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On Modeling the Effects of Inflation Shocks

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Abstract

A popular model in the literature postulates an interest rate rule, a NAIRU price equation, and an aggregate demand equation in which aggregate demand depends on the real interest rate. In this model a positive inflation shock with the nominal interest rate held constant is explosive because it increases aggregate demand (because the real interest rate is lower), which increases inflation through the price equation, which further increases aggregate demand, and so on. In order for the model to be stable, the nominal interest rate must rise more than inflation, which means that the coefficient on inflation in the interest rate rule must be greater than one.

The results in this paper suggest, however, that an inflation shock with the nominal interest rate held constant has a negative effect on real output. There are three reasons. First, the data support the use of nominal rather than real interest rates in aggregate expenditure equations. Second, the evidence suggests that the percentage increase in nominal household wealth from a positive inflation shock is less than the percentage increase in the price level, which is contractionary because of the fall in real wealth. Third, there is evidence that wages lag prices, and so a positive inflation shock results in an initial fall in real wage rates and thus real labor income, which is contractionary. If these three features are true, they imply that a positive inflation shock has a negative effect on aggregate demand even if the nominal interest rate is held constant. Not only does the Fed not have to increase the nominal interest rate more than the increase in inflation for there to be a contraction, it does not have to increase the nominal rate at all!

KEYWORDS: modern view of macro, inflation shocks, monetary policy

1 Introduction

At least since Lucas's (1976) critique of macroeconometric models, macroeconomics has been in a state of flux. Beginning in the 1970's, macroeconomic research scattered in a number of directions, and many have puzzled as to whether the field is going anywhere. Recently, however, a particular view of macroeconomics has emerged that some see as a convergence. Taylor (2000, p. 90), for example, states:

> …at the practical level, a common view of macroeconomics is now pervasive in policy-research projects at universities and central banks around the world. This view evolved gradually since the rational-expectations revolution of the 1970's and has solidified during the 1990's. It differs from past views, and it explains the growth and fluctuations of the modern economy; it can thus be said to represent a modern view of macroeconomics.

This view is nicely summarized in Clarida, Galí, and Gertler (1999), and it is used in Clarida, Galí, and Gertler (2000) to examine monetary policy rules. Taylor (2000, p. 91) points out that virtually all the papers in Taylor (1999a) use this view and that the view is widely used for policy evaluation in many central banks. Romer (2000) proposes a way of teaching this view at the introductory level.

The view is based on the following three equations:

1. **Interest Rate Rule**: The Fed adjusts the nominal interest rate in response to inflation and the output gap (deviation of output from potential).[1] The nominal interest rate responds positively to inflation and the output gap. The coefficient on inflation is greater than one, and so the real interest rate rises when inflation rises.

2. **Price Equation**: Inflation depends on the output gap, cost shocks, and expected future inflation.

3. **Aggregate Demand Equation**: Aggregate demand (real) depends on the real interest rate, expected future demand, and exogenous shocks. The real interest rate effect is negative.

[1] In empirical work the lagged interest rate is often included as an explanatory variable in the interest rate rule. This picks up possible interest rate smoothing behavior of the Fed.

This basic model is, of course, a highly simplified view of the way the macroeconomy works, as everyone would admit. Many details have been left out. If, however, the model captures the broad features of the economy in a fairly accurate way, the lack of detail is not likely to be serious for many purposes; the details can be filled in when needed. The 'modern' view of macroeconomics is that the broad features of the economy have been adequately captured by this model.

It is argued in this paper that the modern-view model has not adequately captured the effects of inflation shocks on the economy. The aggregate demand equation implies that an increase in inflation with the nominal interest rate held constant is expansionary (because the real interest rate falls). The model is in fact not stable in this case because an increase in output increases inflation through the price equation, which further increases output through the aggregate demand equation, and so on. In order for the model to be stable, the nominal interest rate must rise more than inflation, which means that the coefficient on inflation in the interest rate rule must be greater than one. Because of this feature, some have criticized Fed behavior in the 1960s and 1970s as following in effect a rule with a coefficient on inflation less than one—see, for example, Clarida, Galí, and Gertler (1999) and Taylor (1999b).

The argument in this paper is in three parts. First, it will be seen that the data support the use of nominal rather than real interest rates in aggregate expenditure equations. This implies that if inflation increases more than the nominal interest rate, this is not necessarily expansionary. Second, if the percentage increase in nominal household wealth from a positive inflation shock is less than the percentage increase in the price level, which the evidence suggests is the case, there is a fall in real household wealth. A fall in real household wealth has, other things being equal, a negative effect on real household expenditures. Third, there is evidence that wages lag prices, and so a positive inflation shock results in an initial fall in real wage rates and thus real labor income. A fall in real labor income has, other things being equal, a negative effect on real household expenditures.

If these three features are true, they imply that a positive inflation shock has a negative effect on aggregate demand even if the nominal interest rate is held constant. Not only does the Fed not have to increase the nominal interest rate more than the increase in inflation for there to be a contraction, it does not have to increase the nominal rate at all! The inflation shock itself will contract the economy through the real wealth and real income effects.

Section 2 discusses the evidence in favor of the use of nominal over real interest rates in expenditure equations. Section 3 discusses the real wealth effect, and Section 4 discusses the real income effect. Section 5 uses a multicountry econometric model (the MC model[2]) to estimate the overall effect of an inflation shock on the economy. It will be seen that a positive inflation shock with the nominal interest rate held constant is contractionary in this model.

2 Nominal versus Real Interest Rate Effects

This section uses consumption and investment equations in the MC model to test for nominal versus real interest rate effects. It is important to stress that these are not tests using the aggregate demand equation of the modern-view model. The argument here is that if in consumption and investment equations, equations explaining the two major components of aggregate demand, nominal rather than real interest rates matter, then it seems unlikely that the use of the real interest rate in the aggregate demand equation is a good specification.

It should also be stressed that this is not an atheoretical exercise: there is theory behind the consumption and investment equations. The Cowles Commission approach to macroeconometric model building, which is followed for the MC model, is to estimate decision equations, or at least approximations to decision equations. Theory is used to determine left and right hand side variables, i.e., to guide the specification of the equations to be estimated, and then techniques like two stage least squares (2SLS) are used to estimate the equations. Part of the specification concerns expectation formation, and one option is to assume that expectations are rational (i.e., model consistent).

The theory behind the consumption and investment equations in the MC model is that households maximize expected lifetime utility and that firms maximize the present discounted value of expected future profits. The theoretical model is discussed in detail in Fair (1994), and this discussion will not be repeated here. The variables that determine the optimal current period consumption decision include the lagged value of wealth, current and expected future income, and current and expected future interest rates. For the empirical specification expectations of future values are assumed to be a geometrically declining function of current and past values, which introduces the lagged dependent variable as an explanatory variable in the equations. In addition, the equations are estimated by 2SLS, and one can, for example, think of the predicted values of income from the first stage regressions as representing the predictions of the households. In other words, households can

[2]The MC model is described in Fair (1994), and the latest version is on the website listed in the colophon. All the equations in the model, including those used for the results in Tables 1 and 2 below, are presented on the website.

be assumed to use the first stage regressions to predict income.[3] The variables that determine the optimal current period investment decision include the lagged value of the capital stock, current and expected future values of output, and current and expected future interest rates. Expectations are treated in a similar way as they are for consumption. The aim of the tests in this section is to see if the interest rates that households and firms use are better approximated by nominal or real rates.

In the process of arriving at the final specifications of the consumption and investment equations in the MC model the following test of nominal versus real interest rate effects was made. Let for time t i_t denote the nominal interest rate, r_t the real interest rate, and $\dot{p}_t^e$ the expected future rate of inflation, where the horizon for $\dot{p}_t^e$ matches the horizon for i_t. By definition $r_t = i_t - \dot{p}_t^e$. Consider the specification of a consumption or investment equation in which the following appears on the right hand side:

$$\alpha i_t + \beta \dot{p}_t^e$$

For the real interest rate specification $\alpha = -\beta$, and for the nominal interest rate specification $\beta = 0$. The real interest rate specification can be tested by adding $\dot{p}_t^e$ to an equation with $i_t - \dot{p}_t^e$ included, and the nominal interest rate specification can be tested by adding $\dot{p}_t^e$ to an equation with i_t included. The added variable should have a coefficient of zero if the specification is correct, and one can test for this.

Four measures of $\dot{p}_t^e$ were tried for countries with quarterly data: $\dot{p}_t^e = (P_t/P_{t-1})^4 - 1$, $\dot{p}_t^e = P_t/P_{t-4} - 1$, $\dot{p}_t^e = (P_t/P_{t-8})^{.5} - 1$, and $\dot{p}_t^e = (P_{t+1}/P_{t-1})^2 - 1$, where P_t denotes the price level for quarter t. Three measures were tried for countries with only annual data: $\dot{p}_t^e = P_t/P_{t-1} - 1$, $\dot{p}_t^e = (P_t/P_{t-2})^{.5} - 1$, and $\dot{p}_t^e = (P_{t+1}/P_{t-1})^{.5} - 1$, where P_t denotes the price level for year t.

The results of the tests are presented in Tables 1 and 2. In Table 1 the p-value is presented for each equation and each measure of $\dot{p}_t^e$. Table 2 presents estimates of both α and β for each case. It also presents the estimate of α when no measure of $\dot{p}_t^e$ is included, which is the specification used in the MC model.

As mentioned above, other variables in the household expenditure equations include real income, lagged real wealth, and lagged expenditures. In the three consumption equations for the United States age distribution variables are added, and in the durable consumption equation for the United States the lagged stock of durable goods is added. In the housing investment equation for the United States

[3]These expectations, however, are not rational. See Section 6 for a discussion of the rational expectations assumption.

Table 1
Nominal Versus Real Interest Rates: $\alpha i_t + \beta \dot{p}_t^e$

		real test ($\alpha = -\beta$) p-value				nominal test ($\beta = 0$) p-value				Sample
	Variable	*a*	*b*	*c*	*d*	*a*	*b*	*c*	*d*	Period
	Countries with Quarterly Data									
1.	US: CS	.000	.000	.000	.000	.438	.378	.163	.379	1954.1-2001.4
2.	US: CN	.000	.000	.000	.000	.016	.008	.007	.015	1954.1-2001.4
3.	US: CD	.001	.000	.002	.290	.357	.112	.482	.948	1954.1-2001.4
4.	US: IH	.000	.000	.000	.000	.604	.016	.049	.796	1954.1-2001.4
5.	CA: C	.000	.001	.002	.003	.845	.446	.039	.721	1966.1-1999.4
6.	CA: I	.042	.035	.067	.016	.139	.116	.204	.108	1966.1-1999.4
7.	JA: C	.000	.001	.007	.000	.002	.033	.174	.003	1966.1-199.4
8.	JA: I	.004	.001	.000	.005	.348	.001	.012	.566	1966.1-1999.4
9.	AU: I	.416	.962	.790	.525	.023	.007	.030	.087	1970.1-1999.2
10.	FR: I	.000	.000	.000	.000	.290	.028	.068	.047	1971.1-1999.4
11.	GE: C	.000	.002	.007	.000	.008	.885	.822	.007	1971.1-1999.4
12.	GE: I	.175	.085	.251	.393	.258	.656	.853	.165	1971.1-1999.4
13.	IT: C	.086	.024	.062	.077	.972	.085	.537	.991	1971.1-1999.4
14.	IT: I	.000	.000	.000	.000	.001	.185	.736	.004	1971.1-1999.4
15.	NE: C	.019	.034	.429	.028	.013	.173	.094	.006	1978.1-1999.2
16.	NE: I	.002	.002	.003	.002	.292	.786	.772	.395	1978.1-1999.2
17.	ST: C	.004	.006	.032	.008	.505	.046	.293	.528	1983.1-1998.4
18.	UK: C	.006	.001	.001	.002	.038	.575	.990	.187	1966.1-1999.3
19.	UK: I	.000	.000	.000	.000	.039	.564	.894	.007	1966.1-1999.3
20.	AS: I	.009	.002	.002	.008	.472	.193	.285	.668	1966.1-1999.4
21.	SO: I	.000	.002	.047	.000	.378	.087	.001	.345	1961.1-1999.4
22.	KO: C	.022	.019	.028	.024	.615	.506	.118	.221	1974.1-1999.3
	Countries with Annual Data									
23.	BE: I		.000	.000	.000		.086	.259	.111	1962-1996
24.	DE: I		.219	.249	.759		.305	.072	.008	1967-1998
25.	IR: C		.086	.344	.020		.063	.047	.093	1968-1997
26.	PO: I		.001	.002	.001		.736	.952	.706	1962-1996
27.	SP: I		.006	.009	.023		.192	.086	.331	1962-1998
28.	NZ: C		.078	.042	.185		.302	.052	.744	1962-1997
29.	NZ: I		.097	.084	.163		.267	.208	.801	1962-1997
30.	VE: I		.000	.000	.000		.000	.003	.003	1962-1998
31.	CO: C		.001	.006	.008		.136	.506	.462	1971-1997
32.	ID: C		.002	.021	.000		.688	.472	.015	1962-1997
33.	PH: I		.000	.000	.000		.972	.825	.105	1962-1999

- Quarterly countries: P_t = price level for quarter t
  $^a\,\dot{p}_t^e = (P_t/P_{t-1})^4 - 1$, $^b\,\dot{p}_t^e = P_t/P_{t-4} - 1$, $^c\,\dot{p}_t^e = (P_t/P_{t-8})^{.5} - 1$, $^d\,\dot{p}_t^e = (P_{t+1}/P_{t-1})^2 - 1$
- Annual countries: P_t = price level for year t
  $^b\,\dot{p}_t^e = P_t/P_{t-1} - 1$, $^c\,\dot{p}_t^e = (P_t/P_{t-2})^{.5} - 1$, $^d\,\dot{p}_t^e = (P_{t+1}/P_{t-1})^{.5} - 1$
- Countries: US = United States, CA = Canada, JA = Japan, AU = Austria, FR = France, GE = Germany, IT = Italy, NE = Netherlands, ST = Switzerland, UK = United Kingdom, AS = Australia, SO = South Africa, KO = Korea, BE = Belgium, DE = Denmark, IR = Ireland, SP = Spain, NZ = New Zealand, VE = Venezuela, CO = Colombia, ID = India, PH = Philippines
- Variables: CS = Consumption of Services, CN = Consumption of Non Durables, CD = Consumption of Durables, IH = Housing Investment, C = Total Consumption, I = Total Investment

Table 2
Estimates of α and β: $\alpha i_t + \beta \dot{p}_t^e$

		a		*b*		*c*		*d*		
	Variable	α	β	α	β	α	β	α	β	α
					Countries with Quarterly Data					
1.	US: CS	-.129	-.022	-.125	-.026	-.111	-.055	-.136	-.025	-.144
		(-4.41)	(-0.80)	(-4.05)	(-0.91)	(-3.57)	(-1.44)	(-4.77)	(-0.90)	(-6.32)
2.	US: CN	-.142	-.084	-.110	-.093	-.092	-.116	-.147	-.088	-.160
		(-3.49)	(-2.47)	(-2.79)	(-2.74)	(-1.93)	(-2.78)	(-3.62)	(-2.50)	(-3.88)
3.	US: CD	-.548	-.172	-.464	-.350	-.577	-.245	-.226	-.012	-.611
		(-2.81)	(-0.95)	(-2.33)	(-1.63)	(-2.32)	(-0.72)	(-1.30)	(-0.07)	(-3.33)
4.	US: IH	-2.606	.079	-2.483	-.917	-2.686	-1.428	-2.590	-.082	-2.611
		(-5.30)	(0.53)	(-4.78)	(-2.61)	(-5.01)	(-2.44)	(-5.08)	(-0.27)	(-5.35)
5	CA: C	-.139	.005	-.149	.023	-.190	.076	-.141	.010	-.138
		(-3.90)	(0.20)	(-3.95)	(0.76)	(-4.72)	(2.06)	(-3.89)	(0.36)	(-3.97)
6	CA: I	-.261	.089	-.292	.115	-.266	.109	-.269	.109	-.202
		(-2.86)	(1.48)	(-2.92)	(1.57)	(-2.40)	(1.27)	(-2.93)	(1.61)	(-.245)
7.	JA: C	-.077	-.065	-.083	-.049	-.078	-.041	-.089	-.064	-.129
		(-1.90)	(-3.22)	(-1.87)	(-2.19)	(-1.59)	(-1.40)	(-2.13)	(-2.96)	(-3.15)
8.	JA: I	-.269	-.066	-.127	-.233	-.189	-.206	-.288	-.047	-.309
		(-2.25)	(-0.94)	(-1.03)	(-3.21)	(-1.48)	(-2.51)	(-2.37)	(-0.57)	(-2.77)
9.	AU: I	-.722	.402	-1.224	1.243	-1.142	1.024	-.777	.509	-.586
		(-1.90)	(2.27)	(-2.86)	(2.71)	(-2.70)	(2.17)	(-1.97)	(1.71)	(-1.67)
10.	FR: I	-.200	-.064	-.126	-.184	-.118	-.199	-.123	-.182	-.244
		(-2.78)	(-1.06)	(-1.56)	(-2.20)	(-1.36)	(-1.82)	(-1.44)	(-1.98)	(-4.15)
11.	GE: C	-.115	-.151	-.204	-.206	-.216	-.014	-.107	-.178	-.206
		(-1.70)	(-2.68)	(-3.54)	(-0.15)	(-3.67)	(-0.22)	(-1.62)	(-2.71)	(-3.65)
12.	GE: I	-.602	.204	-.486	-.087	-.411	-.048	-.703	.429	-.498
		(-2.04)	(1.13)	(-1.74)	(-0.45)	(-1.41)	(-0.19)	(-2.26)	(1.39)	(-1.79)
13.	IT: C	-.062	-.001	-.029	-.089	-.054	-.044	-.064	-.000	-.062
		(-1.52)	(-0.03)	(-0.57)	(-1.95)	(-1.08)	(-0.69)	(-1.63)	(-0.01)	(-1.74)
14.	IT: I	-.270	.105	-.235	.058	-.173	-.021	-.270	.108	-.181
		(-5.57)	(3.19)	(-4.01)	(1.33)	(-2.47)	(-0.34)	(-5.43)	(2.86)	(-4.42)
15.	NE: C	-.352	.136	-.351	.144	-.298	.218	-.409	.195	-.257
		(-3.41)	(2.48)	(-2.76)	(1.36)	(-2.27)	(1.68)	(-3.67)	(2.74)	(-2.68)
16.	NE: I	-.715	-.217	-.989	.067	-.868	-.097	-1.093	.162	-.933
		(-1.97)	(-1.05)	(-2.68)	(0.27)	(-2.18)	(-0.29)	(-3.09)	(0.85)	(-3.12)
17.	ST: C	-.217	-.036	-.329	.112	-.318	.116	-.200	-.040	-.225
		(-2.12)	(-0.83)	(-4.15)	(2.29)	(-2.40)	(1.16)	(-1.89)	(-0.78)	(-2.55)
18.	UK: C	-.062	-.051	-.122	-.015	-.151	.000	-.093	-.034	-.148
		(-1.10)	(-2.07)	(-2.06)	(-0.56)	(2.15)	(0.01)	(-1.61)	(-1.32)	(-3.89)
19.	UK: I	-.665	.107	-.522	.041	-.523	.011	-.928	.196	-.442
		(-4.44)	(2.07)	(-2.99)	(0.58)	(-2.76)	(0.13)	(-4.81)	(2.71)	(-4.21)
20.	AS: I	-.267	.037	-.175	-.095	-.179	-.090	-.271	.030	-.245
		(-2.91)	(0.72)	(-1.76)	(-1.30)	(-1.71)	(-1.07)	(-2.82)	(0.43)	(-2.87)
21.	SO: I	-.753	.029	-.759	.122	-.749	.321	-.716	-.059	-.748
		(-3.78)	(0.88)	(-3.84)	(1.71)	(-3.68)	(3.24)	(-3.62)	(-0.94)	(-3.80)
22.	KO: C	-.132	-.024	-.199	.039	-.248	.093	-.216	.053	-.154
		(-1.63)	(-0.50)	(-2.10)	(0.67)	(-2.71)	(1.56)	(-2.56)	(1.22)	(-2.28)

Table 2 (continued)

	Variable	*b* α	*b* β	*c* α	*c* β	*d* α	*d* β	α
				Countries with Annual Data				
23.	BE: I	-3.184	.831	-2.769	.496	-3.132	.725	-2.454
		(-4.45)	(1.71)	(-4.27)	(1.13)	(-4.72)	(1.59)	(-4.47)
24.	DE: I	-2.287	1.490	-2.589	1.947	-3.644	3.861	-1.313
		(-2.21)	(1.02)	(-3.25)	(1.80)	(-3.77)	(2.66)	(-3.19)
25.	IR: C	.017	-.355	.269	-.473	-.029	-.400	-.406
		(0.06)	(-1.86)	(0.69)	(-1.99)	(-0.10)	(-1.68)	(-2.32)
26.	PO: I	-1.178	.088	-1.113	.017	-1.359	.097	-1.055
		(-2.41)	(0.34)	(-2.08)	(0.06)	(-2.68)	(0.38)	(-3.33)
27.	SP: I	-.443	-.372	-.233	-.497	-.482	-.271	-.802
		(-1.10)	(-1.31)	(-0.55)	(-1.72)	(-1.14)	(-0.97)	(-2.65)
28.	NZ: C	-.355	.083	-.509	.206	-.240	.030	-.254
		(-1.95)	(1.03)	(-2.58)	(1.95)	(-1.40)	(0.33)	(-1.65)
29.	NZ: I	-1.057	.268	-1.210	.392	-.787	.072	-.784
		(-1.98)	(1.11)	(-2.08)	(1.26)	(-1.46)	(0.25)	(-1.64)
30.	VE: I	-.276	-.425	-.332	-.547	-.217	-.545	-.533
		(-1.43)	(-3.76)	(-1.62)	(-2.95)	(-0.95)	(-3.02)	(-2.49)
31.	CO: C	-.152	-.100	-.183	-.064	-.217	-.067	-.210
		(-1.91)	(-1.49)	(-2.22)	(-0.67)	(-2.57)	(-0.74)	(-2.96)
32.	ID: C	-.568	-.047	-.608	.109	-.534	-.340	-.583
		(-3.06)	(-0.40)	(-3.30)	(0.72)	(-2.97)	(-2.43)	(-3.25)
33.	PH: I	-1.680	-.008	-1.615	-.074	-2.273	.430	-1.688
		(-3.25)	(-0.04)	(-2.87)	(-0.22)	(-5.01)	(1.62)	(-3.77)

• See notes to Table 1.
t-statistics are in parentheses.

the lagged stock of housing is added. Output and lagged investment are the other main explanatory variables in the investment equations for the other countries.[4] The U.S. household expenditure equations and the consumption equations of the other countries are in per capita terms. All the equations are in log form except for the U.S. durable consumption and housing investment equations. For these latter two equations the interest rates and expected inflation measures are multiplied by an exogenous scale variable before being included in the equation.

The equations are estimated by 2SLS, where the first stage regressors are the main predetermined variables for the given country. For example, the right hand side endogenous variables in the consumption of services equation for the United

[4]No significant interest rate effects, real or nominal, could be found in the nonresidential fixed investment equation for the United States. This equation is thus not included in Table 1.

States are income, the interest rate, and, when added, the expected inflation measure. The coefficients in this equation are identified by the assumption that the predetermined variables affect income and the interest rate and are uncorrelated with the error term in the equation. The predetermined variables that are used as first stage regressors for this equation include the current values of three government variables (purchases of goods, purchases of labor, and transfer payments excluding unemployment benefits), the lagged value of a tax rate variable, and the lagged values of income, the interest rate, the unemployment rate, the inflation rate, wealth, and the inventory sales ratio. There are a total of 22 first stage regressors for this equation. The other equations have roughly this number of first stage regressors. Tests of overidentifying restrictions have been performed for all the U.S. stochastic equations, and for none of the equations is the hypothesis that the first stage regressors are uncorrelated with the structural error term rejected at the 95 percent confidence level. Also, the test results in Table 1 are not sensitive to the choice of first stage regressors: adding or subtracting a few predetermined variables makes little difference.

Under standard assumptions the 2SLS estimates are consistent. Also, as discussed above, the predicted values from the first stage regressions can be interpreted as predictions of the agents in the economy. For example, both i_t and $\dot{p}_t^e$ are treated as endogenous in the 2SLS estimation, and the agents can be assumed to have used the first stage regressions for i_t and $\dot{p}_t^e$ for their predictions. These predictions use the information in the predetermined variables in the model. This interpretation is important when considering the use of P_{t+1} in one of the measures of $\dot{p}_t^e$. Agents in effect are assumed to form predictions of P_{t+1} by running first stage regressions.

In most cases a long term interest rate is used, although for a few countries only a short term interest rate is available. The long term interest rate used for the United States is a mortgage rate for the household expenditure equations. A short term rate is used for the U.S. consumption of services equation.

The results for the real interest rate specification are in the left half of Table 1. They strongly reject the specification. For the United States 15 of the 16 p-values are less than .05. For the other quarterly countries 59 of 72 are less than .05, and for the annual countries 23 of 33 are less than .05.

The results for the nominal interest rate specification, which are in the right half of Table 1, are much stronger. For the United States only 6 of the 16 p-values are less than .05. For the other quarterly countries only 22 of 72 are less than .05, and for the annual countries only 6 of 33 are less than .05.

Table 2 presents the estimates of α and β. It also presents in the last column the estimate of α when $\dot{p}_t^e$ is not included (i.e., when β is constrained to be zero). An interesting question is whether most of the estimates of β are positive. The right half of Table 1 shows that most estimates are not significant, but if most estimates are positive, this would be some evidence in favor of a real interest rate effect (or at least of expected inflation having a positive effect on demand).

Table 2 shows that for the United States only 1 of the 16 estimates of β is positive. For the other quarterly countries 38 of the 72 estimates are positive, and for the annual countries 17 of the 33 estimates are positive. Of the positive coefficients, 13 have t-statistics greater than 2.0, and of the negative coefficients, 18 have t-statistics less than -2.0. There is thus more or less an even mix of positive and negative estimates of β except for the United States, where the negative estimates dominate.

Overall, the nominal interest rate specification clearly dominates the real interest rate specification. Why this is the case is an interesting question. One possibility is that $\dot{p}_t^e$ is simply a constant, so that the nominal interest rate specification is also the real interest rate specification (with the constant absorbed in the constant term of the equation). If, for example, agents think the monetary authority is targeting a fixed inflation rate, this might be a reason for $\dot{p}_t^e$ being constant.[5] Whatever the case, the empirical results do not favor the use of $i_t - \dot{p}_t^e$ in aggregate expenditure equations when $\dot{p}_t^e$ depends on current and recent values of inflation.

3 Real Wealth Effects

A second possible problem with the aggregate demand equation of the modern-view model is the omission of real wealth. Household wealth is a channel through which an inflation shock may have a negative effect on aggregate demand. This channel exists if real household wealth affects real household expenditures and nominal household wealth does not change in percentage terms one for one with the price level.

In many structural macroeconometric models real household wealth is an explanatory variable in household expenditure equations. In the MC model, for example, real household wealth appears in the four U.S. household expenditure equations discussed in the previous section.

[5]As mentioned in Section 1, some people have criticized Fed behavior in the 1960s and 1970s as being too cautious in controlling inflation. If this is true, then it may be that agents' expectations about inflation were different in the 1960s and 1970s than later (in particular, not constant). However, the hypothesis that Fed behavior was the same before 1979:3 as after 1982:4 was tested in Fair (2001), and it was not rejected.

Nominal household wealth in the MC model does not increase in percentage terms one for one with the price level. U.S. household wealth changes when the saving of the U.S. household sector changes and when there is a change in the value of corporate equities held. Most of the variation of wealth is from the variation in equity values (stock prices), not from the variation in saving. The key question in the present context is thus how inflation shocks affect stock prices. If the price of a stock is assumed to be the present discounted value of expected future earnings, one needs to estimate how stock prices change when expected future discount rates and earnings change.

In the MC model the capital gains (+) or losses (-) on the equity holdings of U.S. households (denoted CG_t) is constructed from data from the U.S. Flow of Funds accounts. CG_t is highly correlated with the change in the S&P 500 stock price index. When CG_t/GDP_{t-1} is regressed on $(SP_t - SP_{t-1})/GDP_{t-1}$, where SP_t is the value of the S&P 500 index at the end of quarter t and GDP_{t-1} is the value of nominal GDP in quarter $t-1$, the results are:

$$\frac{CG_t}{GDP_{t-1}} = \underset{(5.20)}{.0438} + \underset{(30.88)}{9.69}\ \frac{SP_t - SP_{t-1}}{GDP_{t-1}},\ R^2 = .832,\ 1954.1 - 2001.4 \qquad (1)$$

(GDP_{t-1} is used for scale purposes to lessen the chances of heteroscedasticity.) The fit of this equation is very high, reflecting the high correlation of CG_t and the change in the S&P 500 index.

In the MC model the variable CG_t is taken to be a function of the change in the nominal AAA bond rate (ΔRB_t) and the change in after tax corporate profits ($\Delta\Pi_t$). The change in the bond rate is meant to proxy for changes in expected future discount rates, and the change in after tax profits is meant to proxy for changes in expected future earnings. The estimated equation is:

$$\frac{CG_t}{GDP_{t-1}} = \underset{(4.58)}{.105} - \underset{(-2.57)}{.244}\ \Delta RB_t + \underset{(0.56)}{6.71}\ \frac{\Delta\Pi_t}{GDP_{t-1}}, \qquad (2)$$
$$R^2 = .018,\ 1954.1 - 2001.4$$

If $SP_t - SP_{t-1}$ is used in place of CG_t, the results are:

$$\frac{SP_t - SP_{t-1}}{GDP_{t-1}} = \underset{(2.90)}{.00625} - \underset{(-3.04)}{.0272}\ \Delta RB_t + \underset{(0.69)}{.767}\ \frac{\Delta\Pi_t}{GDP_{t-1}}, \qquad (3)$$
$$R^2 = .015,\ 1954.1 - 2001.4$$

These equations were estimated by 2SLS, with the first stage regressors being the main predetermined variables for the United States. The signs of the coefficient estimates in the two equations are as expected, although very little variance of the variables has been explained, with R^2's of only .018 and .015. In addition, the coefficient estimates for the profit variable are insignificant. Other explanatory variables were tried in equation (2), including various measures of inflation, but no significant variables could be found other than the change in the bond rate. Equation (2) is used for the results in Section 5.

4 Real Income Effects

A third possible problem with the aggregate demand equation of the modern-view model is the omission of real income effects. If a shock increases prices more than wages in the short run, there is a fall in real wages and thus real income, and this has a negative effect on real household expenditures.

The omission of wages from the modern-view model can be traced back to the late 1970s, where there began a movement, led by Robert J. Gordon, away from the estimation of structural price and wage equations to the estimation of reduced form price equations (i.e., price equations that do not include wage rates as explanatory variables).[6] This line of research evolved to the estimation of "NAIRU" equations, where the inflation rate depends on the expected future inflation rate, the deviation of the unemployment rate from its natural rate (the NAIRU value), and cost shocks. The expected future inflation rate is usually taken to depend on past inflation rates, where the coefficients on the past rates sum to one. An output gap measure may be substituted for the deviation of the unemployment rate from its natural rate. Equations of this type represent the modern view.

A more structural approach is to specify a price equation with the wage rate as one of the explanatory variables and a wage rate equation with the price level as one of the explanatory variables, where the two equations are estimated by a technique like 2SLS to account for simultaneity bias. In Fair (2000) a structural price and wage model was compared to the NAIRU model, and the results supported the structural model over the NAIRU model.[7]

[6] See, for example, Gordon (1980) and Gordon and King (1982).

[7] Another difference between the structural price and wage equations tested in Fair (2000) and the price equation of the modern view concerns long run dynamics. Two dynamic restrictions are imposed by the modern-view (NAIRU) specification: 1) the coefficients on past inflation rates sum to one and 2) the current and past price levels (in logs) appear only in first differenced form

The MC model has estimated price and wage equations for each country. These equations have the property that a cost shock, such as an increase in the price of oil, affects prices more than wages initially, so that a positive shock results in an initial fall in the real wage. These equations are used in the next section.

5 Estimated Effects in the MC Model of a Positive Inflation Shock

This section examines the effects of a positive U.S. inflation shock in the MC model. This model 1) uses nominal interest rates in the expenditure equations, 2) accounts for real wealth effects, 3) has structural price and wage equations in which a positive inflation shock like an oil price shock initially lowers the real wage, and 4) accounts for real income effects. Given the discussion in the previous sections, one would expect a positive inflation shock with the nominal interest rate held constant to be contractionary in the model, which it will be seen is the case.

To examine the effects of an inflation shock in the model, the following experiment was run. The period used is 1994:1–1998:4, 20 quarters. The first step was to add the estimated (historical) errors to the model and take them to be exogenous. This means that when the model is solved using the actual values of all the exogenous variables, a perfect tracking solution results. The base path for the experiment is thus just the historical path. Then the constant term in the U.S. price equation was increased by .005 (.50 percentage points) from its estimated value.[8] Also, the estimated interest rate rule for the Fed was dropped, and the nominal short term interest rate was taken to be exogenous for the United States. The model was then solved. The difference between the predicted value of each variable and each period from this solution and its base (actual) value is the estimated effect of the

(i.e., as inflation rates). These two restrictions were tested for the United States in Fair (2000) and rejected. The results suggest that price equations should be specified in terms of price levels with no restrictions on the coefficients of the past price levels. The long run dynamic properties of the NAIRU specification are thus subject to some doubt. For purposes of the present paper, however, the main point is that because of its reduced form nature, the NAIRU specification ignores wage and price interactions.

[8]Note that this is a shock to the price equation, not to the wage equation. It is similar to an increase in the price of oil. In the MC model an increase in the price of oil (which is exogenous) increases the U.S. price of imports, which is an explanatory variable in the U.S. price equation. Either an increase in the constant term in the price equation or an increase in the price of oil leads to an initial fall in the real wage because wages lag prices. If the shock were instead to the wage equation, there would be an initial rise in the real wage, which would have much different effects.

price-equation shock. Remember that this is an experiment in which there is no change in the U.S. short term nominal interest rate because the U.S. interest rate rule was dropped. There is also no effect on U.S. long term nominal interest rates because they depend only on current and past U.S. short term nominal interest rates.

Selected results from this experiment are presented in Table 3. The main point for present purposes is in row 1, which shows that real GDP falls: the inflation shock is contractionary. The rest of this section is simply a discussion of some of the details.

Row 2 shows the effects of the change in the constant term in the price equation on the price level. The price level is .52 percent higher than its base value in the first quarter, 1.00 percent higher in the second quarter, and so on through the twentieth quarter, where it is 4.44 percent higher. (The shock to the price equation accumulates over time because of the lagged dependent variable in the equation.) Row 3 versus row 2 shows that the nominal wage rate rises less than the price level, and so there is a fall in the real wage rate. Row 4 shows that real disposable income falls. (Although not shown, nominal disposable income increases.) Real disposable income falls because of the fall in the real wage rate and because some nonlabor nominal income, such as interest income, rises less in percentage terms than the price level.

The change in nominal profits is higher (row 5), and this in turn leads to a small increase in capital gains (CG) for the household sector (row 6). (This is equation (2) in Section 3 at work.) For example, the increase in capital gains in the first quarter is \$16.4 billion. (CG is not affected by any nominal interest rate changes because there are none.) The increase in CG leads to an increase in nominal household wealth (not shown), but row 7 shows that real household wealth is lower. This means that the percentage increase in nominal household wealth is smaller than the percentage increase in the price level. Put another way, equation (2) in Section 3 does not lead to a large enough increase in CG to have real household wealth rise.

The fall in real income and real wealth leads to a fall in the four categories of household expenditures (rows 8–11). Nonresidential fixed investment is lower (row 12), which is a response to the lower values of output.

Rows 13 and 14 present the Japanese and German nominal exchange rates relative to the U.S. dollar. (An increase in a rate is a depreciation of the currency.) The two currencies appreciate relative to the dollar. This is because the U.S. price

Table 3
Effects of a Positive Shock to the U.S. Price Equation
Nominal Interest Rate Unchanged from Base Values

		Changes from Base Values							
		Quarters Ahead							
	Variable	1	2	3	4	8	12	16	20
1.	Real GDP	-.04	-.12	-.23	-.36	-.91	-1.32	-1.58	-1.76
2.	Price level	.52	1.00	1.43	1.81	2.99	3.72	4.18	4.44
3.	Wage rate	.42	.80	1.15	1.45	2.35	2.87	3.17	3.31
4.	Real DPI	-.21	-.42	-.63	-.84	-1.65	-2.25	-2.73	-3.07
5.	$\Delta\Pi$	2.4	1.7	1.5	1.3	1.5	1.3	1.0	1.4
6.	CG	16.4	11.1	12.2	10.1	17.7	27.5	19.8	65.6
7.	Real Wealth	-.26	-.51	-.74	-.95	-1.62	-2.04	-2.28	-2.42
8.	CS	-.02	-.07	-.13	-.21	-.60	-.99	-1.31	-1.57
9.	CN	-.02	-.07	-.15	-.25	-.74	-1.18	-1.52	-1.76
10.	CD	-.16	-.46	-.85	-1.29	-3.41	-5.27	-6.46	-7.03
11.	IH	-.41	-.99	-1.71	-2.49	-5.67	-7.22	-7.92	-7.80
12.	IK	-.06	-.21	-.44	-.74	-2.33	-3.41	-3.92	-4.10
13.	yen/$ rate	-.03	-.07	-.14	-.21	-.61	-1.05	-1.44	-1.76
14.	DM/$ rate	-.05	-.13	-.25	-.39	-1.03	-1.64	-2.09	-2.36
15.	Price of imports	.13	.18	.24	.30	.70	.94	1.02	.68
16.	Price of exports	.47	.88	1.26	1.60	2.64	3.31	3.73	3.98
17.	Real imports	-.03	-.15	-.37	-.66	-2.27	-3.72	-4.73	-5.34
18.	Real exports	-.04	-.09	-.14	-.20	-.46	-.77	-1.19	-1.33
19.	Cur. Act.	.06	.13	.22	.31	.62	.93	1.12	1.32

- All variables but 13 and 14 are for the United States.
- Notation: DPI = Disposable Personal Income,
  $\Delta\Pi$ = Change in After Tax Corporate Profits,
  CG = Capital Gains or Losses on Stocks Held by the Household Sector,
  CS = Consumption of Services, CN = Consumption of Non Durables,
  CD = Consumption of Durables, IH = Housing Investment,
  IK = Nonresidential Fixed Investment,
  Cur. Act. = U.S. Nominal Current Account as a percent of Nominal GDP.
- Changes are in percentage points except for $\Delta\Pi$ and CG, which are in billions of dollars.
- Simulation period is 1994.1–1998.4.

level rises relative to the Japanese and German price levels, which leads, other things being equal, to an appreciation of the yen and deutsche mark through the estimated equations for two exchange rates.

Row 15 shows that the U.S. import price level rises, which is due to the depreciation of the dollar, and row 16 shows that the U.S. export price level rises, which is due to the increase in the overall U.S. price level.

The real value of imports in the model responds negatively to the import price level relative to the domestic price level and positively to real income. Row 17 shows that the real income effect dominates. The negative effect from the fall in real income dominates the positive effect from the fall in the price of imports relative to the domestic price level. The real value of U.S. exports is lower (row 18), which is due to a higher relative U.S. export price level. (The export price level increases more than the dollar depreciates, and so U.S. export prices in other countries' currencies increase.) Even though the real value of U.S. exports is lower, there is an improvement in the nominal U.S. current account (row 19). This improvement is initially due to the higher U.S. export price level (a J curve type of effect) and later to the fact that the real value of U.S. imports falls more than does the real value of U.S. exports. In other words, the contractionary U.S. economy helps improve the U.S. current account because of the fall in imports.

The MC model is not constrained to have long run steady state values. Regarding long run effects, the present experiment is somewhat artificial because of the dropping of the estimated interest rate rule of the Fed. The rule has the property that, other things being equal, the Fed will lower the nominal interest rate when the U.S. economy contracts. This will then help bring the economy out of the contraction. The present experiment is merely meant to show what would be the case if the rule were dropped. In practice, of course, the Fed would react.

6 Rational Expectations

Expectations are not rational in the version of the MC model used for the experiment in the previous section. The rational expectations (RE) assumption has been tested for many of the equations of the MC model,[9] and very little support has been found. Nevertheless, RE versions of the MC model have been analyzed using the extended path solution method in Fair and Taylor (1983, 1990), and for many experiments these versions have similar properties to those of non RE versions.

[9] See Fair (1993) for a discussion of the testing procedure, and Fair (1994) and the website for results of the tests.

The RE assumption mostly changes the timing of the effects. If, for example, it is assumed in the MC model that U.S. households have rational expectations regarding future real income, it is still the case that a positive inflation shock has a negative effect on current household expenditures. The effect is in fact larger under the RE assumption, since real income is lower in the future as well as the present and households know this and thus cut back expenditures more now. None of the main points about the MC model's properties in Section 5 hinge on whether or not expectations are rational.

7 The FRB/US Model

The FRB/US model—Federal Reserve Board (2000)—is sometimes cited as a macroeconometric model that is consistent with the modern view (see, for example, Taylor (2000), p. 91). This model has strong real interest rate effects. In fact, if government spending is increased in the FRB/US model with the nominal interest rate held constant, real output eventually expands so much that the model will no longer solve.[10] The increase in government spending raises inflation, which with nominal interest rates held constant lowers real interest rates, which leads to an unlimited expansion. The model is not stable unless there is a nominal interest rate rule that leads to an increase in the real interest rate when inflation increases.

It may seem puzzling that two macroeconometric models could have such different properties. Given the empirical results in Sections 2 and 3, how can it be that the FRB/US model finds such strong real interest rate effects? The answer is that many restrictions have been imposed on the model that have the effect of imposing large real interest rate effects. In most of the expenditure equations real interest rate effects are imposed rather than estimated. Direct tests of nominal versus real interest rates like the one used in Section 2 are not done, and so there is no way of knowing what the data actually support in the FRB/US expenditure equations.

Large stock market effects are also imposed in the FRB/US model. Contrary to the estimate of equation (2) in Section 3, which shows fairly small effects of nominal interest rates and nominal earnings on stock prices, the FRB/US model has extremely large effects. A one percentage point decrease in the real interest rate leads to a 20 percent increase in the value of corporate equity (Reifschneider, Tetlow, and Williams (1999), p. 5). At the end of 1999 the value of corporate equity

[10] Private correspondence with Andrew Levin and David Reifschneider.

was about $20 trillion (using data from the U.S. Flow of Funds accounts), and 20 percent of this is $4 trillion. There is thus a huge increase in nominal household wealth for even a one percentage point decrease in the real interest rate. A positive inflation shock with the nominal interest rate held constant, which lowers the real interest rate, thus results in a large increase in both nominal and real wealth in the model. The increase in real wealth then leads through the wealth effect in the household expenditure equations to a large increase in real expenditures. This channel is an important contributor to the model not being stable when there is an increase in inflation greater than the nominal interest rate. Again, this stock price effect is imposed rather than estimated, and so it is not necessarily the case that the data are consistent with this restriction. The empirical work in Section 3 does not find large increases in stock prices in response to changes in interest rates and earnings, certainly nothing close to what is imposed in the FRB/US model.

There is thus no puzzle about the vastly different properties of the two models. It is simply that important real interest rate restrictions have been imposed in the FRB/US model and not in the MC model. One of the main points of this paper is that the data do not appear to support these restrictions.

8 Conclusion

The results in this paper suggest that a positive inflation shock with the nominal interest rate held constant is contractionary, contrary to the properties of the modern-view model. If this is true, it has important implications for monetary policy. If a positive inflation shock is contractionary with the nominal interest rate held constant, the coefficient on inflation in the nominal interest rate rule need not be greater than one for the economy to be stable. Or if one is concerned with optimal policies, the optimal response by the Fed to an inflation shock is likely to be much smaller if inflation shocks are contractionary than if they are expansionary.

Colophon

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