTIONS

Theoretically, the impulse response functions are derived from the moving average representation of the estimates from the vector autoregression. Empirically, it is easier to generate the impulse response function using simulation. This approach is popular in computer codes typically used in vector autoregression (Doan and Litterman).

Following Bessler, equation (2) can be rewritten as

(A.1) $y_t = \theta_1 y_{t-1} + \theta_2 y_{t-2} + \ldots \theta_p y_{t-p} + v_t$,

where y_t represents the 4x1 vector of endogenous variables, O_i is a 4x4 parameter matrix, and v_t is a 4x1 vector of disturbances. It is assumed that the disturbances are contemporaneously correlated, and, hence, $E[v_t v_t'] = \Omega$ is nondiagonal. Ignoring the contemporaneous correlation momentarily, the time path for the vectors y_t, given a unit shock in time period t, can be traced by letting v_t be a vector of zeros with one in the element corresponding to the series shocked. Specifically,

(A.2)
$$y_t^* = y_t + v_t ,$$
$$y_{t+2}^* = \theta_1 y_t^* , \text{ and}$$
$$y_{t+2}^* = \theta_1 y_{t+1}^* + \theta_2 y_{t+2}^* ,$$

where y_s^* represents the response of the vector of endogenous variables to the unit shock in vector v_t.

However, shocking only a single element v_t may be unlike anything that has happened historically if the elements of v_t are contemporaneously correlated. This suggests that a causal ordering should be imposed to more realistically represent the way shocks are transmitted through the system. Adopting the ordering in equation (2) implies that the current period INT affects the other three variables contemporaneously, INC affects PAY and VAL, and PAY affects VAL. Then a Choleski decomposition of $\Omega = HH'$, where H is lower triangular, yields the error shock model.

(A.3) $H^{-1}y_t = H^{-1}\theta_1 y_{t-1} + H^{-1}\theta_2 y_{t-2} + \ldots H^{-1}\theta_p y_{t-p} + H^{-1}v_t$.

The transformed model orthogonalized the shocks because $E[H^{-1}v_t v_t' H^{-1'}] = H^{-1}\Omega H^{-1'} = I$.

HISTORICAL DECOMPOSITION OF FORECAST ERROR

The historical decomposition of forecast error was proposed by Burbidge and Harrison to demonstrate the effect of oil shocks over a specific time period. Featherstone and Baker applied the technique to agricultural asset values. Historical decomposition of forecast error uses counterfactual simulation to decompose errors in one endogenous variable between other errors in the system.

Mathematically, this study decomposed the forecast in the real growth in asset values between 1977 and 1986. The first step is to project the path that growth in real asset values would follow given only initial conditions and the value of exogenous variables. Let y_t be the actual values of the vector of endogenous variables, then the projected path becomes, for example,

$$\text{(A.4)}\quad H^{-1}\tilde{y}^0_{1977} = H^{-1}\theta_1 y_{1976} + H^{-1}\theta_2 y_{1975} + H^{-1}\theta_3 y_{1974} + H^{-1}\theta_4 y_{1973} + H^{-1}\theta_5 y_{1972},$$

$$H^{-1}\tilde{y}^0_{1978} = H^{-1}\theta_1 \tilde{y}^0{}_{1977} + H^{-1}\theta_2 y_{1976} + H^{-1}\theta_3 y_{1975} + H^{-1}\theta_4 y_{1974} + H^{-1}\theta_5 y_{1973}, \text{ and}$$

$$H^{-1}\tilde{y}^0_{1979} = H^{-1}\theta_1 \tilde{y}^0{}_{1978} + H^{-1}\tilde{\theta}_2 y^0{}_{1977} + H^{-1}\theta_3 y_{1976} + H^{-1}\theta_4 y_{1975} + H^{-1}\theta_5 y_{1974},$$

where $\tilde{y}^0_t$ is the projected value of the vector of endogenous variables at time t. Next, information on the actual errors is added in causal order. Let v^1_t be a vector whose first element is the error observed in INT in period t. Thus, a new projected path can be generated using this additional information:

$$\text{(A.5)}\quad H^{-1}\tilde{y}^1_{1977} = H^{-1}\theta_1 y_{1976} + H^{-1}\theta_2 y_{1975} + H^{-1}\theta_3 y_{1974} + H^{-1}\theta_4 y_{1973} + H^{-1}\theta_5 y_{1972} + H^{-1}v^1_{1977},$$

$$H^{-1}\tilde{y}^1_{1978} = H^{-1}\theta_1 \tilde{y}^1{}_{1977} + H^{-1}\theta_2 y_{1976} + H^{-1}\theta_3 y_{1975} + H^{-1}\theta_4 y_{1974} + H^{-1}\theta_5 y_{1973} + H^{-1}v^1_{1978}, \text{ and}$$

$$H^{-1}\tilde{y}^1_{1979} = H^{-1}\theta_1 \tilde{y}^1{}_{1978} + H^{-1}\tilde{\theta}_2 y^1{}_{1977} + H^{-1}\theta_3 y_{1976} + H^{-1}\theta_4 y_{1975} + H^{-1}\theta_5 y_{1974} + H^{-1}v^1_{1979},$$

where $\tilde{y}^1_t$ is the projected value of y_t given the additional information. The change in projection y^0_t - y^1_t is then attributed to the effect of the variable on which information was added. For further detail on this procedure, the reader is referred to Burbidge and Harrison; Bessler; and Featherstone and Baker.

HISTORICAL DECOMPOSITION OF VARIANCE

The historical decomposition of variance is similar to the historical decomposition of forecast error except it considers all periods of length k in the sample rather than a single historical interval. Specifically, the researcher generates all possible k period ahead forecasts using equation (A. 4). Then using the actual values, a variance of forecast is computed. Next, information is added in the Wold causal ordering as in equation (A. 5). After computing a new variance using the new projection, the percentage reduction in forecast error can be computed. For more information on this procedure, see Bessler.

Appendix II. Data Used in Estimation.

Year	Real Income To Assets	Real Total Assets	Average PCE for Year	Nominal Government Payment	Nominal Interest Rate	Real Government Payment	Supply Reduction	Real Interest Rate	Market Return on Assets	Rate of Market Returns	Rate of Government Returns	Growth in Asset Values
46	31,402	448,490	19.3	772	0.0037	4,000	0	-0.0949	27,402	0.0611	0.0089	0.0061
47	26,348	460,489	21.3	314	0.0059	1,474	0	-0.0489	24,874	0.0540	0.0032	0.0264
48	35,497	474,205	22.5	257	0.0103	1,142	0	0.0148	34,355	0.0724	0.0024	0.0294
49	15,945	473,895	22.4	186	0.0110	830	0	-0.0111	15,115	0.0319	0.0018	-0.0007
50	22.681	517,494	22.9	283	0.0121	1,2336	0	-0.0472	21,445	0.0414	0.0024	0.0880
51	28.816	554,883	24.3	286	0.0154	1,177	0	-0.0090	27,639	0.0498	0.0021	0.0698
52	24,007	532.627	24.9	275	0.0175	1,104	0	-0.0024	22,903	0.0430	0.0021	-0.0409
53	17,197	514,732	25.4	213	0.0191	839	0	0.0152	16,358	0.318	0.0016	-0.0342
54	16,127	526,359	22.5	257	0.0095	1,008	0	-0.0022	15,119	0.0287	0.0019	0.0223
55	11,305	532,030	25.8	229	0.0174	888	0	-0.0056	10,417	0.0196	0.0017	0.0107
56	11,546	545,992	26.4	554	0.0262	2,098	13,400	0.0001	9,448	0.0173	0.0038	0.0259
57	12,330	561,519	27.1	1,015	0.0321	3,745	27,800	0.0102	8,585	0.0153	0.0067	0.0280
58	21,209	610,287	27.7	1,088	0.0182	3,928	27,100	-0.0032	17,281	0.0283	0.0064	0.0833
59	10,351	606,815	28.3	682	0.0335	2,410	22,500	0.0160	7,941	0.0131	0.0040	-0.0057
60	13,900	603,014	28.8	703	0.0289	2,441	28,700	0.0151	11,459	0.0190	0.0040	-0.0063
61	18,059	622,477	29.2	1,493	0.0235	5,113	53,700	0.0065	12,946	0.0208	0.0082	0.0318
62	18,012	637,594	29.7	1,746	0.0274	5,879	64,700	0.0140	12,133	0.0190	0.0092	0.0240
63	18,965	651,847	30.1	1,696	0.0311	5,635	56,100	0.0146	13,330	0.0205	0.0086	0.0221
64	15,701	667,404	30.6	2,179	0.0349	7,121	55,100	0.0155	8,580	0.0129	0.0107	0.0236
65	23,237	702,489	31.2	2,463	0.0388	7,894	56,300	0.0103	15,343	0.0218	0.0112	0.0512
66	26,097	720,832	32.1	3,277	0.0477	10,209	63,200	0.0230	15,888	0.0220	0.0142	0.0258
67	20,095	735,076	32.9	3,078	0.0423	9,356	40,800	-0.0023	10,739	0.0146	0.0127	0.0196
68	18,514	741,098	34.4	3,463	0.0520	10,067	49,400	0.0093	8,447	0.0114	0.0136	0.0082
69	22,421	739,447	35.9	3,793	0.0646	10,565	58,000	0.0184	11,856	0.0160	0.0143	-0.0022
70	21,584	731,468	37.6	3,717	0.0626	9,886	57,000	0.0184	11,698	0.0160	0.0135	-0.0108
71	22,474	755,997	39.3	3,145	0.0426	8,003	37,200	0.0027	14,471	0.0191	0.0106	0.0343

Continued

Appendix II. Continued.

Year	Real Income To Assets	Real Total Assets	Average PCE for Year	Nominal Government Payment	Nominal Interest Rate	Real Government Payment	Supply Reduction	Real Interest Rate	Market Return on Assets	Rate of Market Returns	Rate of Government Returns	Growth in Asset Values
72	33,057	822,247	40.9	3,962	0.0399	9,687	61,500	-0.0194	23,370	0.0284	0.0118	0.0827
73	67,243	928,681	43.4	2,607	0.0680	6,007	19,100	-0.0327	61,236	0.0659	0.0065	0.1217
74	41,072	890,659	48.0	530	0.0759	1,104	2,000	-0.0003	39,968	0.0449	0.0012	-0.0418
75	33,447	960,408	51.8	807	0.0567	1,558	0	0.004	31,889	0.0332	0.0016	0.0754
76	21,218	1,052,245	54.8	734	0.0487	1,339	9	-0.0149	19,879	0.0189	0.0013	0.0913
77	18,618	1,095,972	58.4	1,818	0.0513	3,113	0	-0.0197	15,505	0.0141	0.0028	0.0407
78	26,826	1,209,055	62.7	3,030	0.0697	4,833	18,200	-0.0188	21,993	0.0182	0.0040	0.0982
79	30,900	1,280,712	68.5	1,376	0.0957	2,009	13,000	-0.0056	28,891	0.0226	0.0016	0.0576
80	14,920	1,265,322	75.8	1,285	0.1089	1,695	0	0.0206	13,225	0.0105	0.0013	-0.0121
81	26,623	1,181,611	82.8	1,933	0.1317	2,335	0	0.0754	24,288	0.0206	0.0020	-0.0684
82	23,859	1,099,542	87.6	3,492	0.1015	3,986	11,100	0.0613	19,873	0.0181	0.0036	-0.0720
83	12,657	1,032,078	91.2	9,296	0.0828	10,193	78,000	0.0451	2,464	0.0024	0.0099	-0.0633
84	29,470	892,512	94.7	8,431	0.0915	8,903	26,600	0.0572	20,567	0.0230	0.0100	-0.1453
85	28,425	778,943	98.0	7,705	0.0720	7,862	34,000	0.0518	20,563	0.0264	0.101	-0.1361
86	30,115	702,973	100.0	11,814	0.0579	11,814	46,243	0.0371	18,301	0.0260	0.0168	-0.1026