Empirical Economics (1999) 24:415–426

EMPIRICAL ECONOMICS

Money demand, the Cagan model, testing rational expectations vs adaptive expectations: The case of Turkey*

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First version received: March 1998 / final version received: October 1998

Abstract. This paper estimates the Cagan type demand for money function for Turkish economy during the period 1986 : 1–1995 : 3 and tests whether Cagan's specification fits the Turkish data using an econometric technique assuming that forecasting errors are stationary. This paper also tests the hypothesis that monetary policy was implemented in aiming to maximize the inflation tax revenue. Finally, the Cagan model is estimated with the additional assumption of rational expectations for Turkey for the considered period.

Key words: Adaptive expectations, cointegration, hyperinflation, inflation tax, money demand, rational expectations, unit root

JEL classifications: E41, C32, C12

I. Introduction

Cagan (1956) formulated a specific version of the demand for money function and a specific hypothesis about the formation of inflationary expectations. Cagan's paper posed and dealt with questions about the role of money in generating inflation. His paper produced results that have had a wide range of applications in the context of a monetary approach to inflation (see, Phylaktis and Taylor (1993), Easterly et al. (1995), Kiguel and Neumeyer (1995), Loviscek (1996) and Ozmen (1996), inter alia).

This paper estimates the demand for money using Cagan's specification for Turkish economy during the period 1986 : 1–1995 : 3 and it presents new evi-

* We are grateful for the valuable comments of Erdal Ozmen and David Sapsford, Hakan Berument and a referee. All remaining shortcomings are ours alone.

dence for Cagan's hyperinflation model as applied to the case of Turkey. This paper also tests whether this model fits the Turkish data, using an econometric technique assuming that forecasting errors are stationary. Cagan confined his study to hyperinflation where, he argued, fluctuations in the price level and the inflation rate swamped those in real income and the rate of return on capital goods. Hence, he formulated a demand for the real money balances function in which the argument was the expected inflation rate formed by using an adaptive expectation hypothesis.

Cagan (1956) also studied the maximum amount of revenue that is available from the inflation tax, if the equilibrium is stable. The inflation tax is the tax imposed on money holders as a result of inflation, i.e., it is the loss in the value of money holders' real balances. In the paper, we test the hypothesis that the monetary authorities expanded the money supply to maximize the inflation tax revenue in Turkey for the considered period.

During the period 1986–1995, excluding 1994, Turkey experienced a stable annual inflation rate of sixty percent to seventy percent. This can be taken as a clue for rational expectations. We are motivated from the high rates of inflation in Turkey and then conducted a test of the Cagan (1956) model with the additional assumption of rational expectations (for derivations and applications see Campbell and Shiller (1987), McCallum (1989), Phylaktis and Taylor (1993)).

This paper is organized as follows. In section II we briefly discussed the bare bones of the historical circumstances lying behind Turkish inflation and the time paths of several monetary aggregates. In section III, we briefly discuss Cagan's hyperinflation model. Empirical results are given in section IV, including the results of the testing for unit roots and order of integration. An adaptive expectation hypothesis is tested using cointegration analysis in both a univariate and multivariate context. In addition, the rational expectation hypothesis is tested using Cagan's type demand for money. Section V is the conclusion.

II. Setting

The Turkish authorities aimed at placing greater reliance on monetary policy for economic stabilization purposes and therefore, in the second half of the 1980s, the Central Bank of Turkey started to introduce for the first time the policy approach of targeting monetary aggregates. In view of accelerating inflation and instability in financial markets, monetary policy was severely tightened in 1988. In spite of this tigtening policy, M1, M2 and reserve money growth was 31, 50 and 61 percent respectively and consumer price inflation reached 75 percent in 1988 (see figure 1). Since the Central Bank is not completely autonomous and economic policy decisions are taken at the government level, it has been difficult to follow a clear anti-inflationary monetary policy. Yearly consumer price inflation persisted with an average of approximately 70 percent in the period 1988–1992. The Central Bank was again obliged to finance the public sector deficits, and hence fiscal imbalance induced rapid growth in the monetary aggregates. Inflationary pressures intensified, partly in response to the further increase in public sector deficits and the public sector borrowing requirement (PSBR) rose to 16 percent of GNP.

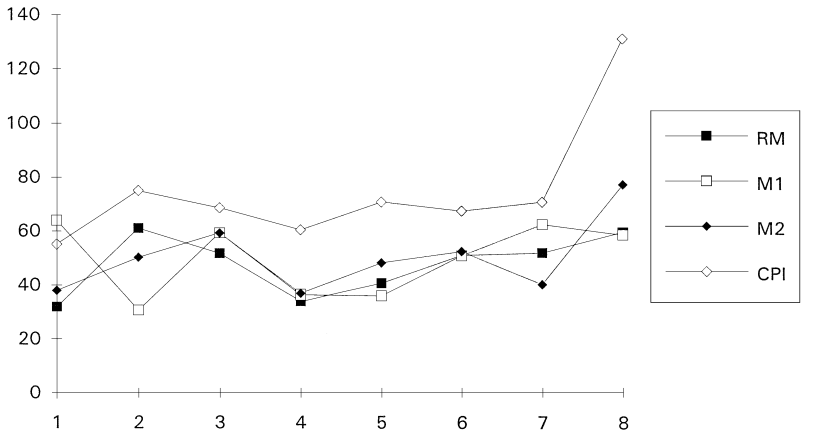

Fig. 1. The growth rates of RM, M1, M2 and CPI

Starting in 1994, the Turkish economy underwent the most important crisis of the last fifteen years. The crisis first began in the finance market and spread to the real part of the economy immediately. Monetary aggregates also increased significantly in 1994, and M1, M2 and reserve money growth reached 59, 78, 60 percent respectively. On April 5, 1994, the government announced a new program which accelerated closure and privatization of SEEs, a decrease in public sector real wages and other unspecified public expenditure cuts. The public sector borrowing requirement fell to 8 percent of GNP, economic expansion stopped, and inflation increased substantially to 132 percent per annum in 1994, stabilizing again around its initial path of 76 percent in 1995. However, an inflationary stimuli persisted.

III. Cagan's hyperinflation model

Cagan (1956) deals with the relation between changes in the quantity of money and price level during hyperinflation. The theory developed by Cagan (1956) involves an extension of the Cambridge cash-balances equation. That equation asserts that real cash balances (M/P) remain proportional to real income (Y) under given conditions $(M/P = kY;\ k\ is\ a\ constant)$.

Cagan's model is composed of two equations, an equation giving the demand for money and an equation describing the formation of expectations. The monetary equilibrium is given by

$$M/P = c\exp(-\alpha\pi^*), \tag{1}$$

where c and α are constant terms and π^* is the expected rate of inflation. The higher expected inflation, the lower will be the demand for real money balances. Two important assumptions are implicit in this formulation. The first is that output is given and thus is part of the constant term c. The second is that the real interest rate is constant and thus also included in the constant term c. The main rationale for this functional form is convenience, though it appears consistent with the data from hyperinflation. In an equilibrium the real money

stock must be equal to money demand, and (1) can be interpreted as an equilibrium equation.

The second equation Cagan used describes the formation of expectations. Cagan assumed adaptive expectations about inflation. Under adaptive expectations, expectations of inflation are adjusted according to

$$d\pi^*/dt = b(\pi - \pi^*), \tag{2}$$

where π is the actual inflation rate. If current inflation exceeds expected inflation, expected inflation increases. The coefficient b reflects the speed at which individuals revise their expectations.

Ignoring the constant term, Cagan's monetary equilibrium can be written:[1]

$$(m - p)_t = -\alpha\pi_t^* + \psi_t,$$

where m and p express logarithm of nominal money balances and prices, respectively, and ψ_t denotes elements of money demand not included by above specification. Using Δp_{t+1}^e as a representation of expected inflation rate instead of π_t^*, the above equation can be written as

$$(m - p)_t = -\alpha\Delta p_{t+1}^e + \psi_t. \tag{3}$$

Cagan demonstrates that changes in real cash balances in hyperinflation result only from variations in the expected rate of change in prices and therefore, ψ_t will be stationary. Replacing expected with actual inflation in (3):

$$(m - p)_t = -\alpha\Delta p_{t+1} + \varepsilon_{t+1}, \tag{4}$$

where $\varepsilon_{t+1} = [\psi_t + \alpha(\Delta p_{t+1} - \Delta p_{t+1}^e)]$. Under hyperinflation circumstances, $(m - p)_t$ and Δp_t are each first difference stationary or integrated of order one, I(1). Adding $\alpha\Delta p_t$ to both sides of (4), the equation will be

$$(m - p)_t + \alpha\Delta p_t = -\alpha\Delta^2 p_{t+1} + \varepsilon_{t+1}. \tag{5}$$

Assume that expectational errors $(\Delta p_{t+1} - \Delta p_{t+1}^e)$ are stationary, then ε_{t+1} is stationary. Since $\alpha\Delta^2 p_{t+1}$ and ε_{t+1} are both stationary, then their linear combination must also be stationary. Real money balances and inflation should also be cointegrated (see Engle and Granger, 1987). If empirically it is shown that real money balances and inflation are cointegrated, then ε_{t+1} will be stationary. With the assumption that expectational errors are stationary, this will support that ψ_t is stationary.

IV. Empirical results

4.1. The data set

The data set consists of monthly observations for the period 1986 : 1–1995 : 3 and data are obtained from the data base of the Central Bank of Turkey. The

[1] Following derivations and explanations are summarized from Phylaktis and Taylor (1993).

variables of the model are price index and money supply. Two indices of price level are used; the Consumer Price Index (CPI) and the Wholesale Price Index (WPI). Money supply is represented by three monetary aggregates; narrow money (M1) which is currency in circulation plus demand deposits, M2 which is M1 plus time deposits, and reserve money (RM) which is currency in circulation plus reserves held by commercial banks at the Central Bank.

4.2. Unit roots and testing for the order of integration

Conventionally, the Dickey Fuller, DF and the Augmented Dickey Fuller, ADF tests are applied to study the unit roots in the real money balance and inflation rate series. Each ADF regression initially includes twelve lagged differences to ensure that the residuals are empirically white noise. Then a sequential reduction procedure is applied to eliminate the insignificant lagged differences. The DF and ADF test results are reported in Table 1. The DF and ADF tests are first applied to each variable for a unit root in levels. Then the same tests are applied to the first differences of the variables that have a unit root in the level specification. The DF and ADF tests are constructed for constant and constant and trend. Lower case letters denote the natural logarithm of variables and Δ denotes first difference of variables. Δcpi denotes consumer price inflation and Δwpi denotes wholesale price inflation. $\Delta\Delta$cpi and $\Delta\Delta$ wpi denote the first differences of these inflation rate series. Real money balance is denoted in the logarithm form, in the form $(m - p)$, where m and p are the logarithm of nominal money balances and prices respectively. So m1-cpi denotes real money balances calculated using M1 and CPI. m1-wpi denotes real money balances calculated using M1 and WPI. m2-cpi denotes real money balances using M2 and CPI, etc.

In all cases the first differenced series do not exhibit a unit root: the I(1) hypothesis can only be rejected when the inflation and real money series are first differenced. So according to the DF and ADF test results, real money balances and inflation rate are each integrated of order one, characterized as I(1), with test statistics significant even at 1% level. Critical values for the DF test statistics are obtained from Fuller (1976), table 8.5.2.

4.3. Testing for cointegration (testing for adaptive expectations)

The null hypothesis of no cointegration between inflation and real money balances against one available cointegrating vector is tested using both the Engle and Granger (1987) two-step procedure and Johansen's (1988) method of maximum likelihood estimation of the multi-cointegrated VAR systems.

The Engle and Granger (1987) two-step procedure involves regressing real money balances on inflation rate first, to obtain the residuals. Then the test for the null hypothesis that cointegration exists is based on testing for unit root in the regression residuals using the ADF tests. The results from the cointegrating regressions are reported in Table 2.

ADF test statistics are initially based on regressions with twelve lags. Then a sequential reduction procedure is applied to eliminate the insignificant lagged differences. The critical values for the ADF test statistics are obtained from Engle and Granger (1987). Real money balances seem to be cointegrated

Table 1. Unit root tests for real money balance and inflation rate series

	Statistic	with constant	with constant and trend
Δcpi	DF	−6.940**	−7.444**
	ADF	−6.828**	−7.403**
$\Delta\Delta$cpi	DF	−12.466**	−12.405**
	ADF	−9.102**	−9.058**
Δwpi	DF	−6.422**	−6.664**
	ADF	−6.422**	−6.664**
$\Delta\Delta$wpi	DF	−13.001**	−12.932**
	ADF	−6.884**	−6.846**
m1-cpi	DF	−2.590	−4.063*
	ADF	−2.859	−3.879
Δ(m1-cpi)	DF	−13.888**	−13.858**
	ADF	−14.924**	−14.857**
m1-wpi	DF	−3.057	−3.217
	ADF	−3.362*	−3.444
Δ(m1-wpi)	DF	−13.006**	−13.016**
	ADF	−13.562**	−13.591**
m2-cpi	DF	−2.392	−2.764
	ADF	−2.721	−2.795
Δ(m2-cpi)	DF	−9.408**	−9.357**
	ADF	−6.620**	−6.583**
m2-wpi	DF	−2.418	−2.394
	ADF	−1.428	−1.346
Δ(m2-wpi)	DF	−8.637**	−8.601**
	ADF	−7.123**	−7.090**
rm-cpi	DF	−1.358	−3.558
	ADF	−0.956	−2.825
Δ(rm-cpi)	DF	−10.405**	−10.384**
	ADF	−10.572**	−10.552**

Table 1 (*continued*)

	Statistic	with constant	with constant and trend
rm-wpi	DF	−2.096	−2.841
	ADF	−2.096	−2.841
$\Delta(rm - wpi)$	DF	−11.043**	−11.072**
	ADF	−11.043**	−11.072**
Critical Values		5%–3.33	5%–3.95
		1%–3.75	1%–4.38

Notes: * Significant at 5% level
** Significant at 1% level

Table 2. Test of cointegration between real money balances and inflation rate

Dependent Variable	Independent Variable	ADF Statistics
m1-cpi	Δcpi	−5.386**
m1-wpi	Δwpi	−4.764**
m2-cpi	Δcpi	−5.393**
m2-wpi	Δwpi	−4.784**
rm-cpi	Δcpi	−5.362**
rm-wpi	Δwpi	−4.770**
Critical values		5%–2.963 1%–3.666

NOTES: * Significant at 5% level
** Significant at 1% level

with inflation rate as ADF test statistics for testing cointegration between real money balances and inflation rate are significant even at 1% level.

Using the procedure suggested by Johansen (1988), cointegration between inflation and real money balances can be investigated by utilizing the, Vector AutoRegression, VAR, model. All empirical models are inherently approximations of the actual data generating process and the question is whether our VAR model is a satisfactorily close approximation. Therefore, we investigated the stochastic specification with respect to residual correlation, heteroscedasticity and normality. The residual tests are reported in Table 3. σ_ε is the standard deviation of the residuals, $\chi^2(2)$ is the Jarque-Bera test statistic for normality, ARCH $F_{(\mathrm{df}:6,58)}$ is the ARCH test for heterocedastic residuals, AR $F_{(\mathrm{df}:6,64)}$ is the test for residual autocorrelation, *skewness* is the third moment around the mean and *excess kurtosis* is the fourth moment around the mean.

Table 3. Residual misspecification tests

Equation	σ_ε	χ^2	Skew.	Ex. kurt.	ARCH 6 F	AR 1–6F
I						
Δ(m1-cpi)	0.0523	5.2473	−0.0289	0.8471	2.1576	0.5801
$\Delta\Delta$cpi	0.0215	71.335	2.6623	12.407	0.0460	0.6436
II						
Δ(m1-wpi)	0.0520	8.3987	−0.1743	1.2193	3.1029	0.5226
$\Delta\Delta$wpi	0.0252	95.613	3.2407	18.469	0.0299	1.8788
III						
Δ(m2-cpi)	0.0212	7.7048	−0.2426	1.1689	0.4264	0.5078
$\Delta\Delta$cpi	0.0181	44.534	2.4360	13.900	0.0491	0.1359
IV						
Δ(m2-wpi)	0.0272	4.8235	−0.2228	0.8143	3.0286	2.5585
$\Delta\Delta$wpi	0.0215	51.185	2.6664	15.210	0.0299	0.8123
V						
Δ(rm-cpi)	0.0425	4.0534	0.1385	0.7027	1.4039	1.0129
$\Delta\Delta$cpi	0.0229	81.052	2.9389	15.2843	0.0481	0.7902
VI						
Δ(rm-wpi)	0.0374	8.7691	0.5873	1.4814	1.1245	0.4862
$\Delta\Delta$wpi	0.0226	43.956	2.3927	12.8392	0.0445	2.3344

The VAR model seems to provide a reasonably good approximation of the data generating process. There is no indication of residual autocorrelation in any of the series ($F_{.99}(6, 64) \approx 3.12$). ARCH 6 F did not reject homoscedasticity of residuals in any of the series ($F_{.99}(6, 58) \approx 3.12$). A few problems remain, such as normality of residuals are rejected for equations of inflation ($\Delta\Delta p$) no matter which price index we used ($\chi^2_{.99}(2) = 9.12$) and first differenced inflation series ($\Delta\Delta p$) appear to be leptocurtic.

In the Johansen (1988) trace test, the null hypothesis is that there are at most r cointegrating vectors and it is tested against a general alternative. In the maximum eigenvalue test, the null hypothesis of r cointegrating vectors is tested against $r + 1$ cointegrating vectors. The hypothesis of at most zero and one cointegrating vectors are tested, respectively, and the maximum eigenvalue and the trace test statistics are reported in Table 4. The critical values for the trace and maximum eigenvalue test statistics are obtained from Johansen and Juselius (1990), table A2.

Applying the trace test and the maximum eigenvalue test for cointegration the hypothesis of at most one cointegrating vector ($H_0 : r \leq 1$) can not be

Table 4. Johansen cointegration tests and estimates

Variables	Eigenvalue Test Statistics		Trace Test Statistics		$\hat{\alpha}$	LR $(100\alpha^{-1} = \pi)$
	$H_0 : r = 0$	$H_0 : r \leq 1$	$H_0 : r = 0$	$H_0 : r \leq 1$		
m1-cpi Δcpi	17.61073	6.41696	24.02769	6.41696	22.0170	2.44227
m1-wpi Δwpi	20.36677	3.451489	23.81827	3.451489	16.7654	1.69635
m2-cpi* Δcpi	15.06210	7.163107	22.22521	7.163107	22.2355	2.76026
m2-wpi Δwpi	20.84050	0.457527	21.29803	0.457527	21.3464	1.73717
rm-cpi Δcpi	15.43711	4.759711	20.19683	4.759711	23.5454	1.86819
rm-wpi* Δwpi	16.01599	8.020865	24.03686	8.020865	22.5000	2.64124

* 11 seasonals are included due to the criterion of having a meaningful long run equilibrium.

rejected in any case, while the hypothesis of zero cointegrating vectors ($H_0 : r = 0$) can be rejected in all cases. Hence, real money balances and inflation are cointegrated with the cointegrating vector $[1, \alpha]$ (after normalization on real balances). This suggests that the Cagan specification can be applicable for the Turkish economy and the monetary and inflationary experiences of Turkey can be explained by Cagan (1956) model.

Cagan (1956) also studied the maximum amount of revenue that is available from inflation tax and proved that the percentage rate of increase in money and prices which maximizes the revenue from inflation tax is equal to $(100/\alpha)\%$ (see, Phylaktis and Taylor, 1993, p. 35). Table 4 reports the estimates of α, which is the cointegrating parameter after normalization on real balances and the likelihood ratio test statistics, LR, constructed as in Johansen (1988), for the null hypothesis that $100/\alpha$ is equal to the realized average inflation rate considering the entire sample period. LR is distributed as chi-square with one degree of freedom. The critical value for chi-square with one degree of freedom at 5% level is equal to 3.84. Therefore the null hypothesis can not be rejected in any case at the 5% level.

4.4. Testing the rational expectations hypothesis

If expectations are formed according to the rational expectations hypothesis, and following Sargent (1977) and Phylaktis and Taylor (1993, p. 35), it is assumed that $E(\psi_t | I_t) = 0$, where denotes the missing variables from the money demand function, then the forecasting errors will be,

$$\xi_{t+1} = \Delta p_{t+1} + \alpha^{-1}(m - p)_t, \tag{6}$$

should be orthogonal to information available at time t, I_t, that is

$$E(\xi_{t+1}|I_t) = 0. \tag{7}$$

Testing the rational expectations hypothesis is equivalent to testing zero coefficients which are obtained from a least squares projection of ξ_{t+1} on its own lagged values in (7) (see Taylor (1991)). Table 5 reports the test results of the hyperinflation model under rational expectations using two kinds of forecasting errors, ξ_t. The first forecasting error were built depending on the Johansen cointegration estimate of α and the second one were built depending on the supposition of inflation tax revenue maximization, $\alpha = 100\pi^{-1}$. Test statistics are distributed as $F(12, 85)$ under the null hypothesis of rational expectations. In all cases the F-statistics are highly significant and these results indicate rejection of the null hypothesis of rational expectations. So, it appears that the Cagan model cannot be linked with the rational expectations for the Turkish case in the considered period. However, we believe that there is another kind of rejection which is isomorphic to the rejection of the hypothesis of rational expectations. That is a rejection of the assumption as made on ψ_t being wrong. Therefore, rational expectation model specification may not be a correct specification for the Turkish case using the monthly data set.[2] This fact requires the rejection of both rational expectation hypothesis and Cagan's rational expectation specification for the Turkish case.

V. Conclusion

This paper considers the demand for money under circumstances of high inflation in Turkey during the period 1986 : 1–1995 : 3. We first determine that real money balances and inflation are each first difference stationary, or I(1), using DF and ADF unit root tests. Thus, a simple test of the suitability of the hyperinflation model lies in testing whether or not real money balances and inflation are cointegrated. The cointegration test is performed using both the Engle and Granger two step approach and Johansen's cointegration. In the paper, we also test the hypothesis that the monetary authorities expanded the money supply in order to maximize the inflation tax revenue in Turkey for the considered period, using Johansen's cointegration analysis. We also believe that, in the last decade, economic agents can have rational expectations for inflation. Following this intuition, we implement Cagan model with the additional assumption of rational expectations for Turkish economy.

[2] The source of this misspecification is the other elements of the demand for money function which are treated as unobservables (inflation expectations and real income). The Cagan model should be augmented as follows including the other unobservables:

$$(m - p)_t = c - \alpha\pi_t^* + \beta y_t + \phi_t^* \tag{8}$$

where y_t is the log of real income. We realize the importance of missing real income variable which grew 2.3 percent over the period of consideration. Since the monthly data on Turkish real income is not available, we are forced to treat y as an unobservable. However, we have repeated the whole analysis including the real income using equation (8) with quartely data for the period 1987:1–1996:2. The findings confirmed that the real money balances are cointegrated with inflation and real income and the rational expectation hypothesis is also rejected by the quartely data. Findings are not reported here but, they can be requested from the authors.

Table 5. Tests of the hyperinflation model under rational expectations

Variables	F-statistics with α as	
	Cointegration Estimate $F(12, 85)$	$100\pi^{-1}$ $F(12, 85)$
m1-cpi Δcpi	271.513	270.470
m1-wpi Δwpi	148.623	151.222
m2-cpi Δcpi	258.756	258.850
m2-wpi Δwpi	152,141	151.550
rm-cpi Δcpi	274.795	274.749
rm-wpi Δwpi	149.328	146.045

The results of this paper suggest that inflationary and monetary behaviour of Turkish Economy can be explained by Cagan's hyperinflation model for the period 1986 : 1–1995 : 3. Moreover, it appears that in the considered period the authorities expanded the money supply as maximizing the inflation tax revenue. Although we had the intuition that in the last decade economic agents have rational expectations for inflation, it appears that both the Cagan's rational expectation specification and the rational expectations hypothesis itself, which are isomorphic to each other are rejected for Turkey for the considered period.

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