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Capital Movements and Sterilization Policy in Pakistan: Evidence from Generalized Method of Moments

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This paper utilizes generalized method of moments and monthly data from 1982M1 to 2013M12 to check the interaction between net domestic assets and net foreign assets. The objective is to check the extent by which the Central Bank neutralizes effects of changes in foreign capital inflows on domestic monetary base and how capital inflows respond to such efforts of monetary authorities in Pakistan. Results indicate that the Central Bank partially sterilized the effects of foreign capital inflows. However, such sterilization measures resulted equal and opposite changes in foreign assets which is consistent with perfect asset substitutability. This finding has important implication that monetary authorities' in Pakistan are not independent in formulating an independent monetary policy. The Central Bank's efforts to maintain domestic monetary base unchanged by changing net domestic assets results equal and opposite changes in its net foreign assets.

Keywords: sterilization, capital movements, foreign exchange reserves, domestic monetary base
JEL Classification Codes: *E31, E44, E51, E52, E58, F 31, F32,*

Pakistan switched from fixed exchange rate to managed float on 8th January, 1982. Shift in exchange rate regime ushered marked fluctuations in country's foreign exchange reserve accumulations. Foreign exchange reserves which stood at US $ 968.5 million in 1982[1] averaged US $ 863.75 million from 1982 to 1989. Foreign inflows averaged US $ 1181.41 million during the decade of 1990s. Despite marked increase, foreign inflows remained more volatile during the decade of 1990s due to political uncertainty, structural adjustments, climatic conditions, cessation of foreign aid from the US and its allies after the collapse of USSR in 1992 and nuclear sanction which were imposed on the country in wake of nuclear explosions on 28th May, 1998.

September 11th, 2001 the US terrorist attack proved turning point in Pakistan's history of reserve accumulation. Pakistan aligned itself with the US and its allies in their war against terror. Sanctions imposed on the country during the decade of 1990s were lifted which resulted massive capital inflows in the country. Prior to 2000 Pakistan reserves stood at the US $ 1513.35 million and increased to the US $ 8078.29 million by the end of 2002. However, abrupt fall in country's reserve accumulation occurred in 2008 due to Benazir Bhutto assassination and ensuing political turmoil and unrest in the country (Maqsood, 2011).[2]The reserves began to rise again in 2009 as new government started taking loans from IMF and other bilateral and multilateral donors. Subsequent years also saw a rise in foreign exchange reserves due to increase in external aid during 2010, 2011 and 2012 devastating floods.

Foreign exchange reserve changes have implications for domestic macroeconomic indicators. Foreign exchange reserve accumulation help the recipient country to benefit from investment opportunities, meet its precautionary needs, avoid balance of payment crisis, stabilize exchange rate, reduce its reliance on IMF and World Bank, ease external debt obligations, pay for overseas expenditures, expedite economic growth and

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[1] All the data on foreign exchange reserves are from International Monetary Fund's International Financial Statistics CD ROM
[2]Within span of one year, foreign exchange reserves of the country decreased from US $ 14,044 million in 2007 to US $ 7192.24 million.

development (Aizenman & Glick, 2009; Khan, 1996; Lee, 1996; Khan & Ahmed, 2005; Zhang 2010; Rizvi et al., 2011).

Foreign exchange reserves accumulation has also negative implications for an economy. Increase in money supply and exchange rate (Calvo et al. 1994, 996; & Hagiwara, 2004); heightened speculative activity and possibility of financial markets disruption (Lee, 1996); enhanced challenge for central bank to choose between competitive objectives and maintain monetary control in a new liberalized environment (Ljubaj et al, 2010; Zhang, 2010; Altınkemer, 1998) are some of undesirable effects of foreign exchange reserve changes. Decline in export competitiveness due to exchange rate appreciation and rise in inflation due to increase in domestic money supply are major consequences of foreign exchange reserves accumulation.

Central banks most often mitigate the effect of foreign exchange reserve changes on domestic monetary base and take sterilization measures[3] which is an opposite action by monetary authorities' with domestic assets or implement other contractionary monetary policies (Zhang, 2010). Sterilized intervention neutralize the impact of capital movements on domestic monetary base by changing domestic component of money supply (Sarno & Taylor, 2001; Waheed, 2010, Gilal 2011) and measures the effectiveness of sterilization policy of the Central Bank (Kouri & Porter, 1974; Cumby & Obstfeld, 1981).[4]A large sterilization coefficient is consistent with country's ability to conduct an independent monetary policy.

However, sterilization measures have their own weaknesses. Central Bank has to offer higher interest rate to attract investors to purchase domestic bonds. Higher interest rate reduces demand for domestic money but attracts further capital inflows in the country.[5] In such a situation, central bank's sterilization measures will be successful only if domestic and foreign bonds are imperfect substitutes. In case domestic and foreign bonds are perfect substitutes, any effort by the central bank to sterilize increase in monetary base is offset by fresh international flows. However, practically domestic and foreign bonds are imperfect substitutes. International flows induced by interest rate differentials only partially offset monetary policy efforts. Offset coefficient estimated from capital flow equation measures the extent by which fresh capital inflows neutralize the central bank's sterilization policy effects.[6] Higher offset coefficient is consistent with perfect capital mobility and is an indicator of economy's openness (Kouri & Porter, 1974; Ouyang et al, 2007).

There is enough empirical literature on the conduct of sterilization operations of the central bank of Pakistan (Qayyum & Khan, 2003; Jan et al, 2005; Waheed, 2007; 2010; Hashmi et al, 2011; Hassan, 2011) yet it is limited in its scope. Most of them have only estimated monetary policy reaction function and are therefore limited to measuring sterilization coefficient. Contrary to them, we simultaneously estimate monetary policy reaction and capital flow equation to check the sensitivity of capital flows to domestic monetary conditions. Secondly, we estimate sterilization and offset coefficient for a greater time period from 1982 to 2013. Further, we divide the entire sample period into two subsamples from 1982 to 2001 and from 2001 to 2013 based on pattern of capital inflows and shift in exchange rate regime from managed float to free float on 17th July, 2000.

Rest of the paper proceeds as: section two discusses empirical models and discussion on data is given in section three. Section four deals with method of estimation and in section five results are discussed. Section six concludes.

[3]Sterilization measures can be defined in general as any set of policies designed to mitigate the impact of reserve accumulation on domestic inflation and interest rates (Lavigne, 2008).

[4]Central banks use open market operations (OMOs) as a tool for sterilized intervention (Cumby and Obstfeld, 1981; Lee, 1996; Sarno and Taylor, 2001; Siklos, 2000; Jan et al. 2005; Zhang, 2010).Open market operations refer to purchase and sale of domestic bonds especially government securities or bonds/ treasury bills or central bank papers by the central bank (Lee, 1996; Sarno and Taylor 2001).

[5]This is a phenomenon of open economy with free capital mobility. In an open economy an interest rate is a key determinant of international capital flows. A higher interest rate attracts capital inflows and vice versa.

[6]Offset and sterilization coefficient measure the effectiveness of capital controls and Central Bank monetary policy respectively (Kim, 1995).

Empirical Model

There are two approaches to evaluate the effects of sterilized intervention on domestic monetary base. One approach follows Cumby and Obstfeld (1981) and estimates sterilization coefficient from Central Bank reaction function. It consists of a single equation that evaluates how the central bank of a country responds to changes in monetary base caused by changes in net foreign assets.

Kouri and Porter (1974) is a second empirical approach and take into account the sensitivity of capital inflows to Central Bank sterilization measures. It argues that domestic and foreign assets are endogenous hence sterilization and offset coefficient can be estimated from the same function by merely inverting the one for the other.

Kouri and Porter (1974) evaluated the effect of changes in net foreign assets on changes in net domestic assets and vice versa.[7] Reduced-form capital flow equation developed by Kouri and Porter (1974) is given in its general and simple form as:

$$\Delta nfa_t = \alpha_0 + \beta_0 \Delta nda_t + \beta_1 \Delta x_{1t} + u_{1t} \quad (1)$$

nfa_t and nda_t represent net foreign assets and net domestic assets respectively. x_{1t} is a vector of other exogenous variables that influence net domestic assets. u_t and Δ are stochastic disturbance term and first difference operator respectively. Since both net domestic assets (nda_t) and net foreign assets (nfa_t) are endogenous hence we can estimate sterilization and offset coefficient from the same equation (1). Based on Kouri and Porter (1974), we estimate sterilization and offset coefficients for Pakistan from following empirical equations:

$$\Delta nda_t = \alpha_0 + \alpha_1 \Delta nfa_t + \alpha_2 \Delta mpi_t + \alpha_3 \Delta id_t + \alpha_4 \Delta q_t + u_t \quad (2)$$

$$\Delta nfa_t = \beta_0 + \beta_1 \Delta nda_t + \beta_2 \Delta mpi_t + \beta_3 \Delta id_t + \beta_4 \Delta q_t + v_t \quad (3)$$

Equation (2) and (3) are monetary policy reaction function and capital flow equation respectively. The former is used for estimating sterilization coefficient and the latter for estimating offset coefficient. α_1 in equation (2) is sterilization coefficient. It ranges between $0 \le \alpha_1 \le -1$. α_1 =-1 is consistent with full sterilization. α_1 =0 implies no sterilization and α_1 < -1 indicates partial sterilization. β_1 is an offset coefficient and same like sterilization coefficient ranges between $0 \le \beta_1 \le -1$. β_1 = 0 implies domestic and foreign assets are imperfect substitutes and hence net foreign assets do not respond to changes in net domestic assets. β_1 = -1 suggests perfect substitutability of domestic and foreign assets and hence any change in net domestic asset is reflected in equal and opposite changes in net foreign assets. Such a situation characterizes inability of monetary authorities' to conduct independent monetary policy. $-1 \le \beta_1 \le 0$ shows partial effect of changes in net domestic assets on net foreign assets. α_2 and β_2 are greater than zero. An increase in manufacturing production index which is a proxy for increase in national income increases net domestic assets nda_t and net foreign assets nfa_t (Ljubaj et al, 2010). Interest rate differential in both equations is uncertain a priori. Domestic interest rate is inversely related with domestic credit and α_3 < 0 if ($i_t > i_t^*$). This means higher domestic interest rates induces higher capital inflows and requires stronger sterilization in sense of reducing central bank's net domestic assets (Ljubaj et al, 2010). α_3 >0 if $i_t < i_t^*$. Higher foreign interest rate results capital outflow and force the Central Bank to increase domestic credit in order to retain domestic monetary base

[7] Kouri and Porter (1974) developed their model from an open economy financial markets general equilibrium model by synthesizing Branson (1986) stock equilibrium approach to capital flows and Mundell (1968) monetary approach to balance of payments.

at same level (Kouri & Porter, 1974). Real exchange rate coefficient (α_4) is expected to be positive as monetary authorities tend to increase domestic credit to lower appreciation in order to improve competitiveness of domestic goods in international market (Cumby & Obstfeld 1981). Same relationship holds between net foreign assets and other independent variables except net domestic assets (nda_t).[8]

Data

Monthly data from 1982M1 to 2013M12 is used. The data on all variables is taken from International Monetary Fund *International Financial Statistic* CD ROM. All data is used in log difference form. Difference data is used to avoid spurious regression that results when the variables are non stationary that is they are integrated of order one *I*(1). Due to unavailability of monthly data, real income / GDP is proxied with manufacturing price index (mpi_t). Interest rate differential (id_t) is a difference between the US three month commercial paper rate and Pakistan call money rate ($id_t = i_t^* - i_t$). Real exchange rate refers to nominal exchange rate adjusted with foreign to domestic price ratio.

Method

Net domestic assets and net foreign assets are simultaneously determined in equation (2) and (3). Use of ordinary least square in presence of simultaneity results biased and inconsistent estimators. This problem is avoided by instrumenting endogenous variables. Two stage least square and generalized methods of moments are two methods of instrumental variable estimation procedure. Method of moments is called two stage least square (2SLS) if number of instruments equals number of endogenous variables ($q = p$).[9] However, when $q > p$ the system is over identified and in such a case, it is important for using all the information in the sample to develop a procedure that reconciles conflicting estimates that emerge from over identified system (Green, 2002). Hansen (1982) constructed such a procedure and named it generalized method of moments. Consider following equation for understanding GMM estimator:

$$y_i = x_i\beta_0 + u_i \tag{4}$$

x_i is an endogenous variable. Orthogonality condition requires replacing endogenous variables with a set of instrumental variables z_i . Population moment condition based on orthogonality condition is defined as:

$$E(z_i u_i) = E[z_i(y_i - x_i^{'}\beta_0)] = 0 \tag{5}$$

β_0 is true population parameter. Sample counterpart of population condition given in (5) can be written as:

$$\frac{1}{n}\sum_{i=1}^{n} z_i(y_i - x_i^{'}\hat{\beta}_0) = 0 \tag{6}$$

After defining sample counterpart of population moment condition, it is important to find out parameter vector $\hat{\beta}_0$ that solves set of *q* equations.

[8]Given large set of variables used in empirical literature, we adopted a general to specific approach to find out variables that have a significant impact on variables of our interest i.e. net domestic assets and net foreign assets. We estimated a large set of related variables subject to availability of reliable data in order to identify a robust model. The variables tested for this purpose are money multiplier, nominal exchange rate, real effective exchange rate, nominal effective exchange rate, domestic interest rate, foreign interest rate, government borrowing, consumer price index and wholesale price index. Estimated coefficients of these variables were statistically insignificant and signed incorrectly. Further their inclusion in the model did not contribute to the model quality and robustness. Therefore we dropped these variables after some experimentation and estimated the models given in 3 and 4.

[9] This is a case of exact identification (Murray, 2006).

When moment conditions exceed parameters, then the system of equation in (6) is over identified and has no unique solution. In such a situation, it is important to construct an objective function like the one given as:

$$Q(\hat{\beta}_0) = \frac{1}{n}\sum_{1=1}^{n}(z_i u_i)' W \frac{1}{n}\sum_{i=1}^{n}(z_i u_i) = \frac{1}{n}\sum_{i=1}^{n} z_i (y_i - x_i^{'}\hat{\beta}_0)' W \frac{1}{n}\sum_{i=1}^{n} z_i (y_i - x_i^{'}\hat{\beta}_0) \quad \textbf{(7)}$$

This criterion function (*Q*) represents a GMM estimator. W in (7) is non-negative definite weighting identity matrix (z_i) and depends on data but converges to a constant positive definite matrix as $n \rightarrow \infty$ (Kunst, 2008; Zsohar, 2012). Now we can estimate $\hat{\beta}_0$ by minimizing objective function. Though we cannot equate sample moment condition to zero but can reformulate the criterion function and select the parameters such that sample moment is as close to zero as possible.

There are two steps involved in estimating GMM estimator from criterion function given in (7). First we have to define *W* and minimize eq. (7). Although *W* matrix produces consistent estimators yet they are not efficient. In order to estimate consistent and efficient parameters, equation (7) is minimized as:

$$\min Q(\hat{\beta}_0) = \frac{1}{n}\sum_{1=1}^{n}(z_i u_i)' W \frac{1}{n}\sum_{i=1}^{n}(z_i u_i) = \frac{1}{n}\sum_{i=1}^{n} z_i (y_i - x_i^{'}\hat{\beta}_0)' W \frac{1}{n}\sum_{i=1}^{n} z_i (y_i - x_i^{'}\hat{\beta}_0) \quad (8)$$

First we have to estimate $\hat{\beta}_0$ from (8).[10] In second step, covariance matrix is defined to find out most efficient estimator (Cochrane, 2005; Baum, 2008; Zsohar, 2012). The covariance matrix helps to identify weighting matrix with smallest value or the smallest distance of estimated $\hat{\beta}_0$ from zero. Population covariance matrix can be defined as (Baum, 2008):

$$M_0 = E(z_i u_i)(z_i u_i)' \text{ or } M_0 = E(u_i^2 z_i z_i^{'}) \quad (9)$$

Sample counterpart of population covariance matrix is:

$$\hat{M} = \frac{1}{n}\sum_{i=1}^{n}(\hat{u}_i z_i z_i^{'}) \quad (10)$$

This is *q x p* matrix and is constructed in such a way that less weight is placed on more imprecise moments. We redefine weighting matrix in terms of inverse of population covariance matrix (Hansen 2001). Hence $\hat{M}^{-1} = \widetilde{W}$. Now $\widetilde{W}$ is an optimal weighting matrix and places moment conditions in such a way that the conditions with higher variance receive less weight in minimization process. After redefining weighting matrix the objective function is solved and is given as:

$$\min Q(\hat{\beta}_0) = \frac{1}{n}\sum_{1=1}^{n}(z_i u_i)' \widetilde{W} \frac{1}{n}\sum_{i=1}^{n}(z_i u_i) = \frac{1}{n}\sum_{i=1}^{n} z_i (y_i - x_i^{'}\hat{\beta}_0)' \widetilde{W} \frac{1}{n}\sum_{i=1}^{n} z_i (y_i - x_i^{'}\hat{\beta}_0) \quad (11)$$

Now the estimated $\hat{\beta}_0$ based on objective function (11) is efficient, consistent and truly represents population parameter (β_0).[11]

Results

We applied GMM in estimating equation (2) and (3). GMM overcomes simultaneity problem that arises due to simultaneous determination of net domestic assets (nda_t) and net foreign assets (nfa_t) and results consistent and unbiased estimators.[12]Newey-West heteroskedasticity and autocorrelation consistent (HAC)

[10] The GMM minimizing estimator in (8) measures the distance of $Q(\hat{\beta}_0)$ from zero (Hall, 2009).

[11] GMM is called two step method because its estimators involves two stages.

[12] Despite empirical evidence, we applied Hausman's exogeneity test to test if nda_t and nfa_t are exogenous to each other and found them to be endogenous.

covariance estimates are used[13]to circumvent potential problems of autocorrelation and heteroskedasticity in residuals, Table 1 shows estimates of monetary policy reaction function. Sterilization coefficient is significant, correctly signed and its value is -0.20 for the entire sample period.[14] Sterilization coefficient in first and second sub-sample is insignificant and significant respectively. Sterilization coefficient in second sub-sample is -0.38. Higher sterilization coefficient in second subsample indicates active response of the central bank to surge in capital inflows to neutralize the effect of changes in net foreign assets on domestic monetary base. Nonetheless, sterilization coefficients for three different samples speak of low response of monetary authorities to capital movement in the country.[15]

Real exchange rate estimate is positive in entire sample and first sub-sample and negative in second sub-sample. Positive estimate of real exchange rate confirm its theoretical predictions that an increase in real exchange rate improves countries competitiveness and hence cause capital inflows in the country. Negative real exchange rate may be due to higher domestic prices. Positive estimate of real income shows that an increase in economic activity increases demand for domestic money. Similarly, positive interest rate differential estimate for entire sample shows higher foreign interest rate. This caused capital outflow which the Central Bank responded by increasing domestic credit to maintain domestic monetary base at same level.

Table 1
Monetary Policy Reaction Function

Sample	Sample 1: 1982M1 to 2013M12		Sample II: 1982M1 to 2001M09		Sample III: 2001M10 to 2013M12	
Variable	Coefficient	T-statistic	Coefficient	T-Statistic	Coefficient	T-statistic
c	-0.934140	-0.629606	-3.414662 [a]	-4.042972	18.86286 [a]	6.576108
nfa_t	-0.202995 [b]	-1.699413	-0.001615	-0.036471	-0.375434 [a]	-4.017643
q_t	2.714667 [a]	2.617824	5.118988 [a]	6.695401	-5.721278 [a]	-5.325935
mpi_t	1.563447 [a]	5.615157	-0.118914	-0.405422	0.559671 [a]	2.125501
id_t	0.335613 [a]	6.765230	-0.035709	-0.475620	0.041374	0.983580
R^2	0.913541		0.987702		0.937875	
$\overline{R}^2$	0.911470		0.985360		0.936062	
DW Test	0.179789		0.671690		0.233129	
J Statistic	0.185074		2.47E-40		0.509867	
Probability	0.667048		0.00000		0.475197	

[13]We also tested real effective exchange rate, nominal effective exchange rate, nominal exchange rate and Central Bank's lending/credit to domestic institutions/banks and government borrowing as proxy for budget deficit as instruments for checking the robustness and validity of the estimated parameters. However, use of these variables as instruments did not contribute to magnitude of the coefficients and robustness of the model. Rather, the estimated parameters based on these instruments were incorrectly signed and hence we dropped these instruments from final estimation.

[14] We also applied Hansen's J Test for checking over identification restriction in GMM framework (Hall, 2009; Waheed, 2010; 2009; Zsohar, 2012) and found that our models satisfied this condition, are correctly specified and are valid. Table 6.1 shows monetary policy reaction function results for three samples.

[15]Sterilization coefficients estimated values by Qayoom and Khan (2003); Waheed (2007 and 2010); and Hashmi et al. (2011) are -0.72, -0.5, -0.69 and -0.83 respectively. However, all of these studies focus on post 2000 period except Qayoom and Khan (2003) which uses quarterly data 1982Q3to 2001Q2. However, Qayoom and Khan (2003) estimate only sterilization coefficient. Secondly, none of these studies have used instrumental variable technique (GMM or 2SLS) except Waheed(2010) who applied GMM on monthly data from 2001:1 to 2007:06. Nevertheless none of these studies provide any evidence of complete sterilization in Pakistan for any period.

Note: Superscripts a and b indicate estimated parameters significance at 5 and 10 percent significance levels.

Table 2 shows results of capital flow equation. It indicates insignificant offset coefficient in entire sample and first sub-sample. However, offset coefficient in second sub-sample is around -0.82 and is statistically significant. Hence in post 9/11 the US terrorist attack and Pakistan's alignment with western countries in their war on terror also increased Pakistan's financial integration with rest of the world. In such a case any attempt by monetary authorities' to change net domestic assets was foiled by almost equal and opposite changes in net foreign assets. Real exchange rate (q_t) estimate is positive in entire sample period and negative in second sub-sample for capital flow equation.

Table 2
Capital Flow Equation

Variable	Sample 1: 1982M1 to 2013M12		Sample II: 1982M1 to 2001M09		Sample III: 2001M10 to 2013M12	
	Coefficient	T-Statistic	Coefficient	T-Statistic	Coefficient	T-Statistic
c	-3.132594	-1.444913	-0.781989	-0.190631	16.46663 ^{a}	5.202425
nda_t	-0.274683	-0.538454	1.632023	0.833208	-0.815477 ^{a}	-2.250775
q_t	2.196481 ^{a}	2.376858	-0.668413	-0.102498	-3.932566 ^{a}	-3.899184
mpi_t	3.253262 ^{a}	3.186224	-2.173863	-0.829900	1.248978 ^{a}	2.273556
id_t	0.040806	0.349664	0.304329	0.499627	0.010370	0.156272
R^2	0.859142		0.275566		0.596706	
$\overline{R}^2$	0.855828		0.149577		0.584931	
DW Test	0.263447		0.780311		0.125940	
J Statistic	12.65872		3.704700		8.512721	
Probability	0.000374		0.054259		0.003527	

Note: Superscript a indicates the significance of estimated parameter at 5 percent significance level.

Positive estimate shows that an increase in real exchange rate resulted increase capital inflows. However, negative estimate of real exchange rate is due to dominant price effect. Similarly positive manufacturing price index coefficient shows that an increase in domestic real income increases demand for money. At unchanged money supply increased demand for real money balance increase interest rate which caused capital to flow in the country. Interest rate differential estimate in capital flow equation is insignificant for entire sample and two sub-samples.

Conclusion

We used GMM method due to over-identifying restriction to estimate monetary policy reaction function and capital flow equation. Objective was to estimate sterilization measures of the Central Bank and how the country's net foreign assets responded to them. Results indicate that on average the Central Bank sterilized twenty percent effect of net foreign asset changes on domestic monetary base over the entire sample period. However, sterilization percent almost doubled and reached to 38 percent in second sub-sample. The increase in sterilization measures in second sub-sample may reflect the Central Bank's efforts to control inflation and maintain country's competitiveness in international market. Despite increase our estimate of sterilization coefficient is still lower compare to earlier studies on Pakistan.

Lower sterilization coefficient in our study is matched by higher offset coefficient which is insignificant for entire sample and first sub-sample but significant in second sub-sample. Larger and significant offset coefficient in second subsample implies free capital mobility and ensuing monetary policy ineffectiveness. Larger second sub-sample offset coefficient indicates substantial integration of the country's financial sector with rest of the world and perfect asset substitutability. This finding has important implication in the conduct of monetary policy. It implies that in post 11th September, 2001, it has become increasingly difficult for monetary authorities of the country to formulate an independent monetary policy.

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