INSIDE MONEY, OUTSIDE MONEY, AND SHORT TERM INTEREST RATES

by

V. V. Chari, Lawrence J. Christiano,

and Martin Eichenbaum

Objective:

We wish to construct dynamic, monetary, business cycle models in order to:

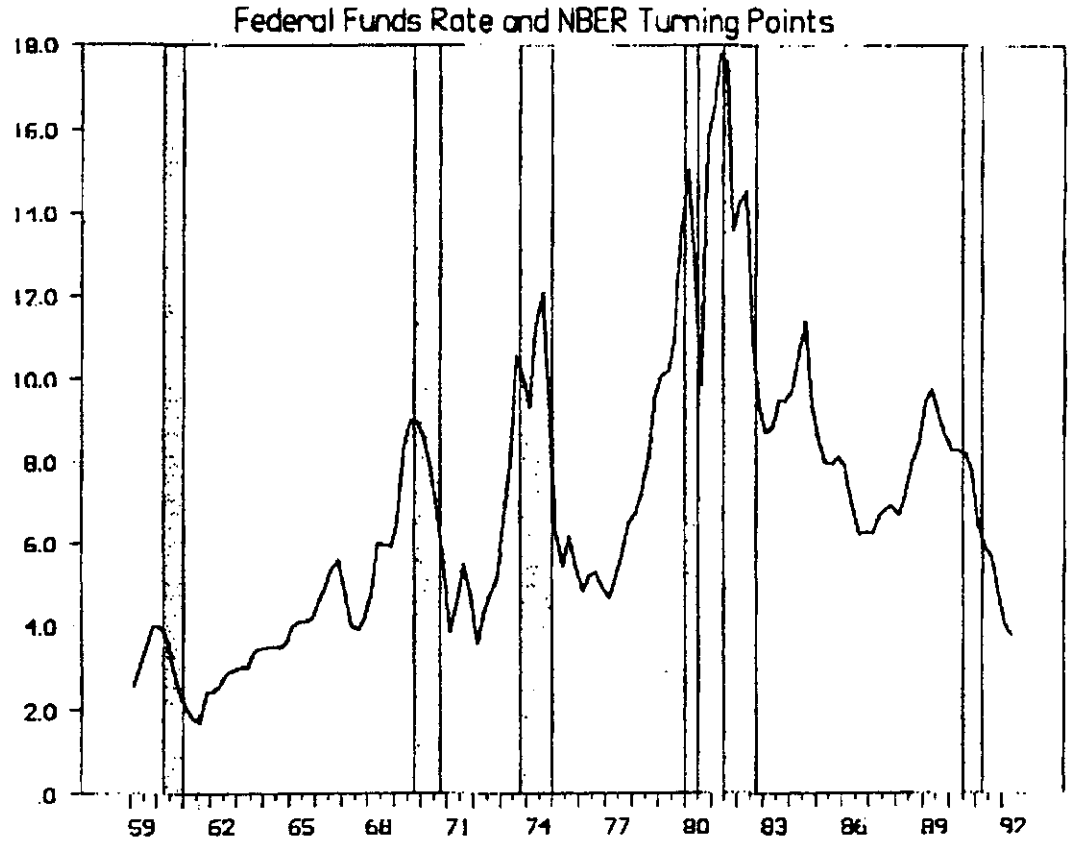
- Assess the role of monetary shocks as impulses into the business cycle
- Have a laboratory for evaluating alternative monetary policies

Evidence That Suggests Exogenous Money Shocks May be an Important Impulse to the Business Cycles

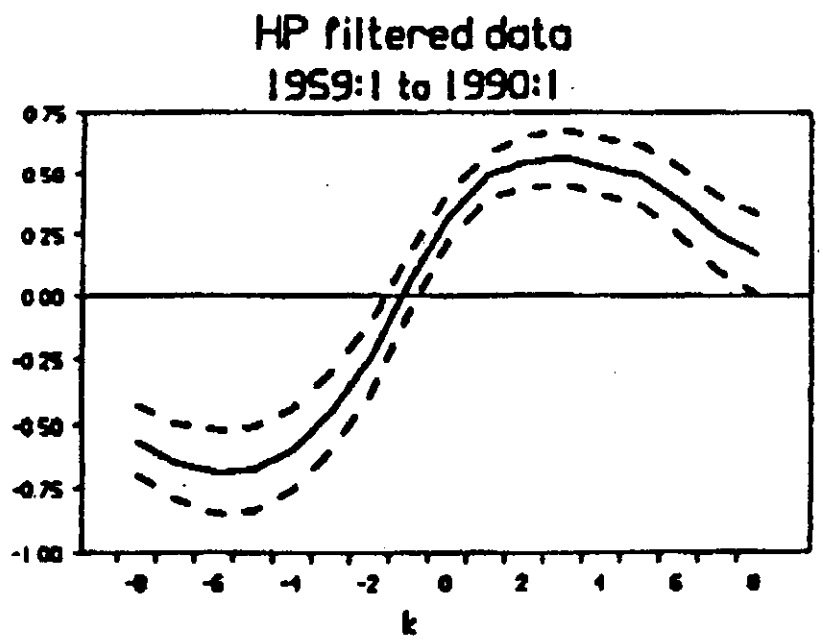
A. The Friedman-Schwartz evidence in their *Monetary History of the U.S.*

B. In Postwar U.S. Data: "High Interest Rates Often Precede Hard Times"

High Interest Rates Forecast Declines in Output and Consumption.



Correlation(Federal Funds Rate$_t$,GNP$_{t-\tau}$), $\tau = -8, -7, ..., 7, 8$



If We Construct a Model With Money, What Monetary Aggregate Should it Correspond to?

PROBLEMS: (i) In the data, there are several monetary aggregates—

M1 ~ Demand deposits and currency.

M0 ~ Monetary base (currency plus bank reserves).

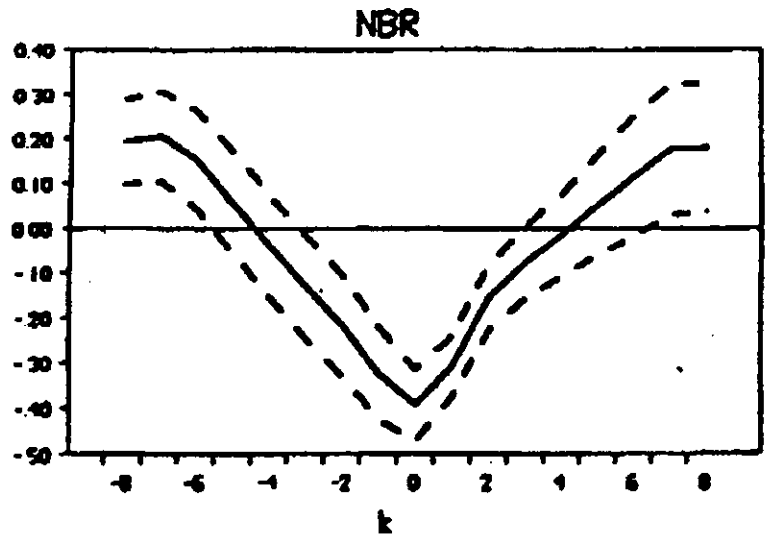
Bank Reserves ~ Vault cash at banks, plus deposits at Fed.

Nonborrowed Bank Reserves (NBR) ~ Reserves not borrowed from the Fed.

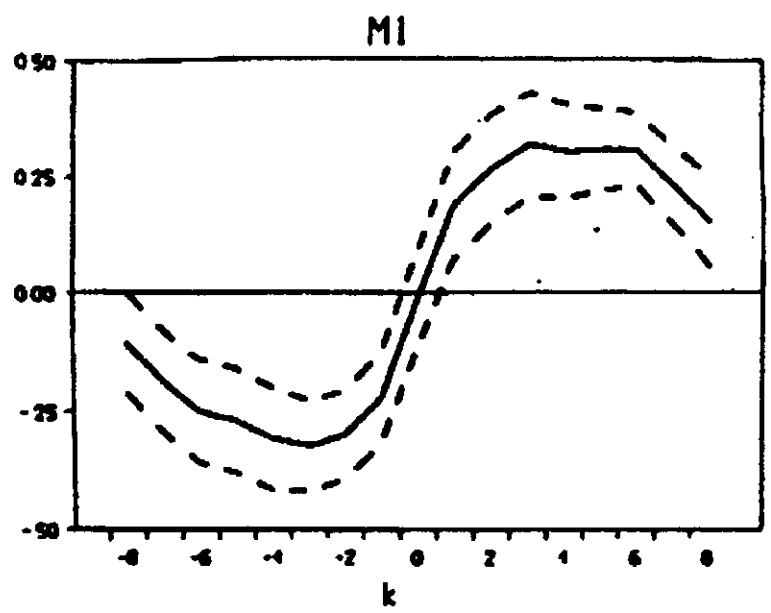
(ii) Different monetary aggregates exhibit different dynamic behavior ("sign switch").

Sign Switch Observations

Correlation(Federal Funds Rate$_t$,Nonborrowed Reserves$_{t-\tau}$), $\tau = -8, -7, ..., 7, 8$



Correlation(Federal Funds Rate$_t$,M1$_{t-\tau}$), $\tau = -8, -7, ..., 7, 8$



Liquidity Effect Observations

An exogenous increase in money, engineered by the Central Bank leads to:

1. A persistent decline in short-term interest rates.

2. A persistent rise in output and employment.

3. Little change in aggregate prices for a quarter or so, followed by a rise.

Summary

A good empirical model of money should be consistent with:

1. Observation that high short-term interest rates forecast hard times.

2. Sign switch observations.

3. Liquidity effect observations.

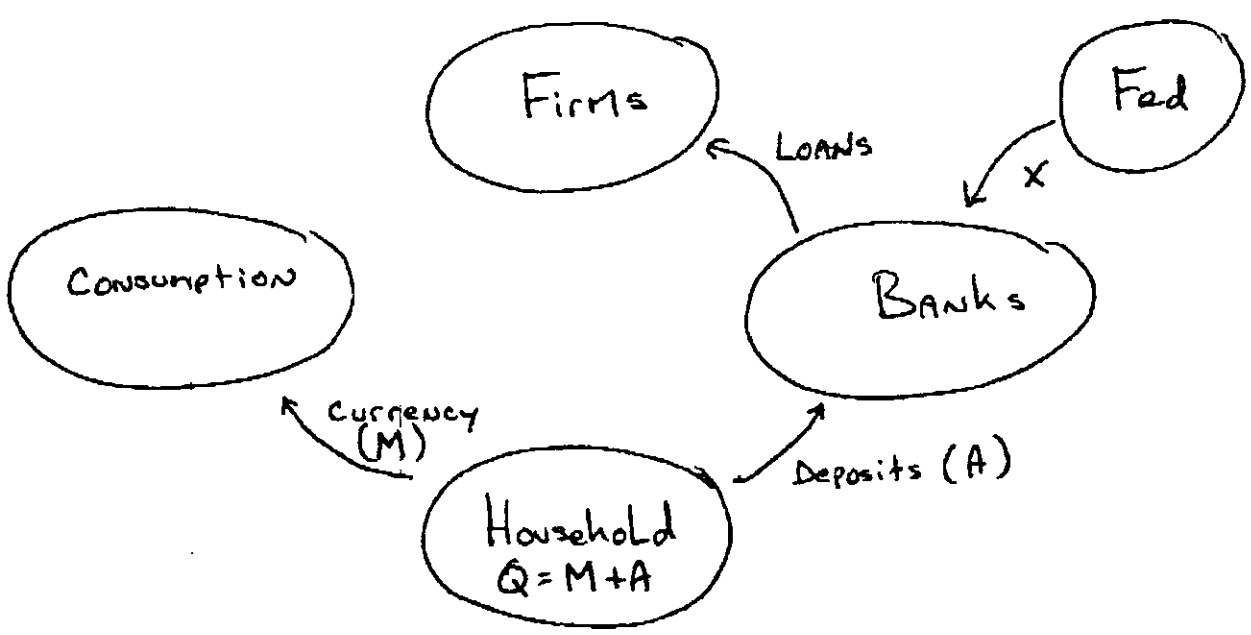
To Account for These Observations We Construct a Model With:

1. Particular Asset Market Frictions
2. Multiple Monetary Aggregates
3. Two Shocks
4. A Banking System

Accounting for Liquidity Effect Observations:

A. **Working Capital Assumption**: Firms must pay factors of production in advance.

B. **Limited Participation Assumption**: Households are slow to adjust currency holdings in response to shocks.



Accounting for Sign Switch Observations

Our hypothesis:

1. Dynamics of broader monetary aggregates (bank reserves, M0, M1) dominated by endogenous response to non-Fed shocks.

2. Dynamics of nonborrowed reserves dominated by exogenous monetary policy shocks.

Three Assumptions Let Us Capture Our Hypothesis About Sign Switch:

1. Limited participation (e.g., sluggish currency adjustment).

2. Deposits in M1 are liabilities of banking system.

3. Specification of monetary policy.

Monetary Policy: Fed Chooses Mϕ

$$M0_{t+1} = (1+x_t)M0_t$$

$$x_t = x_{1t} + x_{2t}.$$

FOMC

$$x_{1t} = (1-\rho_x)x + \rho_x x_{t-1} + \epsilon_t^x$$

$\epsilon_t^x \sim$ exogenous.

Discount Window

$$x_{2t} = a_1\epsilon_{ft} + a_2\left(\frac{1}{1-\rho L}\right)\epsilon_{ft}$$

$a_1 + a_2 > 0$ "interest rate smoothing"

$a_1 + \dfrac{a_2}{1-\rho} = 0$ "window loans repaid"

$\epsilon_{ft} \sim$ innovation to private technology.

The Sign Switch . . . Nailed

M1 ~ Endogenous because of banking system.

Total Reserves, Monetary Base ~ Endogenous because of discount window policy.

Innovations in Nonborrowed Reserves ~ Exogenous because of limited participation (sluggish currency) and specification of Fed policy.

Monetary Base (100)

Currency (79)	Bank Reserves (21)	
	Nonborrowed (20)	Borrowed (1)

Model

Households – Supply labor and capital services, buy consumption goods and investment goods. Hold currency and deposits to reduce transactions costs.

Banking Firms – Use capital, labor, monetary reserves to produce deposit services, provide loans to finance inputs to production and to finance new investment.

Goods Producing Firms – Use capital, labor to produce consumption and investment goods.

Central Bank – Controls quantity of reserves.

Firms Profits:

$$P_t y_t - (1 + r_{ft}) r_{kt} P_t K_{ft} - (1 + r_{ft}) W_t n_{ft}$$

Cash reserves of the banking system:

$$A_t + X_t$$

Loans made by banks:

S_t = wages + capital rentals + investment good purchases

Bank Liabilities = Bank Assets

$$D_t = A_t + X_t + S_t$$

Excess Reserves

$$E_t = A_t + X_t - \tau D_t$$

Bank profits:

$$F_t = r_{ft} S_t - \hat{r}_{at}(S_t + A_t + X_t) - (1 + r_{ft}) r_{kt} P_t k_{kt} - (1 + r_{ft}) Wages_t$$

Households

$$D_{kt} = A_t + X_t + W_t n_t + r_{kt} P_t K_t.$$

$$P_t C_t + Q_{t+1} + Investment\ Purchases_t \leq D_{kt}(1 + \hat{r}_t^a) + M_t + F_t$$

$$Q_t = M_t + A_t$$

Table 1: Model parameters*

Period of model (fraction of year): 0.11

Household	Goods Producing	Banks	Monetary Authority
$\beta^{-1} = 1.04$	$\alpha = 0.36$	$\tau = 0.06$	$x = 0.065$
$\varphi = -0.5$	$A_f = 1$	$1 - \zeta = 0.0206$	$\rho_x = 0.1$
$\theta = 0.488$	$A_b = 1074.76$		$\sigma_{x_1} = 0.0038$
$J = .0036$	$\mu_z = 0.016$		$b_1 = 3.0$
$\gamma = 2.10$	$\rho_f = 0.50$		$b_2 = -2.1$
$\delta = 0.08$	$\sigma_f = 0.0097$		$\rho = .3$
$\nu_0 = 0.18$			
$\nu_1 = 3.41$			
$\Lambda_1 = 1$			
$\Lambda_2 = 0.3$			

* Parameters with a time dimension expressed at an annual rate

Table 2: Some properties of non stochastic steady state*

K_b/K	.001	l_1	.48	π	4.8%	D/M	3.18	PY/M	21.6
N_b/N	.001	l_2	.004	r_f	8.3%	E/(PC)	.0004	PY/M0	18.0
K/Y	2.44	l_3	.015	r_a	6.9%	D/(PC)	.194	PY/M1	5.2
C/Y	.76	n	.48	r_k	14%	M1/M	4.31		
		nl_1	.23			M1/M0	3.36		

* Variables with a time dimension expressed at an annual rate

Table 3: Banking sector balance sheet (non stochastic steady state)*

Assets		Liabilities	
Reserves	.062	Demand deposits	1.0
Required	.060		
Excess	.002		
Working capital	.755		
Wage loans	.483		
Capital rental loans	.272		
Investment loans	.182		

* Numbers expressed as a fraction of total bank assets

Table 4: Response to a money supply shock*

Panel A: Interest rates, inflation and reserves

	r_a	r_f	π	NBR	ER	TR
0	- 0.40	- 0.43	1.76	6.01	93.57	6.01
1	- 0.37	- 0.39	- 0.32	3.59	48.55	3.59
2	- 0.17	- 0.18	- 0.18	2.25	23.03	2.25
3	- 0.08	- 0.08	- 0.08	1.62	10.97	1.62
4	- 0.04	- 0.04	- 0.04	1.34	5.46	1.34
5	- 0.02	- 0.02	- 0.02	1.21	2.95	1.21
6	- 0.01	- 0.01	- 0.01	1.15	1.82	1.15
7	- 0.00	- 0.00	- 0.00	1.12	1.31	1.12
8	- 0.00	- 0.00	- 0.00	1.11	1.08	1.11
9	- 0.00	- 0.00	- 0.00	1.10	0.98	1.10

Panel B: Monetary aggregates

	M	A	Base	M1	Loans
0	0	0	0.99	2.20	2.68
1	0.60	3.07	1.09	1.65	1.87
2	0.87	2.24	1.10	1.36	1.46
3	1.00	1.64	1.10	1.22	1.27
4	1.06	1.35	1.10	1.16	1.18
5	1.08	1.21	1.10	1.13	1.14
6	1.09	1.15	1.10	1.12	1.12
7	1.10	1.12	1.10	1.11	1.11
8	1.10	1.11	1.10	1.11	1.11
9	1.10	1.10	1.10	1.11	1.11

Panel C: Real quantities

	C	I	Y	n_f	n_b	l_1
0	0.14	1.07	0.37	0.31	- 0.38	0.17
1	0.00	0.13	0.03	0.03	- 0.41	0.01
2	0.01	0.06	0.02	0.01	- 0.19	0.01
3	0.01	0.02	0.01	0.00	- 0.09	0.00
4	0.01	0.01	0.01	0.00	- 0.04	0.00
5	0.01	- 0.00	0.00	- 0.00	- 0.02	- 0.00
6	0.01	- 0.00	0.00	- 0.00	- 0.01	- 0.00
7	0.01	- 0.01	0.00	- 0.00	- 0.01	- 0.00
8	0.01	- 0.01	0.00	- 0.00	- 0.00	- 0.00
9	0.01	- 0.01	0.00	- 0.00	- 0.00	- 0.00

*Response to a one percentage point innovation in x_1. Entries for r_a, r_f and π report the percentage point deviation of these variables from their unshocked steady state path. All other entries report percent deviations from their unshocked steady state paths.

Table 5: Response to a technology shock without monetary accommodation*

Panel A: Interest rates, inflation and reserves

	r_a	r_f	π	NBR	ER	TR
0	0.54	0.58	- 0.49	0	- 24.49	0
1	0.31	0.33	0.38	1.21	10.21	1.21
2	0.07	0.08	0.14	1.14	14.84	1.14
3	- 0.00	- 0.00	0.03	0.80	11.31	0.80
4	- 0.02	- 0.02	- 0.00	0.50	6.90	0.50
5	- 0.02	- 0.02	- 0.01	0.28	3.51	0.28
6	- 0.01	- 0.01	- 0.01	0.15	1.29	0.15
7	- 0.01	- 0.01	- 0.01	0.06	- 0.06	0.06
8	- 0.00	- 0.00	- 0.00	0.02	- 0.83	0.02
9	- 0.00	- 0.00	- 0.00	- 0.01	- 1.25	- 0.01

Panel B: Monetary aggregates

	M	A	Base	M1	Loans
0	0	0	0	0.67	0.93
1	- 0.24	1.26	0	0.62	0.86
2	- 0.23	1.19	0	0.44	0.62
3	- 0.16	0.84	0	0.29	0.40
4	- 0.10	0.52	0	0.18	0.25
5	- 0.06	0.29	0	0.11	0.16
6	- 0.03	0.15	0	0.07	0.10
7	- 0.01	0.07	0	0.05	0.07
8	- 0.00	0.02	0	0.04	0.05
9	0.00	- 0.01	0	0.03	0.04

Panel C: Real quantities

	C	I	Y	n_f	n_b	l_1
0	0.20	4.78	1.31	0.26	2.22	0.14
1	0.22	2.98	0.89	0.31	1.18	0.17
2	0.14	1.49	0.47	0.15	0.49	0.09
3	0.10	0.73	0.25	0.07	0.20	0.04
4	0.07	0.35	0.14	0.03	0.07	0.02
5	0.06	0.15	0.08	0.01	0.02	0.01
6	0.06	0.05	0.05	- 0.00	0.00	- 0.00
7	0.05	- 0.00	0.04	- 0.01	- 0.01	- 0.00
8	0.05	- 0.03	0.03	- 0.01	- 0.01	- 0.01
9	0.05	- 0.04	0.03	- 0.01	- 0.01	- 0.01

*Response to a one percentage point innovation in $x_f, b_1 = b_2 = 0$. Entries for r_a, r_f and π report the percentage point deviation of these variables from their unshocked steady state path. All other entries report percent deviations from their unshocked steady state paths.

Table 6: Response to a technology shock with monetary accommodation*

Panel A: Interest rates, inflation and reserves

	r_a	r_f	π	NBR	ER	TR
0	0.05	0.05	- 0.37	0	89.65	5.41
1	0.13	0.14	0.24	0.64	32.83	2.23
2	0.06	0.06	0.12	0.73	16.21	1.17
3	0.01	0.01	0.04	0.59	9.18	0.69
4	- 0.00	- 0.00	0.01	0.41	5.02	0.40
5	- 0.01	- 0.01	- 0.00	0.26	2.29	0.22
6	- 0.01	- 0.01	- 0.00	0.16	0.54	0.11
7	- 0.00	- 0.00	- 0.00	0.10	- 0.54	0.05
8	- 0.00	- 0.00	- 0.00	0.06	- 1.18	0.01
9	- 0.00	- 0.00	- 0.00	0.04	- 1.53	- 0.01

Panel B: Monetary aggregates

	M	A	Base	M1	Loans
0	0	0	0.89	1.84	2.20
1	- 0.12	6.25	0.27	0.84	1.06
2	- 0.14	2.40	0.08	0.45	0.60
3	- 0.11	1.07	0.02	0.27	0.36
4	- 0.07	0.53	0.01	0.16	0.23
5	- 0.04	0.27	0.00	0.10	0.14
6	- 0.02	0.13	0.00	0.07	0.10
7	- 0.01	0.05	0.00	0.05	0.07
8	- 0.00	0.01	0.00	0.04	0.05
9	0.00	- 0.01	0	0.03	0.04

Panel C: Real quantities

	C	I	Y	n_f	n_b	l_1
0	0.39	6.12	1.77	0.64	1.75	0.36
1	0.23	3.04	0.91	0.32	0.99	0.18
2	0.15	1.49	0.47	0.15	0.48	0.09
3	0.10	0.72	0.25	0.07	0.21	0.04
4	0.08	0.33	0.14	0.03	0.09	0.02
5	0.07	0.14	0.09	0.01	0.03	0.00
6	0.06	0.04	0.06	- 0.00	0.00	- 0.00
7	0.06	- 0.01	0.04	- 0.01	- 0.01	- 0.00
8	0.06	- 0.03	0.04	- 0.01	- 0.01	- 0.01
9	0.06	- 0.05	0.03	- 0.01	- 0.01	- 0.01

*Response to a one percent innovation in x_f,where b_1, b_2, ρ are as in table 1. Entries for r_a, r_f and π report the percentage point deviation of these variables from their unshocked steady state path. All other entries report percent deviations from their unshocked steady state paths.

Table 9: Correlation Properties: Money, Output and Interest Rates

Panel A: U.S. data

Correlation of r_{at} with:

	x_{t+2}	x_{t+1}	x_t	x_{t-1}	x_{t-2}
Output	- 0.18	0.09	0.36	0.54	0.59
M1	- 0.32	- 0.24	- 0.05	0.14	0.24
Base	- 0.19	- 0.11	0.06	0.21	0.27
NBR	- 0.34	- 0.48	- 0.55	- 0.41	- 0.22

* Monetary data have been logged and all data have been hp filtered. Sample interval: quarterly.

Panel B: Baseline model

Correlation of r_{at} with:

	x_{t+2}	x_{t+1}	x_t	x_{t-1}	x_{t-2}
Output	0.02	0.15	0.36	0.48	0.11
M1	- 0.08	- 0.06	0.03	0.32	0.15
Base	- 0.24	- 0.22	0.00	0.41	0.29
Reserves	- 0.02	- 0.03	0.02	0.29	0.10
NBR	0.06	- 0.11	- 0.58	- 0.44	- 0.12

*Monetary data have been logged and all data have been hp filtered. Sample interval: model period.

Panel C: Baseline model, no monetary accommodation

Correlation of r_{at} with:

	x_{t+2}	x_{t+1}	x_t	x_{t-1}	x_{t-2}
Output	0.16	0.50	0.89	0.28	- 0.11
M1	0.19	0.33	0.37	0.04	- 0.09
Base	- 0.15	- 0.18	- 0.19	- 0.03	0.11
Reserves	0.34	0.35	- 0.14	- 0.24	- 0.15
NBR	0.34	0.35	- 0.14	- 0.24	- 0.15

*Monetary data have been logged and all data have been hp filtered. Sample interval: model period.

Panel D: Baseline model, monetary accommodation, no limited participation

Correlation of r_{at} with:

	x_{t+2}	x_{t+1}	x_t	x_{t-1}	x_{t-2}
Output	0.02	0.33	0.96	0.59	0.24
M1	0.00	0.29	0.93	0.56	0.23
Base	- 0.10	0.09	0.75	0.48	0.21
Reserves	0.00	0.31	0.96	0.59	0.25
NBR	0.44	0.88	0.79	0.37	0.08

*Monetary data have been logged and all data have been hp filtered. Sample interval: model period.

Table 10: Correlation Properties, Money and Output

Panel A: U.S. data

Correlation of x_t with output_{t-k}

	$k=-2$	$k=-1$	$k=0$	$k=1$	$k=2$
M1	0.33	0.34	0.29	0.18	0.10
Base	0.37	0.39	0.34	0.26	0.20
NBR	0.10	- 0.06	- 0.22	- 0.32	- 0.34

* All variables have been logged and hp filtered. Sample interval: quarterly.

Panel B: Baseline model

Correlation of x_t with output_{t-k}

	$k=-2$	$k=-1$	$k=0$	$k=1$	$k=2$
M1	0.06	0.34	0.92	0.32	0.07
Base	0.08	0.33	0.84	0.15	- 0.05
Reserves	0.08	0.35	0.94	0.29	0.06
NBR	- 0.07	- 0.02	0.16	0.35	0.30

* All variables have been logged and hp filtered. Sample interval: model period.