Exchange Market Pressure and Intervention Index for Pakistan: Evidence from a Time-Varying Parameter Approach

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Abstract- **The paper uses the approach of Weymark (1995) for constructing exchange market pressure and intervention index for Pakistan and to account for potential linearity. A rolling regression indicates unstable real money demand and price equation estimates. Consequently, a Kalman filter approach is used for evaluating the effects of structural changes on parameter constancy. The results indicate unstable real money demand and price equation parameters. The evidence shows downward pressure and active Central Bank intervention. Exchange Market Pressure mean value for the first half is higher than the second half of the sample period suggesting the post-reform period as more tranquil.**

Keywords: Financial markets, Term structure of interest rate, Central Bank Intervention.

1. Introduction

A stable relationship among the variables of interest is a prerequisite for the formulation of effective policy. This implies that an effective response to exchange rate fluctuations in the context of a fixed parameter exchange rate model rests on stable real money demand and price equation. Thus the monetary policy will have any predictable effect on exchange rate stability if real money demand and price equations are stable. This makes it necessary to investigate the stability of model's equilibrium relationship.

Using a simple macroeconomic model with rational expectations, Weymark (1995) constructed a quarterly measure of exchange market pressure and intervention index for Canada between 1975 and 1991. A Weymark-type model was also applied to Australia and Greece by Leu (2009) and Apergis and Eleftheriou (2002), respectively. All these studies use fixed parameter approach for constructing exchange market pressure and evaluating monetary policy of the respective countries over the given sample period.

However, a fixed parameter approach in presence of structural instability is considered as one of the most important factors for the poor performance of exchange rate models. Lucas (1976), Meese and Rogoff (1983) and Wolf (1987) consider changes in policy regime, unstable money demand functions, changes in global trade patterns and productivity differential as the important factors for out-of -sample poor performance of exchange rate models. Frenkel (1981) particularly attributes the 1970s collapse of purchasing power for money, differential productivity growth and uncertain future course of political and economic events which induced sharp and frequent changes in expectations. Pakistan economy has also seen major structural changes over recent decades. These changes include: (a) Pakistan's switch from a fixed to a managed floating exchange rate regime with effect from January 8th, 1982, (b) introduction of an interest-free banking system in 1981and subsequent replacement of interest–bearing deposits with a system based on profit and loss–sharing principle from July 1st, 1985 see Khan (1994); and Ahmad and Khan (1990), (c) denationalisation of public sector banks, (d) enhancement of Central Bank authority over financial system of the country and, (d) the imposition of sanctions on the country in wake of nuclear explosions.[1] We are of the opinion that these structural changes may have influenced parameters stability of the variables of interest. Therefore, it seems important that when estimating real money demand and price equation, we take account of potential time-varying nature of estimated parameters.

The effects of these structural changes on parameter constancy are evaluated using a time varying parameter approach. Contrary to *F* – test or dummy variable, a non-linear approach does not require any prior knowledge of a point in time when a shift in the parameters of equation is suspected; see Laumas (1983). Based on time- varying estimates of real money demand and price equation, an exchange market pressure and intervention index is constructed for Pakistan. The basic objective is to check the direction of pressure and use intervention index values as a tool for evaluating monetary policy implemented over the given sample period. This will determine the extent which Central Bank allows to market forces in determining the value of domestic currency in foreign exchange market.

We are unaware of other studies that attempts to construct Exchange Market Pressure and intervention indices using time varying estimates of real money demand and price equation. Thus it contributes to empirical Exchange Market Pressure literature by evaluating the effects of structural changes on parameter constancy using Kalman filtering approach and hence will enable the monetary authorities to formulate an effective monetary policy response to market pressure. The results show that the estimated parameters are time-varying and exhibit large fluctuations, thus implying parameter instability over the given sample period. The time-varying estimates of Exchange Market Pressure and

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[1] The State Bank of Pakistan took extraordinary measures to mitigate the uncertainty about Pakistan's economy. These include: (a) freezing the foreign currency accounts, (b) introducing multiple exchange rate regime (c) preventing speculative activity in inter-bank forex market, (d) discouraging capital outflows, (e) containing import demand and (f) discouraging overdue export bills.

intervention index show downward pressure and active central bank intervention. The intervention index mean value indicates that foreign exchange reserves rather than exchange rate changes absorbed most of the pressure facing foreign exchange market. Further, Exchange Market Pressure and intervention index mean values for the first half are higher than in the second half of the sample period, implying post-reform period as more tranquil. This suggests that in the post reform period, Central Bank's independence in formulating an effective monetary policy has substantially increased.

The rest of the paper proceeds as follows. The earlier empirical work that has addressed the stability of real money demand and price equation is reviewed in section 2. Section 3 discusses Weymark (1995) model and section 4 details the methodology that includes rolling regression results of real money demand and price equation and discussion on Kalman filtering approach in section 4.1. Section 5 discusses the data while in Section 6 we discuss the results obtained using non-linear approach. Section 7 concludes.

2. Literature Review

The formulation of an effective monetary policy to deal with exchange rate fluctuations requires stable real money demand and price equation. This implies that monetary policy will have a more predictable impact upon exchange rate fluctuations, if there is a stable relationship among the variables of interest. The fixed parameter approach has the disadvantage that it does not evaluate the effects of structural changes on parameter constancy. This makes it necessary to use a non-linear approach for evaluating the effects of structural changes on parameter stability.

A large number of studies have addressed the issue of money demand stability in Pakistan. Mangla (1979) applied Chow's test statistic to ordinary least square estimates of money demand function and found evidence in support of stability. Khan (1980) evaluated the effects of country's split in two wings in 1971 on the stability of money demand function using a covariance analysis.[2] The results suggested a structural shift due to country's disintegration. However, a Chow test statistic in Khan's (1980) provided evidence that supported stable money demand function from 1971 to 1978. Nisar and Aslam (1983) also used the same approach and obtained results supportive of parameter constancy. These studies are spurious due to use of non-stationary data and ordinary least square approach. Further, Chow and covariance test statistics do not tell if the instability in the estimated macroeconomic model is due to change in intercept or slope or both. Furthermore, the Chow test assumes prior knowledge of structural breaks (Gujarati, 2003).

Contrary to above studies, Ahmad and Khan (1990) evaluated the stability of *M*1 and *M*2 for the period 1959-1960 to 1986 –1987 using Cooley and Prescott (1976) time varying parameter approach. The results support stability hypothesis for the period 1959-1960 to 1980-1981 and unstable thereafter. Chow test applied by Qayyum (2001) to cointegration and error correction estimates of aggregate, business and personal demand for *M*2 do not reject the null of stability of all these money demand specifications. Qayyum (2005) applied CUSUM and CUSUMSQ to short run estimates of *M*2 money demand and found evidence that support stability hypothesis. The above discussion shows that all studies except Ahmad and Khan (1990) have applied either Chow or covariance tests to the residuals of fixed parameter estimates and found evidence that support stable real money demand function. Ahmad and Khan (1990) on the other hand, relied on Cooley and Prescott's (1976) time varying approach for testing the stability of money demand function.

There is an extensive literature on purchasing power parity from developed countries perspective. However, it has not received adequate attention from developing countries perspective. Baillie and Selover (1987), Corbae and Ouliaris (1988) and Taylor (1988) examined the recent float period for Canada, France, Germany, Italy, Japan, the UK, the US and West Germany using Engle and Granger's (1987) residual-based cointegration approach. Although they found evidence of unit root in exchange rate and relative prices, the null of non-stationarity of the residuals was not rejected. Taylor and McMahon (1987) on the other hand, applied the same approach to bilateral rates between the US dollar, the UK pound, the French franc and the German mark and found evidence that supported the validity of an absolute version of PPP for all countries except the UK from February, 1921 to May, 1925. Kim (1990) also obtained the same results for France, Italy, Japan, the UK and the US using a wholesale price index. However, for consumer price index, the results do not support the validity of long run purchasing power parity. Contrary to these studies, Dutt (1998) applied the Harris-Inder null of cointegration approach to real exchange rate and found evidence supportive of PPP for European Monetary System member countries.[3] Frenkel (1981) instead of adopting a cointegration approach tested the validity of purchasing power parity for the US, the UK, France and Germany using two-stage least square approach. He found evidence that supported PPP for the period 1920 to 1925. However, 1973 to 1979 estimates do not support the validity of PPP. Frenkel (1981) attributed the collapse of purchasing power parity during 1970s to volatile nature of the decade that resulted from real shocks, supply shocks, commodity booms and shortages, shifts in the demand for money and differential productivity growth. He re-estimated PPP equation for exchange rates that do not include US dollar or US prices and found evidence that was more supportive of PPP.

The above studies provide mixed evidence on long run validity of purchasing power parity. This may be due to failure of fixed parameter approach in taking account of the effects of structural changes on parameter constancy. Corbae and Ouliaris (1991) and Flynn and Boucher (1993) evaluated the effects of structural breaks on real exchange rate using Augmented Dicky Fuller (1984) and Perron (1989) modified unit root tests. The results show that the hypothesis of unit root in real exchange rate cannot be rejected. On the other hand, Liu and Burkett (1995) relied on a Kalman filtering approach for testing the stability of short run adjustment to long run purchasing power parity and found evidence that did not support the null of stability for Argentina, Chile, Colombia, and Mexico. Contrary to these studies, Canarella et al. (1990) re-examined the cointegration property of exchange rate and relative prices in a time varying parameter framework. Based on monthly data for Canada, Germany, Japan and the UK vis-à-vis the US, they show that a cointegration approach in a time-varying framework yields

[2] Prior to December 1971, Pakistan consisted of two wings namely East and West Pakistan. However, East Pakistan separated from West Pakistan in 1971 and emerged as a new country called Bangladesh.

[3] Harris-Inder tests the null of stationarity against the alternative of a unit root. It makes a distinction between series with unit and near unit roots.

results that support the validity of long run purchasing power parity.

3. Time-Varying Parameter Model

Prior to Weymark's (1995) model, Girton and Roper (1977) and Roper and Turnovsky (1980) constructed exchange market pressure indices. Girton and Roper (1977) assign equal weights to exchange market pressure index components and is a simple sum of exchange rate and foreign exchange reserves changes. On the other hand, Roper and Turnovsky (1980) use stochastic *IS-LM* framework for deriving weights to the components of exchange market pressure index. However, none of these indices show what fraction of pressure Central Bank relieves through the purchase and sale of foreign exchange reserves.

Weymark (1995) addressed this issue. Based on estimated exchange market pressure index, she constructed an intervention index that shows what fraction of pressure, the Central Bank relieves through the purchase and sale of foreign exchange reserve. Weymark (1995) developed a small, open economy model of Exchange Market Pressure. This consists of nominal money demand, price equation, uncovered interest rate parity, money supply process and monetary authority response function to exchange rate fluctuations and is given as:

$$m_t^d = p_t + b_{t1} y_t - b_{t2} i_t + v_t$$
$$b_{t1} > 0 \text{ and } b_{t2} > 0 \quad (1)$$

$$p_t = a_0 + a_{t1} p_t^* + a_{t2} s_t$$
$$a_{t1}, a_{t2} > 0 \quad (2)$$

$$i_t = i_t^* + E_t s_{t+1} - s_t \quad (3)$$

$$m_t^s = m_{t-1}^s + \Delta d_t + \Delta f_t \quad (4)$$

$$\Delta f_t = -\rho_t \Delta s_t \quad (5)$$

Asterisks denote foreign counterpart of domestic variables. The *t* subscripts show that the estimated parameters are allowed to vary over a time to account for the effects of structural changes on parameter constancy. Hence the estimated parameters are time varying.

Equation 1 is a money demand function, which is a positive and negative function of domestic income and interest rate. Similarly, equation 2 is a purchasing power parity, which indicates that domestic prices are positively influenced by changes in foreign prices and exchange rate. Equation 3 is uncovered interest rate parity, which shows that the difference between domestic and foreign interest rate is reflected in expected exchange rate changes. Equation 4 shows the evolution of domestic monetary base. It indicates that domestic money supply (m_t^s) is determined by inherited money stock (m_{t-1}^s), changes in domestic credit (Δd_t) and foreign exchange reserves (Δf_t). Equation 5 is monetary authority's response function. It suggests that Central Bank reduces pressure by intervening in foreign exchange market. This explains negative sign for exchange rate changes.

Substitution of equation 2 and 3 into 1, taking the difference of the resulting equation, combining it with the central bank's response function and re-arranging the resulting equation yields an equation for the changes in exchange rate:

$$\Delta s_t = \frac{-\{(a_{1t}\Delta p_t^* + b_{1t}\Delta y_t - b_{2t}\Delta i_t^* + v_t - \Delta d_t - b_{2t}\Delta ES_{t+1}) + \Delta f_t\}}{a_{2t} + b_{2t}} \quad (6)$$

Partial derivative of exchange rate with respect to foreign exchange reserve changes yields:

$$\eta_t = -\frac{\partial \Delta s_t}{\partial \Delta f_t} = \frac{-1}{a_{2t} + b_{2t}} \quad (7)$$

The negative sign of exchange rate elasticity with respect to foreign exchange reserves (η_t) show that exchange rate changes and foreign exchange reserve move in the opposite direction. Hence a rise in foreign exchange reserves causes the exchange rate to appreciate, and vice versa.

The log linear small open economy model given above allows us to construct exchange market pressure (EMP_t^{TVP}) index given as:

$$EMP_t^{TVP} = \Delta s_t + \eta_t \Delta f_t \quad (8)$$

Based on the above definition of Exchange Market Pressure index, Weymark (1995) defines intervention index as:

$$\omega_t^{TVP} = \frac{\eta_t(\Delta f_t)}{EMP_t} = \frac{\eta_t \Delta f_t}{\Delta s_t + \eta_t \Delta f_t} \quad (9)$$

Division of numerator and denominator of right hand side of equation (9) by $1/\eta_t$ gives:

$$\omega_t^{TVP} = \frac{\Delta f_t}{\frac{1}{\eta_t}\Delta s_t + \Delta f_t} \quad (10)$$

ω_t^{TVP} is a fraction of pressure that Central Bank relieves through the purchase and sale of foreign exchange reserves. It takes values between $-\infty < \omega_t^{TVP} < \infty$. $\omega_t^{TVP} = 0$ indicates absence of Central Bank intervention. This is consistent with flexible exchange rate system. $\omega_t^{TVP} = 1$ indicates that the Central Bank relieves the entire pressure by sale and purchase of foreign exchange reserves. This is consistent with fixed exchange rate regime. $0 < \omega_t^{TVP} < 1$ shows that the Central Bank used both exchange rate and foreign exchange reserves changes for restoring foreign exchange market equilibrium. $\omega_t^{TVP} < 0$ shows Central Bank leaning with wind–that Central Bank purchasesd foreign exchange reserves in presence of downward pressure. $\omega_t^{TVP} > 1$ suggests $\Delta f_t > EMP_t^{TVP}$. This results exchange rate changes opposite to those warranted by the pressure.

4. Methodology

The structure of the economy does change over a time and these structural changes may have significant effect on the constancy of estimated parameters. The fixed parameter approach has the disadvantage that it does not take into account the effects of structural changes on parameter constancy. This makes it necessary to adopt a time varying

parameter approach for evaluating the effects of structural changes on the constancy of the estimated parameters.

Prior to discussing Kalman filter approach, the rolling regression method based on three three-quarter window is used to justify the use of time-varying parameter approach. Initially, first twelve observations are used for estimating coefficients using ordinary least square approach. Since serial correlation is a fundamental problem of time series data therefore, Newey-West test statistic is used for adjusting standard errors of the estimated parameters. The first observation is then dropped and another one added (in this case the thirteenth observation) and re-estimated. This process continues until the last observation is used in the analysis. Figure 1 (given in appendix) shows that the rolling regression estimates of real money demand and price equation are time varying, thus justifying the use of Kalman filtering approach.

4.1 Kalman Filter Approach

The Kalman Filter algorithm-based time-varying parameter approach is a non-linear approach and allows us to evaluate the effects of structural changes that have taken place in the economy over the given sample period on parameter constancy. It is given as:

$$y_t = x_t^{'}\beta_t + \varepsilon_t \qquad (11)$$

where y_t denotes dependent variables, x_t is a vector of explanatory variables, β_t is k x 1 vector of time–varying coefficients and ε_t is a disturbance term. The error term ε_t is assumed to be normally distributed with mean $E(\varepsilon_t) = 0$ and variance $[\text{var}(\varepsilon_t) = \sigma^2_{R,t}]$. Equation (11) is also called observation or measurement equation. Generally, the elements of β_t are not observable and are generated by first order Markov process, see Harvey (1989):

$$\beta_t = \beta_{t-1} + u_t \qquad (12)$$

Equation (12) is called a transition equation because it describes the transition of state equation from period $t - 1$ to period t, see Lutkepohl (2005). The matrix β_t is a coefficient matrix that depends on its past values and the error process u_t. It is assumed that the transition equation error term is normally distributed with mean $E(u_t) = 0$ and variance $[\text{var}(u_t) = \sigma^2_{Q,t}]$. Furthermore, it is assumed that ε_t and u_t are independently distributed: that is $E(\varepsilon_t u_t) = 0$ and ε_t, u_t and β_t are independent of each other. Equations 11 and 12 are called state space system that can be estimated recursively using Kalman filter algorithm.

The basic objective of Kalman filter is to update the knowledge of the system each time a new observation is brought in, see Durbin and Koopman (2001). If it is assumed that the errors ε_t and u_t have normal distribution and that the coefficient matrix β_t has a prior distribution with mean $\beta(0|0)$ and covariance matrix $p(0|0)$ then the conditional distribution $p(\beta_t | Y_t)$ and $p(\beta_{t+1} | Y_t)$ are also normal. If we denote the mean and the covariance of the state vector by $p(\beta_t | Y_t)$ by $\beta_{t/t}$ and $P_{t/t}$ respectively and those of $p(\beta_{t+1} | Y_t)$ by $\beta_{t+1/t}$ and $P_{t+1/t}$ then the Kalman filter recursion which is commonly referred to as Kalman filter are given by equations 13 to 16, see Abraham and Ledolter (1983):

$$\beta_{t+1/t} = \beta_t \qquad (13)$$

$$P_{t+1/t} = P_{t/t} + Q \qquad (14)$$

$$\beta_{t+1/t+1} = \beta_{t+1/t} + k_{t+1}(y_t - x_{t+1}^{'}\beta_{t+1/t}) \qquad (15)$$

$$P_{t+1/t+1} = P_{t+1/t} - k_{t+1}x_{t+1}^{'}P_{t+1/t} \qquad (16)$$

where

$$k_{t+1} = P_{t+1/t}x_{t+1}^{'}[x_{t+1}P_{t+1/t}x_{t+1}^{'} + R]^{-1}$$

Equation (13) and (14) are one step ahead estimate of state vector and its covariance matrix. Equation (15) and (16) are updated means and variances of state vectors once new observation y_{t+1} becomes available. The revised estimate is simply the sum of estimates of state vector up to period t and a linear combination of one step ahead forecast error. The matrix k_{t+1} is the Kalman gain matrix and determines the weight assigned to the most recent forecast errors.

5. Data

The data on all variables except nominal Gross Domestic Product and monetary aggregate come from International Monetary Fund *International Financial Statistic*. Statistical Department State Bank of Pakistan provided us quarterly nominal GDP data. The data on nominal monetary aggregate come from Thomson Reuter's datastream. Real GDP and real monetary aggregate data is obtained by adjusting their nominal counterparts using Pakistan CPI. Real GDP and money (*M*1) were seasonally adjusted using X–12 ARIMA seasonal adjustment program. All variables are in logarithmic form.

6. Results

Figure 2 (given in appendix) shows $\pm$ two standard error time varying parameter estimates of interest rate, foreign price, exchange rate and domestic real income. It is evident from the figure that initially, the estimated parameters show some fluctuation with increased standard errors. This is due to a small number of observations that are used for estimating additional parameter of interest. Once the information that is used for predicting t+1 observation increases, the estimated parameters stabilise and their corresponding errors are reduced.

Figure 2 further shows that all variables stay within $\beta_t \pm$ two standard error band. The interest rate shows positive sign for the short period. However, for the later period, it is negative and insignificant. The estimated exchange rate parameter is negative for the initial period. However, for the later period, it is positive and significant. The foreign price coefficient is positive and significant for the entire period. Initially, it increases and then fluctuates around its unity value. Furthermore, exchange rate changes dominate foreign price changes. This could be due to monetary authorities' management of exchange rate with corresponding implications for domestic price level, see Liu and Burkett (1995) and Mahdavi and Zhou (1994). The domestic real

income coefficient shows pattern similar to foreign price. It first increases and then fluctuates around its unity value. These findings confirm that the structural changes that have taken place over the given sample period have caused parameter instability. Exchange market pressure mean values for the pre and post financial liberalization period are 0.01 and 0.003 respectively. This provides evidence that financial liberalization has reduced pressure on domestic currency to depreciate. Similar to market pressure values, intervention index mean value has reduced from 0.954 to 0.536. This implies that in the post financial liberalization period, Central Bank has given major role to market forces in determining the value of domestic currency in foreign exchange market. This shows that in the post financial liberalization period, monetary authorities were more independent in formulating an effective monetary policy.

7. Conclusion

In this paper, we examined the prevailing market pressure on domestic currency in foreign exchange market and evaluated the Central Bank's monetary policy using non linear approach. The results indicate that the structural changes have caused instability in the estimated parameters. The exchange market pressure and intervention index show downward pressure and active Central Bank intervention. Furthermore, the exchange market pressure and intervention index mean values for the first half are higher than the second half suggesting post financial reform period more tranquil. This has an important policy implication that in the post financial liberalization period, monetary authorities were more independent in formulating an effective monetary policy.

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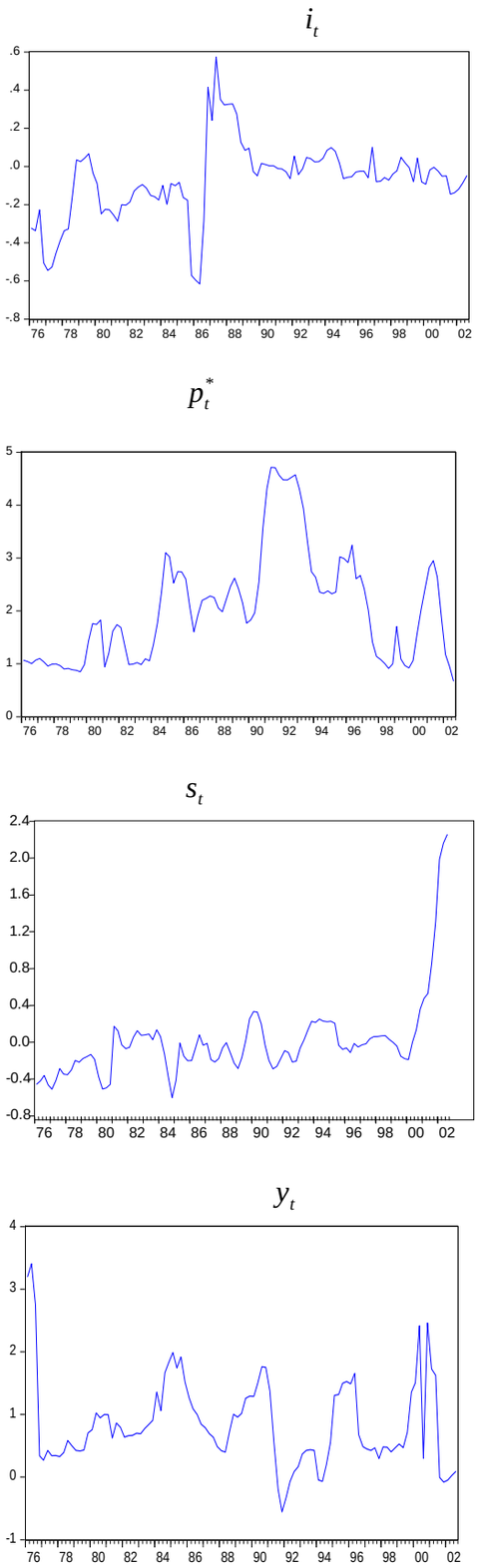
Appendix 1

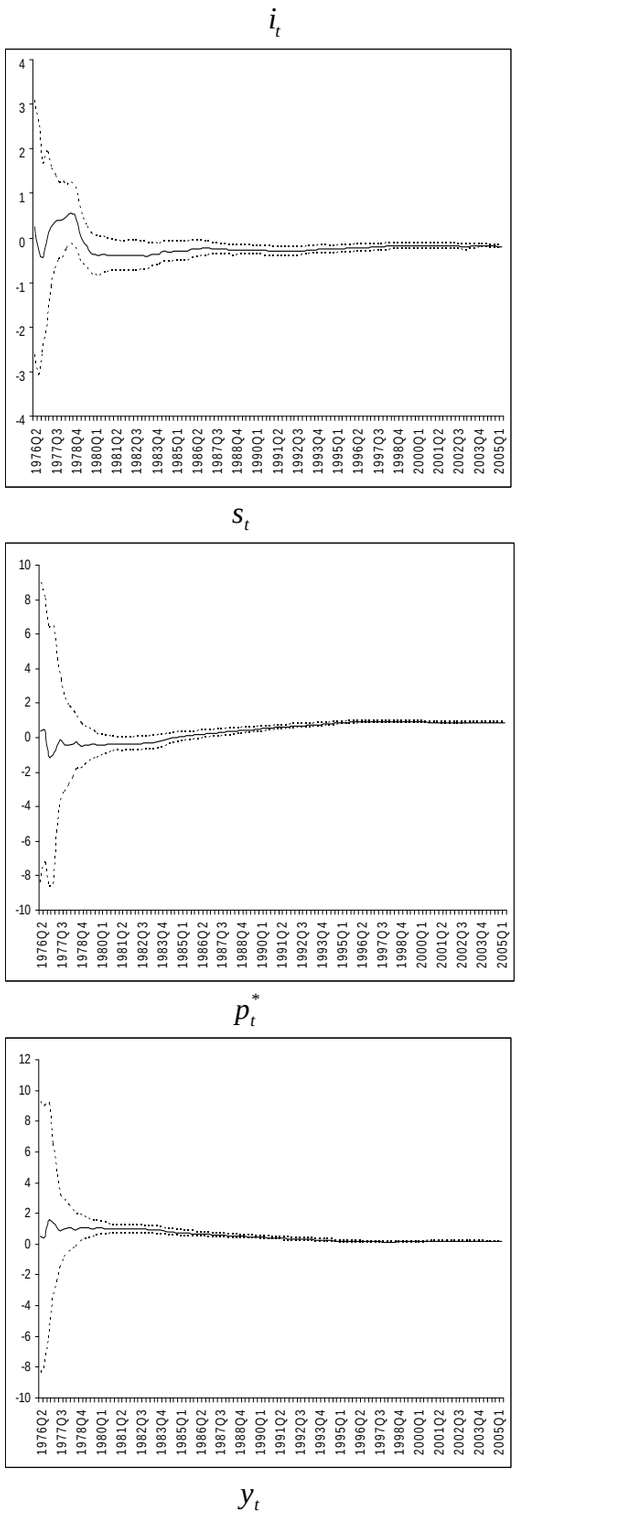
Figure 1: Rolling Regression Estimates

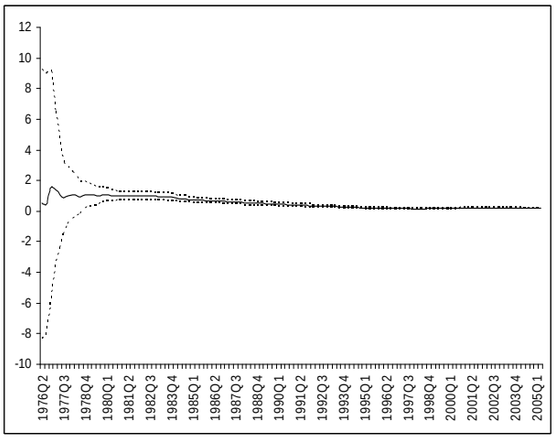


Note: Rolling regression estimates of real money demand and price equation

Appendix 2

Figure 2 Time varying parameter estimates of money demand and price equation





Note: dotted lines show $\beta \pm 2$ standard errors.

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