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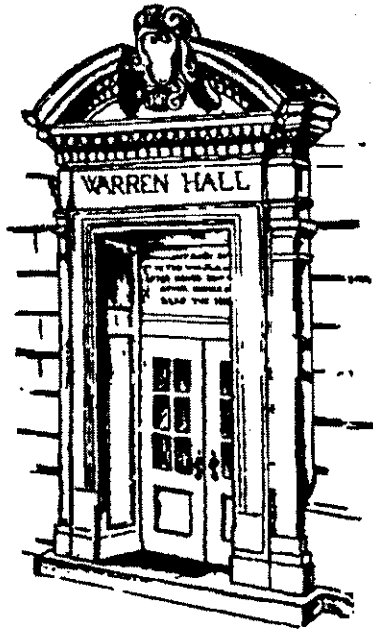
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# Working Paper

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## **A Vector Autoregression Analysis of Bulgarian Inflation**

**Steven Kyle and Tzvetan Tsalinski**

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**A Vector Autoregression Analysis of Bulgarian Inflation**

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October 2000

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## **Abstract**

This paper presents a vector autoregression analysis of the determinants of Bulgarian inflation over the period from 1991 to 2000. Monthly data are available for the entire period and various combinations of money aggregates, interest rates and the exchange rate were considered in modeling the dynamics of inflation in the Bulgarian economy. Bulgarian inflation is shown to have undergone two radically different regimes over the past decade. The dividing point between the two is the spring of 1997 when the hyperinflationary trends of the prior period were ended by the institution of a currency board. Inflation during the prior period is determined predominantly by monetary growth and to some extent by past inflation. Inflation after the institution of the currency board is no longer as dependent on monetary growth, while impulse response functions for the latter period clearly show the negative response of monetary authorities to price increases. In contrast, impulse response functions for the pre-currency board period demonstrate the explosive nature of the inflationary process, as monetary shocks cause the price level to grow without bound.

## **Introduction**

This paper presents a vector autoregression analysis of the determinants of Bulgarian inflation over the period from 1991 to 2000. Monthly data are available for the entire period and various combinations of money aggregates, interest rates and the exchange rate were considered in modeling the dynamics of inflation in the Bulgarian economy.

This effort grew out of interest in Bulgaria in the construction of a leading indicator for inflation. This analysis shows that such an indicator is not possible - inflation responds rapidly to shocks to money aggregates, and cannot be shown to be responsive in any significant way to other variables. Moreover, rapidity of the response shows that a long-leading indicator cannot be constructed since inflation responds to monetary shocks within a month of their occurrence. Hence, any attempt to interpret past data would be rendered irrelevant before it could be calculated and disseminated.

One interesting aspect of the results is the difference between monetary behavior before and after resolution of the monetary/financial crisis of 1997. The explosive behavior of the response functions prior to that time are a testament to the hyperinflationary forces operating by the end of the period in the Spring of 1997. The rigid adherence of authorities to a zero inflation goal after the institution of the currency board in 1997 is also evident in the results.

The Vector Autoregression (VAR) and Vector Error Correction (VEC) models used are sufficiently well known so as not to require extensive discussion here. (See for example, Said & Dickey 1984, Johansen 1991, Johansen 1995 and Hamilton 1994.) All data proved non-stationary and required differencing in order to generate stationary series for estimation. Cointegrating relationships were found between money and inflation, confirming the obvious empirical observation that these two variables were closely linked

over the estimation period while they experienced radical changes in levels during the hyperinflationary episode.

### **Determinants of Changes in the Price Level**

There are a variety of candidate series which can be considered as determinants of inflation, among them various money aggregates, interest rates, the exchange rate, foreign inflation, and assets of the currency board. However, by far the most important potential candidate is the quantity of money. While the precise aggregate to be used can be debated (M1, M2 and M3 are available in Bulgaria), as a practical matter all of the aggregates in Bulgaria are highly correlated, with results highly similar regardless of which aggregate is used.

All data series were obtained from data banks at the Bulgarian Agency for Economic Analysis and Forecasting. The origin of the data is the Bulgarian National Bank, the country's central bank. Monthly data were available from June of 1991 through May of 2000.

The analysis focused on M3 and inflation (measured by the Consumer Price Index). As noted above, similar results are obtained regardless of which monetary aggregate is used. It was therefore decided to use the broadest measure of money, M3. The CPI was the best available measure of inflation since, in spite of some changes in its calculation over the years, it is nevertheless the best and most consistent measure of inflation available. It was obvious that there had been a significant regime change with the institution of the currency board in Spring 1997. Accordingly the monthly data series was divided into pre and post-currency board periods and separate analyses were carried out on each period.

The raw data were tested for stationarity in logged form and Augmented Dickey-

Fuller tests indicated that the inflation series exhibited integration of order 1 while the money series exhibited integration of order 2. A Johansen test for cointegration showed that these series were indeed cointegrated and further analysis proceeded on this basis. (See Tables 1-3 for the period 1991-1997 and Tables 4-6 for 1997-2000). The ordering of the variables chosen was (M3,INFL) since these results demonstrated obviously superior ability to explain the variation in the data as well as being in accord with prior beliefs as to the nature of the inflationary process in Bulgaria.

The results for the Vector Error Correction Models for each of the periods involved emphasize the fact that inflation is highly dependent on money and inflation developments one and two periods before, making it impossible to develop a reliable long-leading indicator at the present time. However, the results did reveal some interesting patterns, reflecting the radically different mechanisms at work in Bulgaria over the two periods involved. (See Tables 7 and 8 for results of estimation of the VEC models.)

Figures 1 and 2 show impulse response functions and the variance decomposition for the first period from 1991 - 1997. The explosive nature of inflation is evident in the impulse response functions in the earlier period, which reflect the inertial and unstable nature of the process at work during that time. Inflation is seen to grow without bound in response to shocks in money and past inflation, an accurate characterization of the path inflation took over this period. The variance decomposition demonstrates that in the very short run, inflation is highly dependent on its past value, showing that it is inertial (i.e. it is feeding upon itself), while in the long run money growth is responsible for by far the greatest percentage of the variance in price growth.

In contrast, the second period shows a radically different pattern, with inflation responding quickly to past shocks, but rapidly returning to trend after a few periods. Figure 3 shows the impulse response functions for the 1997-2000 period where it can be



seen that though the response takes as much as a year to be completed, the majority of the adjustment is complete within 6 months of the initial shock. In addition, the quick response of monetary authorities to any rise in prices can be seen in the negative response of money to inflation in the upper right panel of Figure 3. The variance decomposition in Figure 4 reflect the essentially non-inflationary nature of currency board policy during this period with money variance accounting for a far lower amount of inflation variance than in the earlier period (Figure 2).

Numerous experiments were undertaken with other potential determinants of inflation, most notably the exchange rate and various interest rates. While some of these variables could be shown to be correlated with either money or inflation, none of them proved to be at all important in terms of explaining future changes in the price level. Figure 5 shows the results of one of these experiments, using the interest rate on government securities. This “basic interest rate” was significant in cointegrating equations with money and inflation, but the variance decomposition in Figure 5 shows that it had a near zero share in the variance decomposition of inflation during the 1997-2000. This is in line with results for other variables as well as for the earlier period (results not shown).

## **Conclusions**

**Bulgarian inflation has been shown to have undergone two radically different regimes over the past decade. The dividing point between the two is the spring of 1997 when the hyperinflationary trends of the prior period were ended by the institution of a currency board. Inflation during the prior period is determined predominantly by monetary growth and to some extent by past inflation. Inflation after the institution of the currency board is no longer as dependent on monetary growth, while impulse response functions for the latter period clearly show the negative response of monetary authorities to price increases. In contrast, impulse response functions for the pre-currency board**

**period demonstrate the explosive nature of the inflationary process, as monetary shocks cause the price level to grow without bound.**

## References

Hamilton, D. (1994) *Time Series Analysis* Princeton University Press

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**Table 1**  
**1991-1997**

**Augmented Dickey-Fuller Unit Root Test on D(LOG(M3),2)**

<b>ADF Test Statistic</b>	<b>-0.810381</b>	<b>1% Critical Value*</b>	<b>-3.5267</b>	
		<b>5% Critical Value</b>	<b>-2.9035</b>	
		<b>10% Critical Value</b>	<b>-2.5889</b>	
<b>*MacKinnon critical values for rejection of hypothesis of a unit root.</b>				
<b>Augmented Dickey-Fuller Test Equation</b>				
Dependent Variable: D(LOG(M3),3)				
Method: Least Squares				
Date: 06/22/00 Time: 14:37				
Sample(adjusted): 1991:06 1997:02				
Included observations: 69 after adjusting endpoints				
<b>Variable</b>	<b>Coefficient</b>	<b>Std. Error</b>	<b>t-Statistic</b>	
			<b>Prob.</b>	
D(LOG(M3(-1)),2)	-0.160260	0.197759	-0.810381	0.4207
D(LOG(M3(-1)),3)	-0.387121	0.161730	-2.393618	0.0196
D(LOG(M3(-2)),3)	-0.178746	0.121088	-1.476169	0.1447
C	0.004252	0.003896	1.091159	0.2792
R-squared	0.275852	Mean dependent var	0.001374	
Adjusted R-squared	0.242430	S.D. dependent var	0.036645	
S.E. of regression	0.031895	Akaike info criterion	-3.996504	
Sum squared resid	0.066124	Schwarz criterion	-3.866991	
Log likelihood	141.8794	F-statistic	8.253573	
Durbin-Watson stat	1.797126	Prob(F-statistic)	0.000099	

**Table 2**  
**1991-1997**

Augmented Dickey-Fuller Unit Root Test on D(LOG(INFL),2)

ADF Test Statistic	-0.766427	1% Critical Value*	-4.0948	
		5% Critical Value	-3.4749	
		10% Critical Value	-3.1645	
*Mackinnon critical values for rejection of hypothesis of a unit root.				
Augmented Dickey-Fuller Test Equation				
Dependent Variable: D(LOG(INFL),3)				
Method: Least Squares				
Date: 06/22/00 Time: 14:41				
Sample(adjusted): 1991:06 1997:02				
Included observations: 69 after adjusting endpoints				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LOG(INFL(-1)),2)	-0.294704	0.384516	-0.766427	0.4462
D(LOG(INFL(-1)),3)	-0.080033	0.217687	-0.367650	0.7143
D(LOG(INFL(-2)),3)	0.443843	0.184732	2.402639	0.0192
C	-0.039420	0.028318	-1.392064	0.1687
@TREND(1991:01)	0.001291	0.000648	1.991728	0.0507
R-squared	0.143609	Mean dependent var	0.012748	
Adjusted R-squared	0.090085	S.D. dependent var	0.106062	
S.E. of regression	0.101172	Akaike info criterion	-1.674283	
Sum squared resid	0.655091	Schwarz criterion	-1.512392	
Log likelihood	62.76277	F-statistic	2.683066	
Durbin-Watson stat	1.429138	Prob(F-statistic)	0.039205	

**Table 3**  
**1991-1997**

**Johansen Cointegration Test**

Date: 06/22/00 Time: 14:44 Sample: 1991:01 1997:02 Included observations: 71 Test assumption: Linear deterministic trend in the data Series: LOG(M3) LOG(INFL) Lags interval: 1 to 2				
Eigenvalue	Likelihood Ratio	5 Percent Critical Value	1 Percent Critical Value	Hypothesized No. of CE(s)
0.454210	45.60659	15.41	20.04	None **
0.036155	2.614572	3.76	6.65	At most 1
*(**) denotes rejection of the hypothesis at 5%(1%) significance level L.R. test indicates 1 cointegrating equation(s) at 5% significance level				
Unnormalized Cointegrating Coefficients:				
LOG(M3)	LOG(INFL)			
-1.395549	1.107826			
0.779494	-0.471313			
Normalized Cointegrating Coefficients: 1 Cointegrating Equation(s)				
LOG(M3)	LOG(INFL)	C		
1.000000	-0.793829 (0.01375)	-6.459450		
Log likelihood	257.8211			

Table 4  
1997-2000

Augmented Dickey-Fuller Unit Root Test on D(LOG(M3),2)

ADF Test Statistic	-14.19966	1% Critical Value*	-3.6228	
		5% Critical Value	-2.9446	
		10% Critical Value	-2.6105	
*MacKinnon critical values for rejection of hypothesis of a unit root.				
<b>Augmented Dickey-Fuller Test Equation</b>				
Dependent Variable: D(LOG(M3),3)				
Method: Least Squares				
Date: 06/22/00 Time: 12:23				
Sample(adjusted): 1997:05 2000:04				
Included observations: 36 after adjusting endpoints				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LOG(M3(-1)),2)	-1.280070	0.090148	-14.19966	0.0000
D(LOG(M3(-1)),3)	0.281700	0.066654	4.226298	0.0002
C	-0.002450	0.004196	-0.583871	0.5633
R-squared	0.859393	Mean dependent var	0.006322	
Adjusted R-squared	0.850872	S.D. dependent var	0.063943	
S.E. of regression	0.024693	Akaike info criterion	-4.484943	
Sum squared resid	0.020121	Schwarz criterion	-4.352983	
Log likelihood	83.72897	F-statistic	100.8486	
Durbin-Watson stat	2.010633	Prob(F-statistic)	0.000000	

**Table 5**  
**1997-2000**

**Augmented Dickey-Fuller Unit Root Test on D(LOG(INFL))**

ADF Test Statistic	-5.035108	1% Critical Value*	-3.6171	
		5% Critical Value	-2.9422	
		10% Critical Value	-2.6092	
*MacKinnon critical values for rejection of hypothesis of a unit root.				
Augmented Dickey-Fuller Test Equation				
Dependent Variable: D(LOG(INFL),2)				
Method: Least Squares				
Date: 06/22/00 Time: 12:08				
Sample(adjusted): 1997:04 2000:04				
Included observations: 37 after adjusting endpoints				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LOG(INFL(-1)))	-0.776689	0.154255	-5.035108	0.0000
D(LOG(INFL(-1)),2)	0.029885	0.020959	1.425893	0.1630
C	0.006486	0.003289	1.971956	0.0568
R-squared	0.641304	Mean dependent var	-0.003363	
Adjusted R-squared	0.620204	S.D. dependent var	0.029275	
S.E. of regression	0.018042	Akaike info criterion	-5.114650	
Sum squared resid	0.011067	Schwarz criterion	-4.984035	
Log likelihood	97.62103	F-statistic	30.39383	
Durbin-Watson stat	1.844934	Prob(F-statistic)	0.000000	



**Table 6**  
**1997-2000**

**Johansen Cointegration Test**

Date: 06/22/00 Time: 12:40 Sample: 1997:03 2000:12 Included observations: 37 Test assumption: Linear deterministic trend in the data Series: LOG(M3) LOG(INFL) Lags interval: 1 to 2				
Eigenvalue	Likelihood Ratio	5 Percent Critical Value	1 Percent Critical Value	Hypothesized No. of CE(s)
0.506799	31.89873	15.41	20.04	None **
0.143832	5.745677	3.76	6.65	At most 1 *
(**) denotes rejection of the hypothesis at 5%(1%) significance level L.R. test indicates 2 cointegrating equation(s) at 5% significance level  Unnormalized Cointegrating Coefficients:				
	LOG(M3)	LOG(INFL)		
	1.316974	-0.896228		
	-3.182839	9.822297		
Normalized Cointegrating Coefficients: 1 Cointegrating Equation(s)				
	LOG(M3)	LOG(INFL)	C	
	1.000000	-0.680521	-12.22410	
		(0.94283)		
	Log likelihood	205.7346		

**Table 7**  
**1991-1997**

Vector Error Correction Estimates

Date: 06/22/00 Time: 14:47		
Sample(adjusted): 1991:04 1997:02		
Included observations: 71 after adjusting endpoints		
Standard errors & t-statistics in parentheses		
Cointegrating Eq:	CointEq1	
LOG(M3(-1))	1.000000	
LOG(INFL(-1))	-0.793829 (0.01375) (-57.7445)	
C	-6.459450	
Error Correction:	D(LOG(M3))	D(LOG(INFL))
CointEq1	-0.284360 (0.03929) (-7.23780)	-0.274867 (0.09936) (-2.76643)
D(LOG(M3(-1)))	1.243735 (0.12287) (10.1225)	2.119847 (0.31073) (6.82220)
D(LOG(M3(-2)))	0.345099 (0.18078) (1.90892)	0.963225 (0.45719) (2.10684)
D(LOG(INFL(-1)))	-0.359799 (0.10128) (-3.55249)	0.133346 (0.25613) (0.52061)
D(LOG(INFL(-2)))	-0.098226 (0.05458) (-1.79955)	-0.436155 (0.13804) (-3.15964)
C	0.010000 (0.00544) (1.83857)	-0.037326 (0.01375) (-2.71366)
R-squared	0.855166	0.796224
Adj. R-squared	0.844025	0.780549
Sum sq. resids	0.051516	0.329478
S.E. equation	0.028152	0.071196
F-statistic	76.75769	50.79568
Log likelihood	155.8683	89.99420
Akaike AIC	-4.221642	-2.366034
Schwarz SC	-4.030430	-2.174821
Mean dependent	0.050623	0.078320
S.D. dependent	0.071283	0.151981
Determinant Residual Covariance	2.40E-06	
Log Likelihood	257.8211	
Akaike Information Criteria	-6.868200	
Schwarz Criteria	-6.422038	

**Table 8**  
**1997-2000**

Vector Error Correction Estimates

Date: 06/22/00 Time: 12:43		
Sample(adjusted): 1997:04 2000:04		
Included observations: 37 after adjusting endpoints		
Standard errors & t-statistics in parentheses		
<hr/>		
Cointegrating Eq:	CointEq1	
LOG(M3(-1))	1.000000	
LOG(INFL(-1))	-0.680521 (0.94283) (-0.72178)	
C	-12.22410	
<hr/>		
Error Correction:	D(LOG(M3))	D(LOG(INFL))
CointEq1	-0.159822 (0.02851) (-5.60507)	-0.027592 (0.01663) (-1.65968)
D(LOG(M3(-1)))	0.580263 (0.11963) (4.85049)	0.185504 (0.06975) (2.65955)
D(LOG(M3(-2)))	-0.085591 (0.10368) (-0.82552)	0.221572 (0.06045) (3.66527)
D(LOG(INFL(-1)))	-0.433334 (0.24748) (-1.75096)	-0.190058 (0.14429) (-1.31715)
D(LOG(INFL(-2)))	-0.104560 (0.04106) (-2.54642)	-0.115248 (0.02394) (-4.81384)
C	0.019959 (0.00471) (4.24144)	0.001290 (0.00274) (0.47003)
<hr/>		
R-squared	0.716541	0.584540
Adj. R-squared	0.670822	0.517530
Sum sq. resids	0.014532	0.004940
S.E. equation	0.021651	0.012624
F-statistic	15.67267	8.723207
Log likelihood	92.58236	112.5432
Akaike AIC	-4.680128	-5.759091
Schwarz SC	-4.418898	-5.497861
Mean dependent	0.022796	0.008031
S.D. dependent	0.037737	0.018174
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Determinant Residual Covariance	5.07E-08	
Log Likelihood	205.7346	
Akaike Information Criteria	-10.36403	
Schwarz Criteria	-9.754495	

Response to One S.D. Innovations

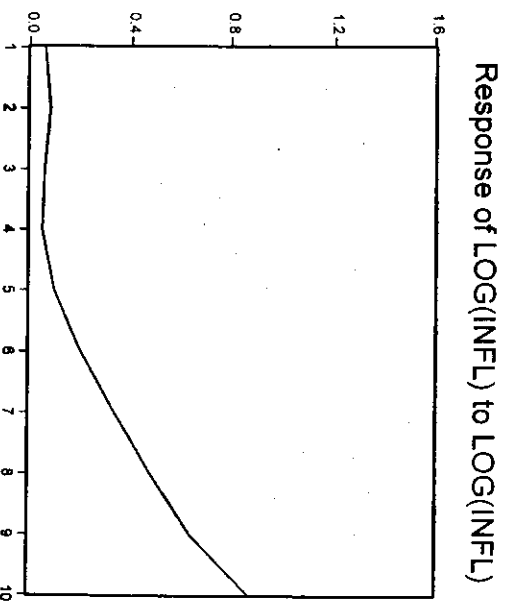
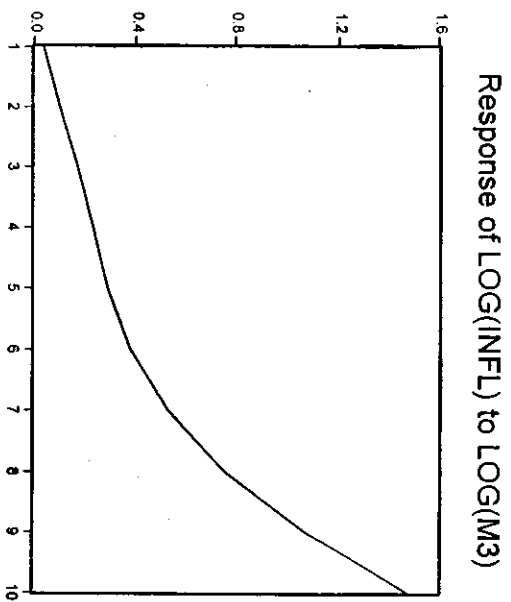
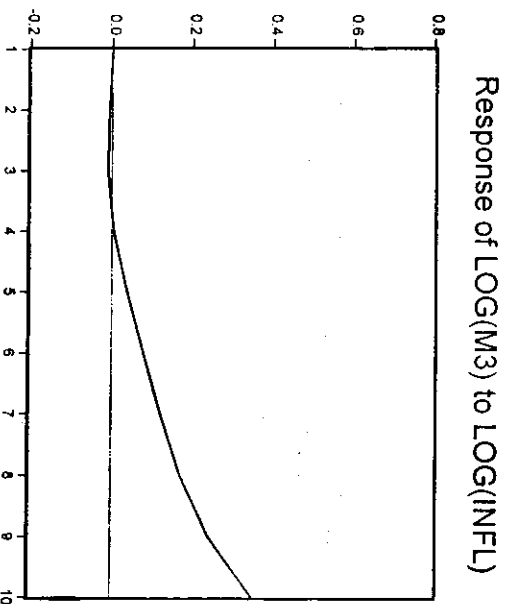
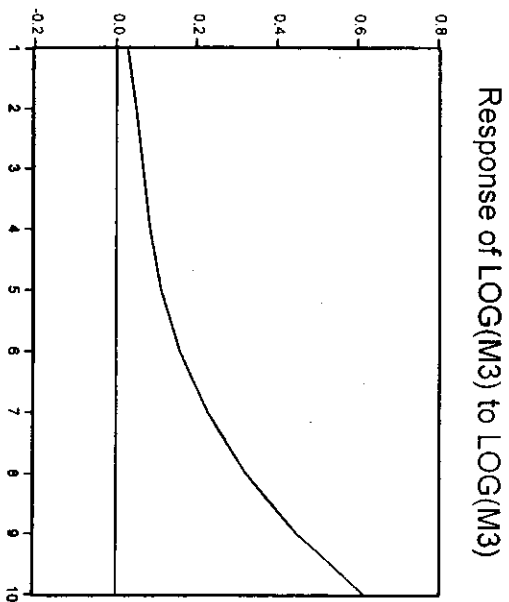
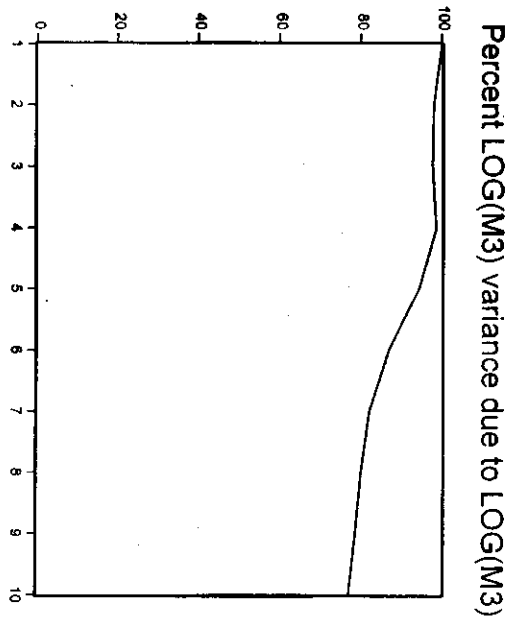
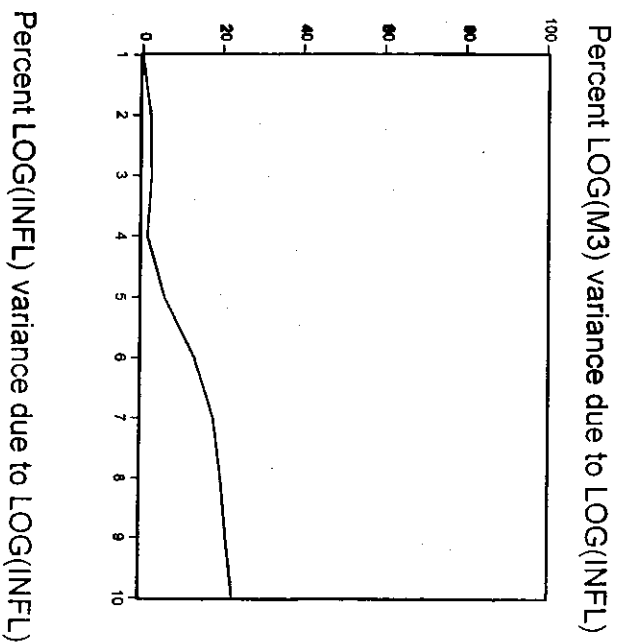
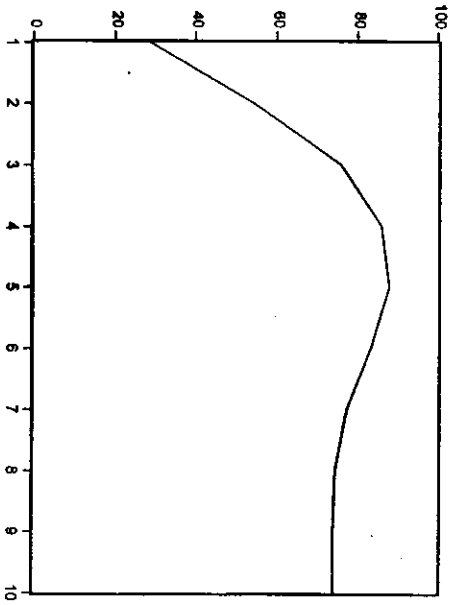


Figure 1  
1991-1997

### Variance Decomposition



Percent LOG(INFL) variance due to LOG(M3)



Percent LOG(INFL) variance due to LOG(INFL)

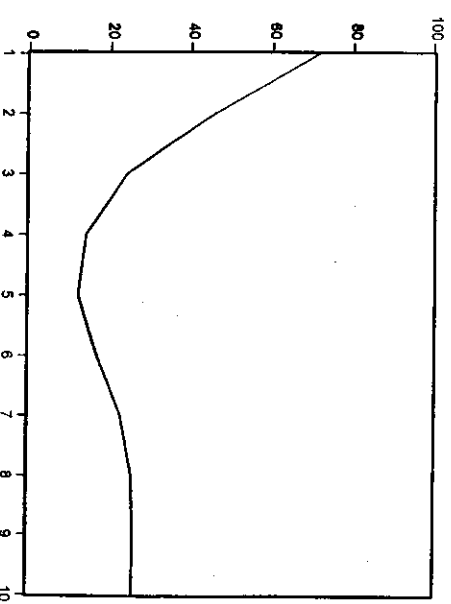
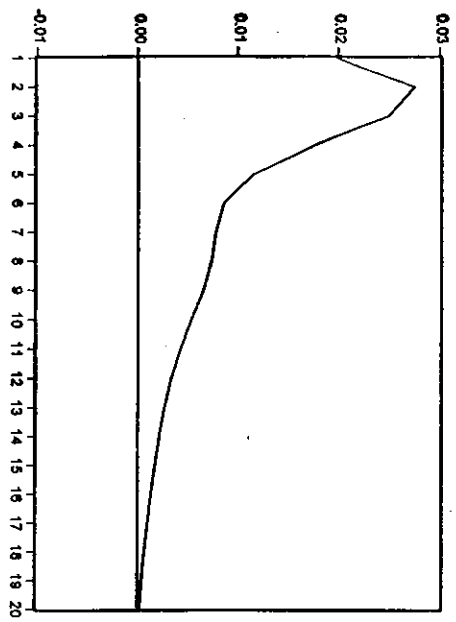


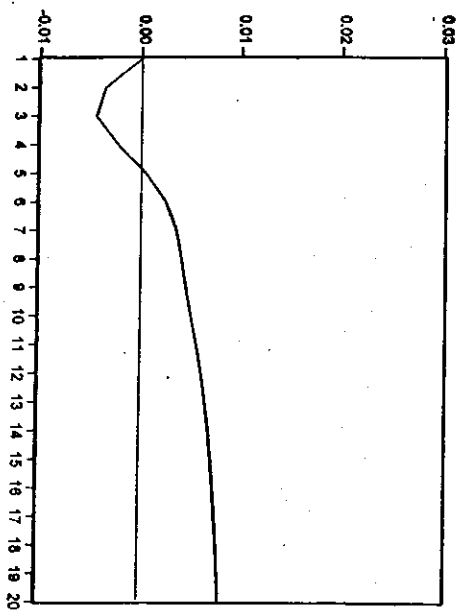
Figure 2  
1991-1997

Response to One S.D. Innovations

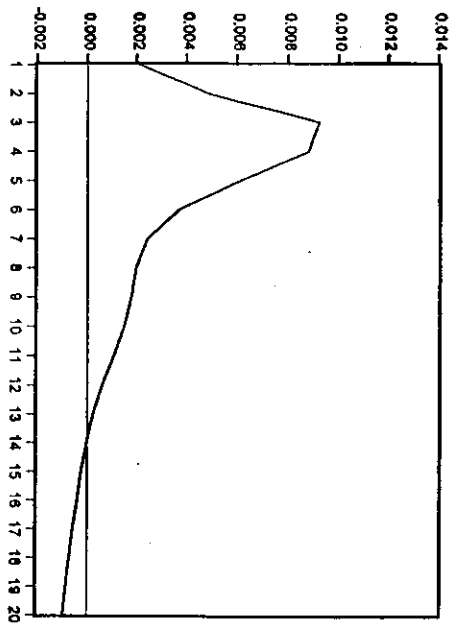
Response of LOG(M3) to LOG(M3)



Response of LOG(M3) to LOG(INFL)



Response of LOG(INFL) to LOG(M3)



Response of LOG(INFL) to LOG(INFL)

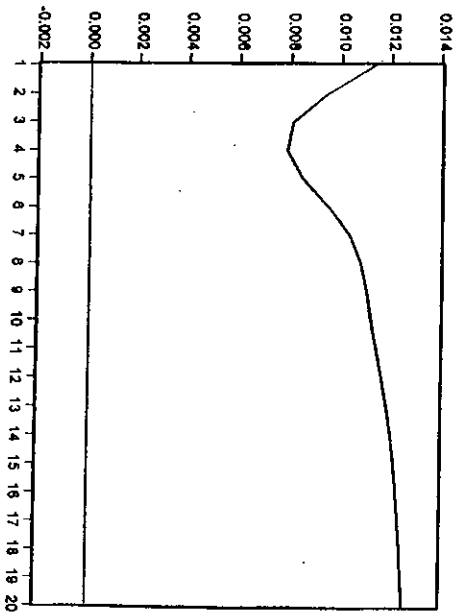


Figure 3  
1997-2000

Variance Decomposition

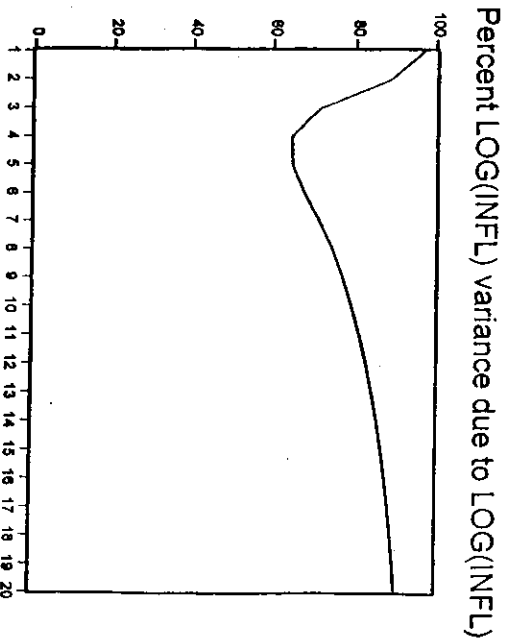
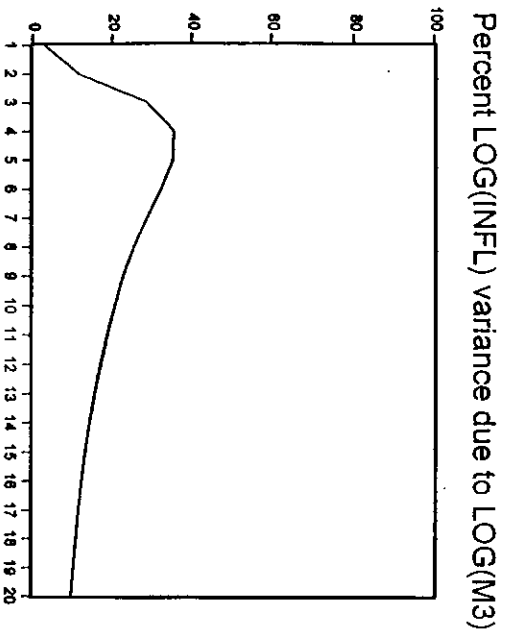
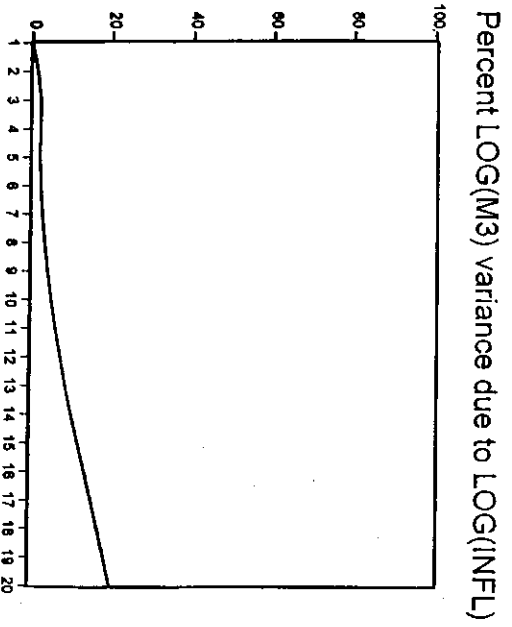
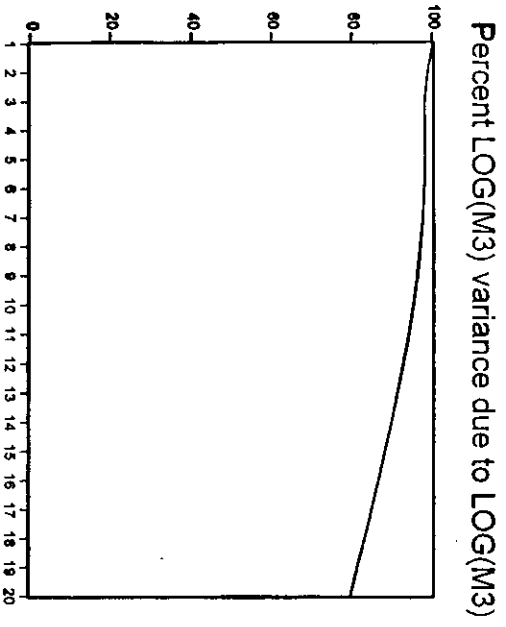


Figure 4  
1997-2000

Variance Decomposition

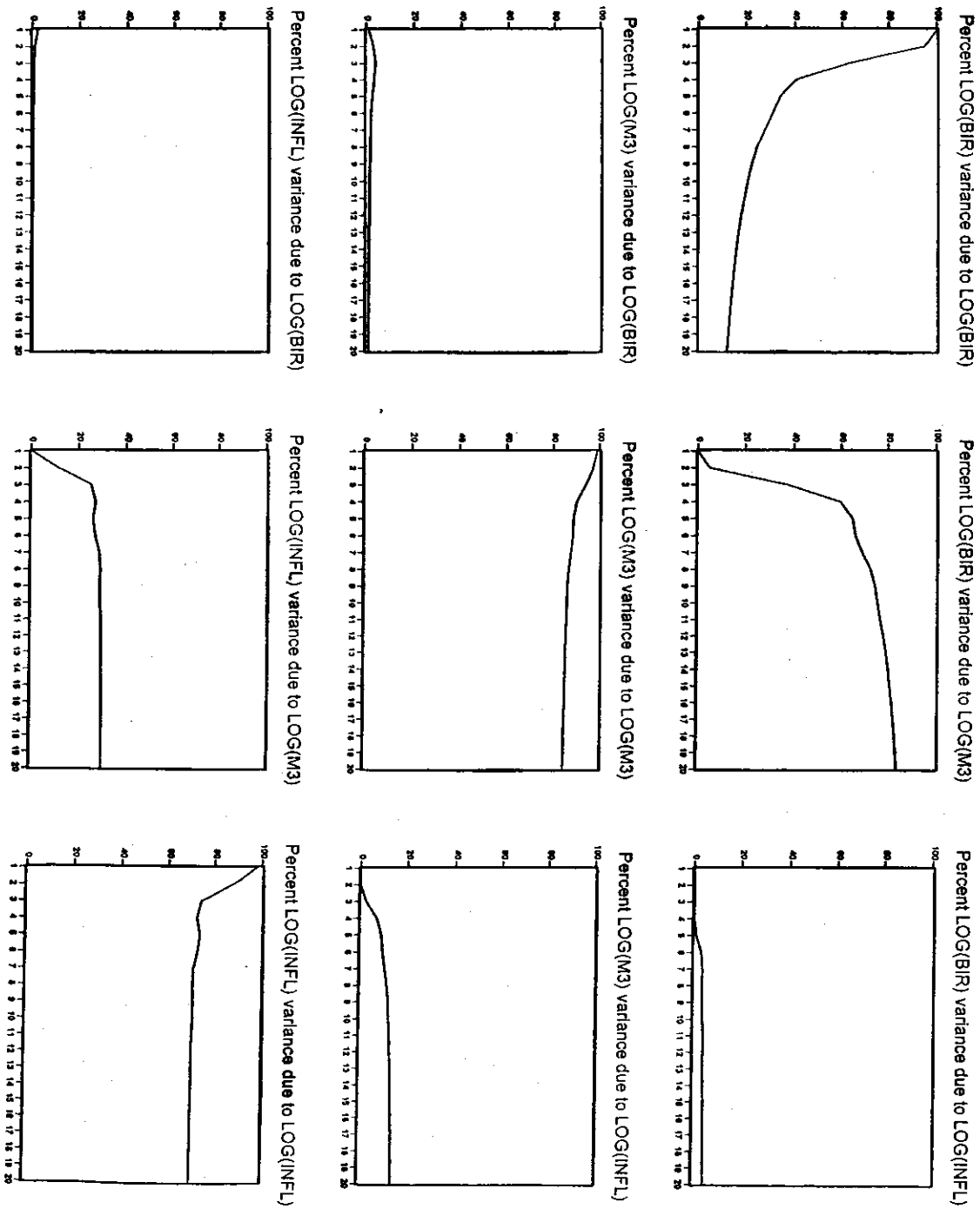


Figure 5  
1997-2000



**OTHER A.R.M.E. WORKING PAPERS**

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