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DISCUSSION PAPER

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DOMESTIC SAVING AND INVESTMENT REVISED: CAN THE FELDSTEIN-HORIOKA EQUATION BE USED FOR POLICY ANALYSIS?

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DISCUSSION PAPER

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SUMMARY

SINOPSE

Com base na relação entre investimento e poupança doméstica que deriva da equação de Feldstein-Horioka (FH), este estudo objetiva, a partir da aplicação de testes de exogeneidade, verificar de que maneira esta equação pode ser usada como instrumento na formulação de política econômica no Brasil. Numa etapa posterior, utilizam-se os resultados do teste de exogeneidade fraca para identificar um VAR estrutural (SVAR) e obter as funções de impulso resposta (IRFs) que derivam do modelo identificado. Quanto aos resultados referentes aos testes de exogeneidade temos que: *a*) a elasticidade da poupança doméstica estimada de acordo com metodologia apropriada acena na direção de uma alta mobilidade de capital para o Brasil; *b*) a poupança doméstica é fracamente exógena na equação FH; *c*) a poupança doméstica não é fortemente exógena na equação FH, o que significa dizer que não se pode projetar o investimento com base no valor condicionado da poupança doméstica a partir da equação FH; *d*) mostrou-se ainda que poupança doméstica é superexógena na equação FH, o que quer dizer que a crítica de Lucas não se aplica no caso da equação FH; e *e*) os resultados advindos das funções de impulso-resposta mostraram que o investimento é sensível a uma inovação contemporânea na poupança doméstica e que o efeito positivo permanece longo tempo. No que se refere à poupança doméstica, a resposta desta a um choque não esperado do investimento tem uma descrição um pouco mais complicada. Inicialmente a poupança doméstica sofre uma ligeira queda. A seguir, este efeito se aprofunda. Numa etapa posterior o quadro se reverte, passando a poupança doméstica a sentir um efeito positivo desse choque.

ABSTRACT

Based on the relation between investment and domestic saving proposed by Feldstein and Horioka (1980) to verify capital mobility, this study performs some exogeneity tests in order to determine the capacity of the FH equation of supporting and implementing economic policies in Brazil. We then use the result of weak exogeneity test to identify a structural vector autoregressive (SVAR) involving investment and saving in order to evaluate the effect of exogenous shocks through impulse response functions (IRFs) on both variables. The main findings of this paper are: *a*) the elasticity of domestic saving estimated using appropriate methods points out to high capital mobility for Brazil; *b*) domestic saving is weakly exogenous in the FH equation; *c*) domestic saving is not strongly exogenous, therefore this equation should not be used to make forecasts for the Brazilian economy; *d*) superexogeneity is accepted for domestic saving, meaning that Lucas' criticism does not apply; and *e*) the IRFs showed that investment is sensitive to contemporaneous innovation on saving and this effect lasts for a long time. Regarding to domestic saving, the response of this variable to a non-expected shock on investment has a more is more complicate description. Initially domestic saving goes down. After some lags this movement changes and domestic saving begins to react positively to the shock.

1 INTRODUCTION

The correlation between domestic saving and investment is one of the most interesting issues appearing in economics. Academics and policy makers frequently formulate questions regarding their temporal precedence and the relationship between them. Feldstein and Horioka (1980) interpret this correlation as a sign of capital mobility. The basic idea is that in a closed economy and in a low capital mobility scenario, internal saving finances all investment. On the other hand, in an open economy, domestic saving would be used to obtain better returns in the world, and would not necessarily be used to finance domestic investment. Thus, a strong correlation between domestic saving and investment would be a sign of low capital mobility. However, a weak correlation would indicate high capital mobility.[1]

This article attempts to verify the robustness of the Feldstein-Horioka (FH) equation in exogeneity tests for the Brazilian economy during the period 1947-2004. First, Section 2 presents the FH equation, introducing the different kinds of exogeneity, and comments on the importance of these tests for economic policy. In Section 3, we perform an analysis in order to verify whether the investment and saving series are co-integrated. Before performing the Johansen-Joselius procedure to detect co-integration, we apply the Augmented Dickey Fuller (ADF) test in order to verify whether these series follow a nonstationary process. The results of the unit root and co-integration tests show that the investment and saving series are not stationary, and there is no long-run relationship between them. In order to verify whether the relation between investment and saving derived from FH equation is spurious or not in the sense of Granger and Newbold (1974), we estimated in Section 4 the FH equation based on three distinct methods proposed by Hamilton (1993). All the results show that the correlation between investment and saving is not spurious. In Section 5 the exogeneity tests of weak, strong and super exogeneity are undertaken. Then, in Section 6 we use the exogeneity test results to identify a structural dynamic model associated with investment and saving. Using a vector autoregressive (SVAR) we evaluate the effect of the exogenous shocks by impulse response functions (IRFs) on both these variables. Final comments are reserved for Section 7.

2 THE FH REGRESSION AND THE DIFFERENT CONCEPTS OF EXOGENEITY

In a cross-section of 21 OECD countries, Feldstein and Horioka (1980) estimated the relation between the gross investment rate[2] (*INVEST*) and the domestic saving rate[3] (*SAVING*), obtaining the following equation.

$$INVEST = \underset{(0.018)}{0.035} + \underset{(0.074)}{0.887}\,SAVING \tag{1}$$

1. More details on the Feldstein-Horioka test can be obtained in Baxter and Crucini (1993) and Bayoumi (1990).

2. The ratio between investment and Gross Domestic Product (GDP). Investment is the gross capital formation by the public and private sectors, excluding inventories.

3. The ratio between gross domestic saving and GDP.

The authors interpreted the high value of the estimated domestic saving parameter as evidence of low capital mobility across countries. The basic idea is that in a country with a low degree of capital mobility, such as a closed economy, all domestic saving is used to finance domestic investment. Some authors[4] do not consider this correlation as being a sign of capital mobility. For instance, Sachsida and Abi-Ramia (2000) state that this test does not reflect capital mobility in the real world economy, reflecting only the variability between external and domestic saving.

In spite of the criticism, the equation proposed by FH continues to be estimated for several countries in an attempt to reproduce a stylized fact for the economy,[5] and is also used to help formulate economic policies based on the following: *a*) to make inferences regarding the elasticity of domestic saving; *b*) to forecast investment conditional to domestic saving; and *c*) to test whether the relationship in (1) is structurally invariant. Three types of exogeneity tests correspond to these objectives, namely, weak, strong and super exogeneity tests.

The modern treatment of this subject extends and develops the Cowles Commission approach. The classic reference here is the article by Engle, Hendry and Richard (1983), hereinafter referred to as EHR. The basic elements in the EHR treatment are explained in terms of a bivariate data generated process (DGP). Let us consider a simple regression model

$$y_t = \beta x_t + \varepsilon_{1t} \tag{2}$$

where the variables (y_t, x_t) have a bivariate normal distribution $(\mu_y, \mu_x, \sigma_y{}^2, \sigma_x{}^2, \sigma_{yx})$. The conditional distribution of y_t given x_t, is $y_t |, x_t \sim IN(\alpha + \beta x_t, \sigma^2)$. The joint distribution of y_t and x_t, may be written as $f(y_t, x_t) = g(y_t | x_t) h(x_t)$, where g involves the parameter θ, and h is the marginal distribution of x_t. The evolution of x_t may be represented by a regression, such that $x_t = \varphi z_t + u_t$, which is known as the marginal equation. Based on these two distributions, EHR proposed three definitions of exogeneity: weak, strong and super exogeneity.

A variable is said to be *weakly exogenous* if the inference conditional on x_t does not involve a loss of information. If the variable x_t is weakly exogenous and is not Granger caused by y_t, x_t is said to be *strongly exogenous*. Finally, if x_t is weakly exogenous, and the parameters in g remain structurally invariant to changes in the marginal distribution of x_t, then x_t is said to be *super exogenous*.

The remainder of this section is dedicated to shedding more economic light on the importance placed on exogeneity. With regard to weak exogeneity, this property does not have a direct economic interpretation. In the absence of weak exogeneity the estimation of a single equation model would be affected by endogeneity bias,

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4. Sachsida and Abi-Ramia (2000); Coakley, Kulasi and Smith (1996); Baxter and Crucini (1993) and Bayoumi (1990).

5. Hussein (1998) and Mamingi (1997).

meaning that the OLS estimator is biased. Thus, if saving was not weakly exogenous with regard to the FH equation, it would not be correct to use this equation to estimate the relation between investment and domestic saving. Furthermore, its presence is necessary for both the occurrence of super as well as strong exogeneity. Thus, the appeal of testing for weak exogeneity resides in the fact that without this property the variable would have neither strong nor super exogeneity properties.

The strong exogeneity property suggests the capacity of the model to be used in forecasts. Thus, in the presence of strong exogeneity, the FH equation may be used to make forecasts regarding future rates of investment, given certain domestic saving rates. With regard to the super exogeneity property, it allows the FH equation parameters to be used to simulate the effects of different policies. This means that, in the presence of super exogeneity, the Lucas criticism does hold. Hence, due to the fact that the rate of domestic saving is super exogenous in relation to the rate of investment, it is concluded that structural breaks in the domestic saving series did not alter the parameter of this variable in the FH equation. Therefore, policies aimed at increasing the rate of domestic saving (or reducing it) will not be successful in changing the parameter of this variable in the FH equation.

The consequence of super exogeneity is that the adoption of a new economic policy aimed at increasing (or decreasing) the share of domestic saving will not be successful. Thus, when the rate of domestic saving increases (decreases), the rate of investment increases (decreases) at the value of the parameter β, meaning that breaks in the domestic saving series are not able to alter the FH coefficient. This way, the adoption of a new economic policy aimed at increasing the share of domestic saving that is invested, by way of mechanisms that alter the saving series, will probably not be successful.

A second economic interpretation of super exogeneity is that which assumes the coefficient of saving in FH equation as expressing the degree of capital mobility, which did not change over the years, for if it had, the β parameter would not have been the same for the entire series. By definition, super exogeneity implies structural invariance. Thus, if the variable were super exogenous, this would mean that its parameter would not change over time. So, assuming that β expresses the degree of capital mobility, it nevertheless remained constant over the entire period. Thus, by definition, if the rate of domestic saving was super exogenous, this would mean that the degree of capital mobility would not change over time. This result is curious, to say the least, for it means that technological innovations were not able to influence capital mobility.

In spite of not being very intuitive, this last result is not new in the literature, for Tesar and Werner (1995), and Bekaert (1995), in financial integration studies, found that the volatility of financial assets is not related to any financial integration measure, and does not increase as a result of financial liberalization. Thus, if we consider volatility as a measurement of capital mobility, these studies suggest that capital mobility is not affected by technological innovation (which could be understood here as liberalization or greater integration).

3 ARE INVESTMENT AND SAVING SERIES CO-INTEGRATED?

One important problem in applying the original EHR framework is that is common to find in literature macroeconomic time series that are nonstationary processes with unit root [Nelson and Plosser (1982)]. Many consequences arise from this. In general, we can no longer use the standard asymptotic theory. To be more specific, two important facts may arise as a consequence of the presence of the unit root. First, the object equation (2), henceforth the conditional equation, may reflect the long run relationship between variables. In this case, it is said that the series are co-integrated and thus the conditional equation only serves to identify what happens in the long run. Second, when two series have unit roots and are not co-integration, the conditional equation (2) may possibly be spurious. As Montiel (1994) points out, the correlation between investment and saving could be caused by the state of business cycle, i.e., both S/Y and I/Y could be functions of a third variable Y/W. In particular both S/Y and I/Y are said to be procyclical. Yet one can imagine that government could respond to current account deficits (increases I/Y in relation to S/Y) by contracting fiscal policy to achieve an account target. Taking national (domestic) saving as the sum of private and public saving, this making national saving endogenous through its public component. In this case Hamilton (1993) defines some procedures in order to avoid spurious regression.

The unit tests can be used to check the order of integration of the variables. The estimation is performed using annual data between 1947 and 2004. The data used to estimate the FH regression for Brazil was obtained from the IBGE (Brazilian Institute of Geography and Statistics). Using the ADF test,[6] Table 1 investigates whether the investment and saving series have two unit roots. For each series, the first and second lines test the null for a single unit root. The unit root tests are done including constant and constant + time trends. The statistics of the time trend are reported. The lag order was chosen in order to eliminate misspecification (absence of normality, autocorrelation, heteroskedasticity etc). The third line presents the result of tests for a second unit root, i.e., for a unit root test in the first difference allowing for the alternative that the series is stationary in first differences. According to the results of Table 1, the tests do not reject the null of nonstationarity for investment and saving in the level, but reject the null for the series in differences.

Although the ADF test shows that there was no significant evidence against the unit root hypothesis for the series in the level, the tests are not quite confident regarding the presence of time trend in the series. In fact, these tests do not concern the joint hypothesis involving trend and unit root. To ascertain whether a linear time trend is present for both series we introduced two procedures. First, following Stock

6. The Phillips-Perron and other tests like the KPSS test [Kwiatkowsky et al. (1992)] can also be used. The advantage of the PP test is that it is more general than the ADF test because it allows for fairly mild assumptions concerning the distributions of the errors. The usual unit root tests are very sensible to the presence of atypical values in the sample [Frances and Haldrup (1994)]. The presence of atypical values has influence on the power of the test. In this case we can apply the KPSS test. The KPSS test inverts the null hypothesis testing the absence of unit root. The rejection of the null of stationarity hypothesis has an even stronger significance when atypical values are present. We applied the PP and KPSS tests and the results do not reject the null of nonstationarity. For economy we did not include these results in the text. They can be obtained from the authors by request.

and Watson (1987) each series was regressed against a constant, time and three of its lags. Second, we used the ADF test based on the OLS F statistic to test the joint null hypothesis that $\beta = 0$ and $\rho = 1$ in the following equation

$$\Delta y_t = \alpha + \beta t + (\rho - 1)\Delta y_t + \varepsilon_t \qquad (3)$$

TABLE 1
ADF TEST—1947-2004
[H0: the series has an unit root]

Variable	Equation model (1)	Lags (2)	t-ADF (3)	Critical values 1/5 % (4)	Trend[b] (5)
INVEST	Constant + Trend	1	–2.934	–4.128 –3.490	0.0017 (0.145)
INVEST	Constant	4	–1.528	–3.557 –2.917	-
DINVEST[a]	Constant	2	–5.986	–3.555 –2.916	-
SAVING	Constant + Trend	2	–2.177	–4.131 –3.493	0.001 (0.500)
SAVING	Constant	4	–1.524	–3.557 –2.917	-
DSAVING[a]	Constant	3	–6.145	–3.557 –2.917	-

[a] The operator D means the first difference of the variable.
[b] t-statistic and P-value on the time trend.
Note: The series are transformed to logs.

The results of these two methodologies are shown in Table 2. The F test does not reject the null of $\beta = 0$ and $\rho = 1$ which means that both series follow a unit root process without time trend and the test based on Stock and Watson (1987) does not find significance for time trend.

In view of the long period of our sample one may claim that the series may be subject to structural change possibly due to the modification of the economic environment along this period. According to Perron (1989) the presence of one or more structural changes could affect the validity of conclusion that the variables are not stationary. A difficulty with the conventional unit root test, given a structural break, is that the critical values are too small in absolute terms, which leads to the frequent rejection of the hypothesis of the unit roots.[7] Although, as one can see, since our unit root test does not reject the hypothesis of nonstationarity, there is no need to apply a specified method to check for a unit root in presence of structural change. In the following section we will study structural change using parameter stability tests for the estimated VAR which is requested before implementing co-integration analysis.

7. Zivot and Andrews (1992) developed a rigorous methodology to address the problem of structural change based on an earlier study by Perron (1989).

TABLE 2
ADF TEST—1947-2004
[H0: the series has an unit root and no trend]

Variable	Equation Model (1)	Lags (2)	F-stat (3)	Critical values[a] 1/5 % (4)	Trend (P-value)[b] (5)
INVEST	Constant + Trend	1	–4.64	–9.312 –6.730	–0.0017 (0.447)
SAVING	Constant + Trend	2	–4.61	–9.312 –6.730	0.001 (0.556)

[a] Critical values for ADF test based on the OLS F statistic.

[b] t-statistic and P-value on the time trend.

In view of our results based on unit root tests, we can state that investment and saving are nonstationary processes in level without a time trend. Further analysis based on the same approach confirms that both variables are stationary in differences. To verify the consistence of the FH equation, the investment and saving series need to be checked for co-integration. If this is verified, the FH equation reflects the long run relationship between these variables, and Hendry`s methodology (1995) for testing exogeneity can be performed. If not, one has to estimate the FH equation with another method in order to avoid spurious regression, and still another procedure to test the different types of exogeneity.

Engle and Granger (1987) show that if the series are co-integrated they have an error correction representation. Engle and Granger (1987) suggest a two-step estimation approach for dynamic specification, each step requiring only OLS. It consists in estimating the FH equation using OLS and checking whether the residual series is stationary. If so, the FH equation represents the long run relationship between investment and saving. The Engle-Granger procedure is better than the one suggested by Johansen (1988), and generalized in Johansen and Joselius[8] (1990). This method considers a system in which all variables are endogenous, allowing to verify whether more than one co-integrated relationship remains. The Johansen`s methodology is implemented in two steps. First, one has to estimate a vector autoregressive (VAR) determined by some information criteria. After estimating the VAR with the appropriate lag we perform Johansen`s methodology in order to identify the error correction mechanism and the co-integrated relationship.

Appendix 1 presents the results regarding the appropriate lag based on different choice criteria (SBC, HQC, AC etc). The majority of results, including the Schwartz Bayesian criterion (SBC), indicate that the VAR must be estimated with five lags, while the other results indicate that the best choice lag-order selection points out a one lag-order VAR. According to Sims (2005) the SBC leads to a consistent model choice whenever consistent model choice is possible. The diagnostic test residual analysis including normality, autocorrelation and heteroskedasticity tests also appear in Appendix 1. The results of these tests stress that the estimated VAR has no specification problem associated to the residuals for both equations. Appendix 2 shows the tests concerning the parameter stability of VAR. We perform three

8. For more details about the advantages of Johansen and Joselius`s methodology to the procedure developed by Engle and Granger, see Enders (1995) and Hamilton (1993).

different tests for each VAR equation; the recursive residuals, the CUNSUM of squares test, and the N-step forecast test. Neither shows a serious stability problem. In practice, this means that there is no need to use in estimations some specific procedure that considers structural change. Finally, the results of co-integration tests based on the Johansen-Joselius procedure are listed in Table 3.

TABLE 3
JOHANSEN-JUSELIUS COINTEGRATION RANK TESTS

Lag Order	Ho: rank	ML Statistic	Trace Statistic	ML 1%	ML 5%	Trace 1%	Trace 5%
5	p <= 0	15.47	18.64	18.63	14.07	20.04	15.41
	p <= 1	3.17	3.17	6.55	3.76	6.64	3.76

Notes: ML = Max-Lambda. Critical values are based on Osterwald-Lenum tabulated values.

Neither the ML test nor the Trace test shows any evidence of co-integration. This means that one cannot observe any long-run relationship between investment and saving. Because both investment and saving are nonstationary series with unit root, the standard asymptotic theory does not apply. In this case, in accordance to Granger and Newbold (1974), the FH equation may suggest the absence of any consistent relationship between these variables. Thus, one cannot pose anything related to the FH equation without further investigation. Furthermore, one cannot perform any exogeneity test without first resolving this question.

4 ESTIMATING THE FH EQUATION FOR BRAZIL

As Hamilton (1993) points out there are three ways in which the problems associated to spurious regression can be avoided. The first is to include lagged values of both the dependent and independent variables in the regression. According to Hamilton (1993), it can be shown that OLS regression of the equation (3) yields consistent estimation.[9] In this study we denote equation (3) by the augmented FH (AFH) equation.

$$INVEST_t = \alpha + \beta SAVING + \sum_{i=1}^{T} \varphi_1(i) SAVING_{t-i} + \sum_{i=1}^{T} \varphi_2(i) INVEST_{t-i} + \varepsilon_t \qquad (3)$$

The second approach differentiates the data before estimating the relation, as in:

$$\Delta INVEST_t = \alpha + \beta \Delta SAVING_t + u_t \qquad (4)$$

Clearly, since the regressors and error term are $I(0)$ in (4), under the null hypothesis the parameters of the regression based on (4) converge to Gaussian variables. Any t or F test based on regression (4) has the usual limiting Gaussian or

9. However a F-test of the joint null hypothesis that β, ϕ_1\`s and $\phi_2$\`s are zero has a nonstandard distribution.

Chi2 distribution. A third approach is to estimate FH equation with the Cochrane-Orcutt adjustment for first-order serial autocorrelation of the residuals. Blough (1992) showed that the Cochrane-Orcutt GLS regression is thus equivalent to the differentiated equation (3). It is important to pose that, according to Hamilton (1993), if the data are really stationary, then differencing the data can result in a misspecified regression. Table 4 shows the results of the FH equation estimated with each one of these methodologies, in columns (2)-(4).

The results appearing in Table 4 show that although investment and saving are not co-integrated variables, the FH equation is not spurious. The elasticity of saving in the FH regression is significant for the method applied. The results appearing in columns (2)-(4) converge their results. The saving elasticity coefficients estimated with the three methods are very similar. Table 4 also shows in column (1) the results related to the FH equation estimated without correction.

Comparing the elasticity of saving estimated without correction to the one estimated using appropriate methods, one can see that if we do not consider the bias the idea regarding the relationship between investment and saving would be completely wrong. If one interprets the saving coefficient related to capital mobility, the biased elasticity is associated to low mobility of capital and the elasticity estimated by the appropriate estimators points to high capital mobility. This indicates the possibility of using this equation in formulating economic policy. It is now necessary to perform the exogeneity test. This will be done in the next section.

TABLE 4
ESTIMATED REGRESSIONS FOR THE FH EQUATION

Method = / Estimator = / Dep. Variable =	OLS *INVEST* (1)		Method 1 OLS *INVEST*[a] (2)		Method 2 OLS *DINVEST* (3)		Method 3 C.-Orcutt GLS *INVEST* (4)	
Ind. Variables	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value
Constant	0.654	(0.020)	0.527	(0.046)	0.008	(0.000)	0.058	(0.000)
SAVING	0.784	(0.000)	0.363	(0.003)	-	-	0.371	(0.000)
DSAVING	-	-	-		0.352	(0.000)	0.352	-
INVEST_1	-	-	0.872	(0.000)	-	-	-	-
INVEST_2	-	-	–0.321	(0.095)	-	-	-	-
SAVING_1	-	-	–0.123	0.402	-	-	-	-
SAVING_2	-	-	–0.022	0.866	-	-	-	-
AR	-	-	-	-	-	-	-	-
L1	-	-	-	-	-	-	0.879	(0.000)
L2	-	-	-	-	-	-	–0.153	(0.463)
L3	-	-	-	-	-	-	0.111	(0.419)
Normality[b]	0.026	0.986	2.02	0.3635	0.346	0.840	-	-

Notes: D = first difference, _1: first lag of the variable, AR = autoregressive error term regression, L1 = first lag of the error term. *P*-value in parenthesis. *INVEST* and *SAVING* in log.

[a] The OLS regression was estimated using five lags. For economy we present the results up to lag two.

[b] The Jarque-Bera statistic has a distribution with two degrees of freedom under the null hypothesis of normally distributed errors.

5 APPLYING EXOGENEITY TESTS FOR SAVING ON THE FH EQUATION

In the last section, based on a rigorous methodology regarding the nonstationary process for investment and saving for the Brazilian economy, we reached the following conclusions: *a*) the investment and domestic saving series are $I(1)$; *b*) they are not co-integrated; and *c*) the FH equation is not spurious. Hendry (1995) developed an interesting analysis to perform exogeneity considering the existence of a unit root and cointegration. In view of (*c*), we cannot apply the Hendry analysis directly. In order to perform the exogeneity test in the present context, we use the following system of equations involving the variables *SAVING* and *INVEST* as follows:

$$\Delta INVEST = \alpha + \beta \Delta SAVING + u_t, \tag{5.1}$$

$$\Delta SAVING_t = \sum_{i=1}^{T} \lambda_1(i) \Delta INVEST_{t-i} + \sum_{i}^{T} \lambda_2(i) \Delta SAVING_{t-i} + \varepsilon_{1t}, \tag{5.2}$$

$$\Delta INVEST_t = \sum_{i=1}^{T} \phi_1(i) \Delta SAVING_{t-i} + \sum_{i=1}^{T} \phi_2(i) \Delta INVEST_{t-i} + \varepsilon_{2t}, \tag{5.3}$$

Based on 5.1, 5.2 and5.3, the following proposition can be placed:

a) equation 5.1 represents the correct form of estimating the FH equation according to the methods of differences proposed in Section 4;

b) equation 5.2 and 5.3 are the marginal processes;

c) $\lambda_1(i) \neq 0$ and $\phi_1(i) = 0$ determine the failures of the Granger-causality of *SAVING* on *INVEST*; and

d) The condition that $\sigma(\varepsilon_{1t}, \varepsilon_{2t}) \neq 0$ determines the presence of contemporaneity, where $\sigma(\varepsilon_{1t}, \varepsilon_{2t})$ is the correlation between ε_{1t} and ε_{2t}.

In view of the commentaries posed in last section, the conditional equation must be placed on differences in order to be correctly specified. Due to the presence of unit root, the Granger causality test on a VAR in levels is biased[10] which means that we have to apply this test in VAR on differences represented by equations 5.2 and 5.3. Lastly, contemporaneity will continue to be tested as it appears in item (*c*) using the residuals of a VAR on differences.

10 As Sims, Stock and Watson point out the asymptotic distribution of causality tests are sensitive to unit root and time trends in the series. The analysis of causality between investment and savings will be performed in Section 5.2.

5.1 WEAK EXOGENEITY AND CONTEMPORANEITY

In models of only one equation, if the variables on the right side are not exogenous, then the coefficient estimated is biased. Thus, in a model of one equation, it is necessary to warrant that the right-side variables are exogenous. The statistical test that verifies this condition is the test of weak exogeneity. In order to test weak exogeneity for the variable saving in conditional equation (5.1) we use the LM test developed by Engle (1984) and the Durbin-Wu-Hauman test [Durbin (1953), Wu (1973) and Hausman (1978)]. In order to perform the Engle test the error of conditional equation (5.1) is included in the equation (5.2). If the error of conditional equation is not statistically significant in this marginal process for saving, then this means that domestic saving is weakly exogenous in the FH equation. Table 5 shows the results of this test. As one can see, the coefficient of the error of the conditional equation in the marginal is not significant.

The Durbin-Wu-Hauman test is done using the estimated results of equation (5.1) obtained by ordinary least squares (OLS) and an instrumental variable (IV). The null hypothesis states that an (OLS) estimator of the same equation would yield consistent estimates: that is, any endogeneity among the regressors would not have deleterious effects on OLS estimates.[11] A rejection of the null indicates that endogenous regressors' effects on the estimates are meaningful, and IV techniques are required. We also evaluated another test statistic to check for endogeneity in the Wu-Hausman [Wu (1973), Hausman (1978)][12] In this case, a rejection of the null indicates that the instrumental variable estimator should be employed. The results appear on the right side of Table 5. Based on the results of these two tests we conclude for the weak exogeneity of domestic saving in the FH equation.

TABLE 5
WEAK EXOGENEITY TESTS

1 The LM test	2 The Durbin-Wu-Hauman test.
Statistical significance of error of conditional equation (5.1) in the marginal equation (5.2):	H0: Regressor is exogenous Chi-sq[1] (P-value) = 0.0137 (0.9070)
Coeff (P-value) = -0.154 (0.443)	3 The Wu-Hauman test
	H0: Regressor is exogenous F[1,52] (P-value) = 0.0129 (0.9099)

Note: *P*-value in parenthesis. We use the lags of the differences of variables *SAVING* and *INVEST* as instruments.

The contemporaneity test proposed by Engle (1984) consists of verifying the correlation between the errors of equation (5.2) with the errors of the conditional equation (5.1). This test is based on the coefficient estimated by the OLS regression

11. Under the null, it is Chi-squared distributed with m degrees of freedom, where m is the number of regressors specified as endogenous in the original IV regression.

12. It can be showed that this test could be calculated straightforwardly through the use of auxiliary regressions. The test statistic, under the null, is distributed F(m,N-k), where m is the number of regressors specified as endogenous in the original instrumental variable regression.

between the residuals of equation (5.1) and (5.2). Under the null there is no contemporaneity. We performed the regression and the t test showed that we could not reject the null hypothesis that the correlation is 0. Then, we verified that there is no contemporaneity according to this test.

5.2 STRONG EXOGENEITY

If domestic saving is strongly exogenous in the FH equation, this means that this equation can be used to make forecasts. But if the independent variable is not strongly exogenous, then the FH equation cannot be used to make forecasts. The strong exogeneity of *SAVING* property in the FH equation is comprised of two requisites: *a*) *SAVING* is weak exogeneity; and *b*) *INVEST* does not cause *SAVING* in the Granger sense. Requisite *a* was demonstrated in Subsection 5.1. Thus, for domestic saving to be strongly exogenous and for the FH equation to be used to make forecasts, we only need to demonstrate requisite *b*.

It may be useful to point out that the Granger causality test is not a test that is used to verify causality with respect to established temporal precedence. In the Granger causality test, four alternatives are possible: 1) *SAVING* Granger causes *INVEST*, but the contrary is not true; 2) *INVEST* Granger causes *SAVING*, but the contrary is not true; 3) *SAVING* Granger causes *INVEST* and the contrary is true; and 4) *SAVING* not Granger causes *INVEST* and *INVEST* not Granger causes *SAVING*. To accept the strong exogeneity of *SAVING* it is necessary to obtain the alternative 1.

The operational form of the Granger causality test related to the integrated variables $I(1)$ is to test the hypothesis in item (*b*) of Section 3. In view of the presence of unit root the Granger test on a VAR in level is based [Hamilton (1993)]. Then, in order to apply the Granger test in this context of both the variable being $I(1)$ and not co-integrated we have to use the first to estimate a VAR on difference and use the Granger causality methodology. The majority of information criteria indicate four lags for the VAR on difference. The Granger causality test is shown in Table 6. The results show that investment Granger causes domestic saving, but that the contrary is not true (alternative 2). Thus, the FH equation cannot be used to make forecasts regarding the Brazilian economy. In the next section, the robustness of the FH equation with regard to policy changes will be verified.

TABLE 6
GRANGER CAUSALITY TEST

Equation	Excluded	Chi2	Lags	Prob > chi2
DSAVING	*DINVEST*	20.333	4	0.000
DSAVING	All	20.333	4	0.000
DINVEST	*DSAVING*	5.630	4	0.228
DINVEST	All	5.630	4	0.228

5.3 SUPEREXOGENEITY

The superexogeneity test allows an econometric model to escape from the Lucas criticism.[13] Lucas (1976) argued that, under a rational expectation hypothesis, econometric models could not be used to formulate economic policy because, when the policy maker changes the policy, the agents change their behavior. Consequently, the parameter found before the political change would not be the same after the change. However, in an article on the consumption function in the United Kingdom, Davidson *et al.* (1978) presented conditions under which Lucas' criticism does not apply. The variables that satisfied these conditions were labeled super exogenous. Whenever a variable is super exogenous, policy makers can use it to formulate economic policies. In this section, we propose two tests in order to verify superexogeneity. First, we employed the testing framework suggested by Engle and Hendry (1993). To implement this methodology, a marginal model for saving must be proposed. We implement the Engle and Hendry (EH) test using the equation (6) as the marginal stochastic process for domestic saving.

$$saving_t = \alpha + \sum_{j=1}^{p} \varphi_j saving_{t-j} + v_t \tag{6}$$

The idea of the EH test is to include the squared residuals of the marginal equation (6) and its lags in the conditional equation represented by the FH or AFH equation. If the squared residuals of the marginal equation and its lags were not statistically significant in the conditional equation, then this would indicate the acceptance of superexogeneity. Table 7 displays the results of the EH test applied for both the FH and AFH equations. The results show that one cannot find evidence to reject the hypothesis that domestic saving is superexogenous in the FH or AFH equations.

For the second test of superexogeneity we will apply the approach proposed by Charemza-Király [CK test (1990)]. The idea of this test is to estimate a regression where the forecast error of the conditional equation is the dependent variable. The first difference of domestic saving and its lags are the independent variables. To accept superexogeneity, the independent variables should not be statistically significant. This test has an advantage in relation to other superexogeneity tests, for it does not need a marginal equation. Table 7 shows the results of this test. As one can see, the difference of domestic saving and its lags are not statistically significant in the regression where the forecast error of the conditional equation is the dependent variable. Thus, the CK test accepts that saving is superexogenous in the FH equation. In summary, both tests we performed in this section did not reject superexogeneity hypothesis.

13. A discussion of the empirical relevance of the Lucas criticism was put forth by Ericson and Irons (1995).

TABLE 7
SUPEREXOGENEITY TESTS

1 Engle and Hendry (EH) test	2 Charemza-Király test
Statistical significance of error and its lags of the marginal process for saving (7) in the conditional equation:	Statistical significance of the first difference of domestic saving and its lags error in forecast error (FE) of the conditional equation
FH equation (4) F test (Prob > F) = –1.28 (0.291)	FE of FH equation (4) F test (Prob > F) = –0.44 (0.778)
AFH equation (3): F test (Prob > F) = 1.27 (0.299)	FE of AFH equation (4): F test (Prob > F) = 0.02 (0.998)

Note: Instruments: lags of investment and saving. The F-test of the first stage rejects the null hypothesis that the instruments are weak.

6 STRUCTURAL ANALYSIS FOR INVESTMENT AND SAVING

In order to explore the usefulness of the exogeneity tests performed in this study, in this section we consider a structural model consisting of investment and domestic saving. The question posed is the extent to which the investment affects saving and vice-versa. In this context we have two hypothesis of interest. First, can domestic saving be considered an exogenous variable in for the purpose of investment modeling. In other words, the OLS regression yields consistent estimation of the structural parameters. The second hypothesis is a considerably stronger conjecture about the lack of feedback from investment to domestic saving. We resume these two conjectures in the following way. Does domestic saving exert any influence, either directly (contemporaneously) or indirectly (with a lag) on investment? Unfortunately in the absence of prior restriction derived from theory, neither of these two hypotheseses can be tested [Jacobs, Leamer and Ward (1979)].

To make these points more clear we consider the following structural model involving *invest* and *saving*,[14]

$$invest_t = \alpha_1 + \beta saving_t + \beta_{11} invest_{t-1} + \beta_{12} saving_{t-1} + \varepsilon_{1t} \tag{7}$$

$$saving_t = \alpha_2 + \delta invest_t + \beta_{21} invest_{t-1} + \beta_{22} saving_{t-1} + \varepsilon_{2t} \tag{8}$$

where ε_{1t} and ε_{2t} are independent, serially uncorrelated random variables with zero mean and constant variance. The reduced form of this structural system is given by

$$\begin{pmatrix} invest \\ saving \end{pmatrix}_t = [\Pi] \begin{pmatrix} invest \\ saving \end{pmatrix}_{t-1} + \begin{pmatrix} u_1 \\ u_2 \end{pmatrix}_t$$

14. For simplification we work with just one lag.

where Π is the matrix

$$\Pi = (1-\beta\gamma)^{-1}\begin{bmatrix} \beta_{11}+\beta\beta_{21} & \beta_{12}+\beta\beta_{22} \\ \gamma\beta_{11}+\beta_{21} & \gamma\beta_{12}+\beta_{22} \end{bmatrix} \tag{9}$$

and

$$\begin{pmatrix} u_1 \\ u_2 \end{pmatrix}_t = (1-\beta\gamma)^{-1}\begin{bmatrix} 1 & \beta \\ \gamma & 1 \end{bmatrix}\begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \end{pmatrix}_t \tag{10}$$

According to [Jacobs, Leamer and Ward (1979)] the assumption of exogeneity is under-identifying or just-identifying and hence is not testable, but a set of over-identifying restriction on the parameter space can be tested [Cooley and LeRoy (1985)]. Therefore if the hypothesis of exogeneity is included with sufficient number of other restriction (sufficient to over-identifying the model), a joint test of exogeneity can be conducted [Wu (1973) and Hausman (1978)]. In section 5.1 the LM test and the Durbin-Wu-Hauman test do not reject the hypothesis that domestic saving is exogenous in the FH equation. We observe the same diagnostic when we perform these tests for the equation (7). Based on this point we propose to include in the structural dynamic generating process for investment and saving expressed by (6)-(7) the constraint that $\beta = 0$. Taking this point into consideration, the system (7)-(8) can be rewritten as

$$invest_t = \alpha_1 + \beta saving_t + \beta_{11} invest_{t-1} + \beta_{12} saving_{t-1} + \varepsilon_{1t} \tag{7}$$

$$saving_t = \alpha_2 + \beta_{21} invest_{t-1} + \beta_{22} saving_{t-1} + \varepsilon_{2t} \tag{8'}$$

It is important to note that Granger causality does not guarantee neither of the hypothesis posed in the beginning of this section. To see this, in order that investment does not cause saving in Granger sense we must have $\gamma\beta_{11} + \beta_{12} = 0$. But, in order the disturbance in the equation (7) is never transmitted to (8) the following joint restriction that $\beta = \beta_{21} = 0$ must be satisfied.

The dynamic structural generating process expressed by (7)-(8') can be used to help us evaluate economic performance. Our objective is to verify the effect of the exogenous shock of saving on investment, and vice-versa, using the impulse response functions (IRFs). The advantage of this instrument is that it is immune to Lucas' critique because it considers only the effects of new non-expected information. For instance a shock to saving or investment in a country could replicate that of shocks to world economy related to these variables.

The implementation of the dynamic structural analysis may initially be done by noting that the stochastic process modeled by (7)-(8') may be viewed as structural vector autoregressive (SVAR) with the restriction that the investment does not affect saving contemporaneously. This restriction derives from the weak exogeneity test. It must be said that weak exogeneity for saving derived from section 5.1 does not guarantee that this identification is the only one [Cooley and LeRoy (1985)], [Jacobs, Leamer and Ward (1979)]. But this one is consistent to the theory and it also appears more plausible for us taking the tests of weak and strong exogeneity in consideration. Taking $y_t = (invest, saving)$, the system (7)-(8) can be cast in the following way,

$$A_0 y_t = a + A_1 y_{t-1} + \ldots + A_1 y_{t-p} + \mu_t \tag{9}$$

where $\mu_t \sim N(0, I)$. The restrictions appearing in (7)-(8) imply that the element (2,1) of matrix A_0 is are zero.[15] Unfortunately the SVAR cannot be estimated directly. This can be done using a reduced form VAR such that,

$$y_t = b + B_1 y_{t-1} + \ldots + B_p y_{t-p} + \omega_t \tag{10}$$

with:

$$\omega_t \sim N(0, \Sigma) \text{ and } E(\omega_t \omega_s^{''}) = 0, \forall t \neq s$$

The relation between models (8) and (9) is based on the following identities $b = A_0^{-1} a$, $B_i = A_0^{-1} A_i$ and $\omega_t = A_0^{-1} \mu_t$. We can retrieve the SVAR from the reduced form VAR using the following relation: $\Sigma = A_0^{-1} E(\varepsilon_t \varepsilon_t^{'})(A_0^{-1})^{'} = A_0^{-1}(A_0^{-1})^{'}$. Without additional restrictions, we cannot recover the structural form because Σ does not have enough estimated coefficients to recover an unrestricted A_0 matrix.[16] We call attention to an important point related to economic analysis which is that the reduced form VAR does not allow for the identification of the effects of exogenous independent shocks to the variables because the VAR reduced form residuals are contemporaneously correlated (the Σ matrix is not diagonal).[17]

The usual procedure used to estimate VAR is a special case of seemingly unrelated regression (SURE) in which the explanatory variables are identical in all equations. In general SURE, the error covariance matrix is not diagonal, thus the estimation must be done using GLS (generalized least square) methodology.[18] In our case A_0 is just identified and one can retrieve structural parameters of A_0 from Σ directly because the number of equations and variables is the same. The case we

15. We also impose for normalization that the elements of the principal diagonal of A_0 are equal to 1.

16. In our case, matrix A_0 is just identified because we imposed the constraint that the element (2,1) of A_0 is zero. This means that A_0 is upper superior. Because the VAR is composed by only two variables, the identification can be done necessarily in this triangular faction.

17. That is, the reduced form residuals (ν_t) can be interpreted as the result of linear combinations of exogenous shocks that are not contemporaneously (in the same instant of time) correlated. It is not possible to distinguish which exogenous shocks affect the residual of each reduced form equation.

18. This point implies that in VAR we have got a striking result in which (GLS) and (LS) least square generate the same result.

examine in this study links just-identified SVAR to constraint in lag, and it is not difficult to solve. This can be done estimating the reduced form VAR,[19] which enables us to retrieve the matrix A_0 using the methodology described below. Because we impose the constraint that elements of the principal diagonal of A_0 are equal to one, only the element (1,2) of this matrix has to be estimate.

Appendix C displays the structural IRFs. According to the results one can observe that a non-expected temporary shock in saving implies a positive effect on investment and the effect of this shock lasts for a long time. Concerning to domestic saving, the response of this variable to a non-expected shock on investment has a more complicated description. At the beginning, the domestic saving reacts negatively and this effect remains for about six years. After it, the effect of the innovation on investment changes and domestic saving begins to react positively to the shock.

7 FINAL REMARKS

In this section we will interpret the results obtained in this study. First, we analyse the results of the exogeneity tests derived from the FH equation in order to determine how this instrument can be used in economic policy analyses. According to Favero (2001), these three concepts of exogeneity are useful in defining the validity of the reduction from the data-congruent reduced form and the adopted structural equation. The exogeneity tests showed evidence that saving is weak and super exogenous but not strong exogenous in the FH equation. Concerning the weak exogeneity, this means that if the objective is to infer the parameter associate to saving, β, the reduced form expressed by the FH or the AFH equation can in fact be used to obtain the parameter of interest. On the other hand, if the objective of the analysis is dynamic simulation, then one cannot use the FH to make forecasts in order to predict future behavior of investment conditioned by the anticipated value of saving. As Favero (2001) points out, it is possible to admit a situation as the one we observed, where saving do not cause investment in the Granger sense, but is weakly exogenous because Granger-causality is independent from the choice of the parameters of interest. The superexogeneity test showed that the FH equation it is not subject to Lucas' criticism. Thus, one can use the FH equation in econometric policy evaluation. Second, comparing the elasticity of saving estimated using appropriate methods, one can see that this coefficient points out to high capital mobility.

Finally, the IRFs derived from the SVAR showed that investment is sensitive to contemporaneous innovation on saving and the major positive impact lasts for some years. The effect of an innovation of investment on saving is more complicated. Initially domestic saving goes down. After some lags this movement changes and domestic saving begins to react positively to the shock.

19. The Bayesian Schartz criterium indicates lag length equal to five.

APPENDIX A

TABLE A1
INFORMATION CRITERION

Inf. Crit. =	LR	FPE	AIC	HQIC	SBIC
	5	5	5	1	1

Notes: LR = , FPE = Forecast Predictor Error, AIC = Akaike Information Criterion HQIC = Hanna-Quin Criterion, SBIC = Scharwz Criterion.

TABLE A2
RESIDUAL DIAGNOSTIC FOR VAR

	AR 1-2 F-statistics	Xi^2[a] F-statistics	Portmanteau	ARCH[b] F-statistic	Normality[c] Chi^2
INVEST	0.507	1.8209	0.258	2.183	2.17
	(0.605)	(0.108)	_	(0.147)	(0.34)
SAVING	0.520	1.802	0.281	2.083	2.61
	(0.598)	(0.119)	_	(0.156)	(0.27)
SYSTEM	1.426	3.29	7.860	_	2.827
	(0.199)	(0.50)	_	_	(0.30)

Notes: AR1-2 Lagrange Multiplier test for order 1-2 autocorrelation, H0=white noise.

[a] Homoscedasticity vs residual heteroscedasticity.

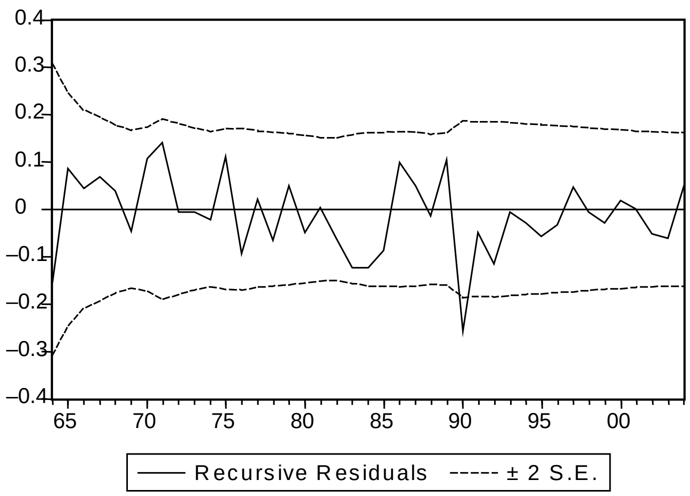
[b] Constant variance vs residual ARCH.

[c] The Jarque-Bera statistic has a distribution with two degrees of freedom under the null hypothesis of normally distributed errors. The H0 hypothesis is normality.

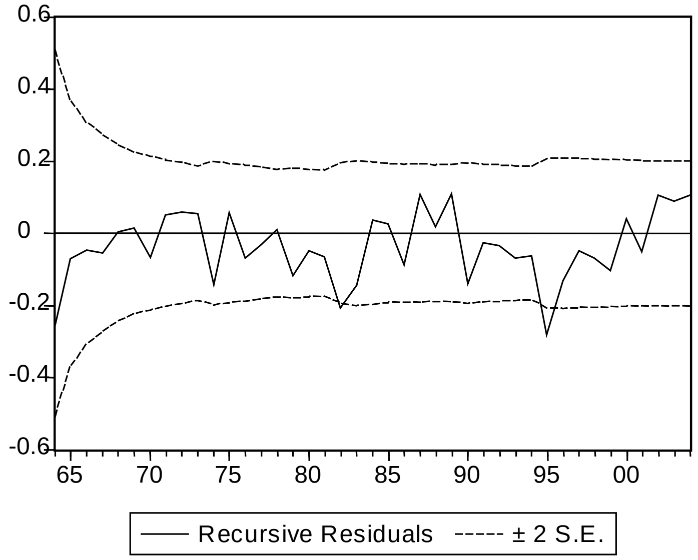
APPENDIX B

STABILITY TESTS FOR VAR

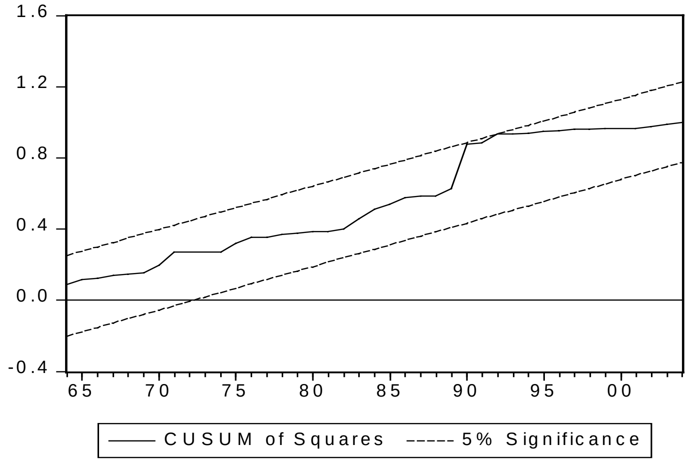
GRAPH 1
RECURSIVE RESIDUALS: INVESTMENT



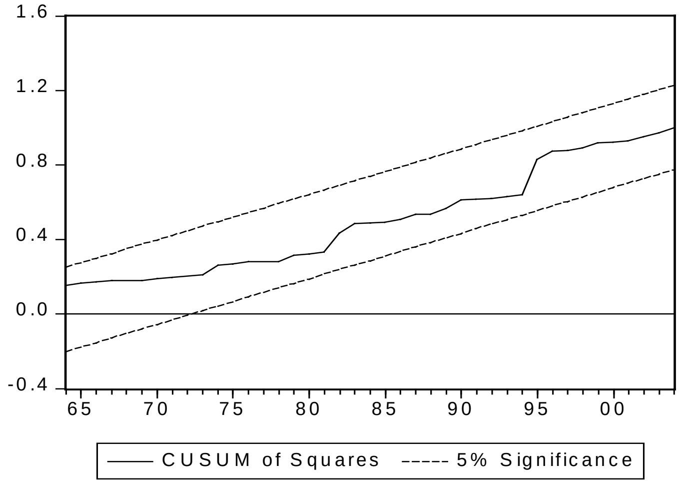
GRAPH 2
RECURSIVE RESIDUALS: SAVING



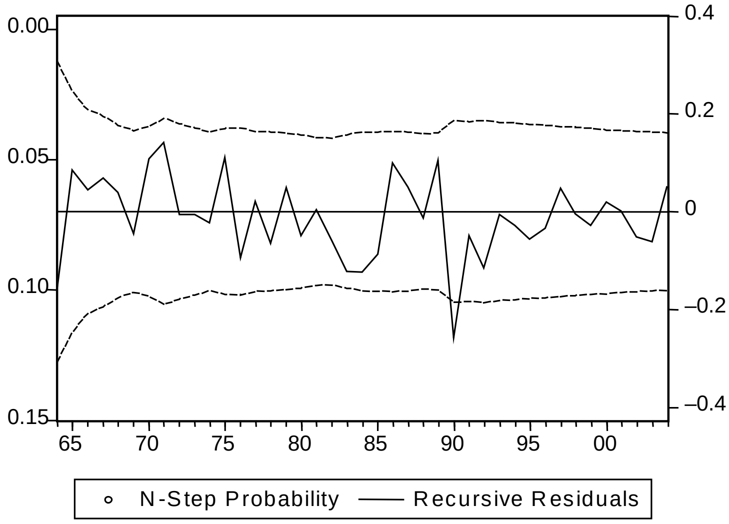
GRAPH 3
CUSUM OF SQUARES TEST: INVESTMENT



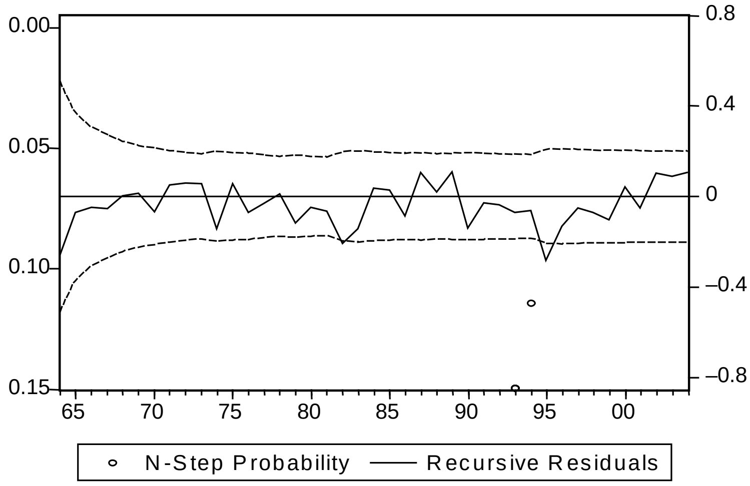
GRAPH 4
CUSUM OF SQUARES TEST: SAVING



GRAPH 5
N STEP FORECAST TEST: INVESTMENT

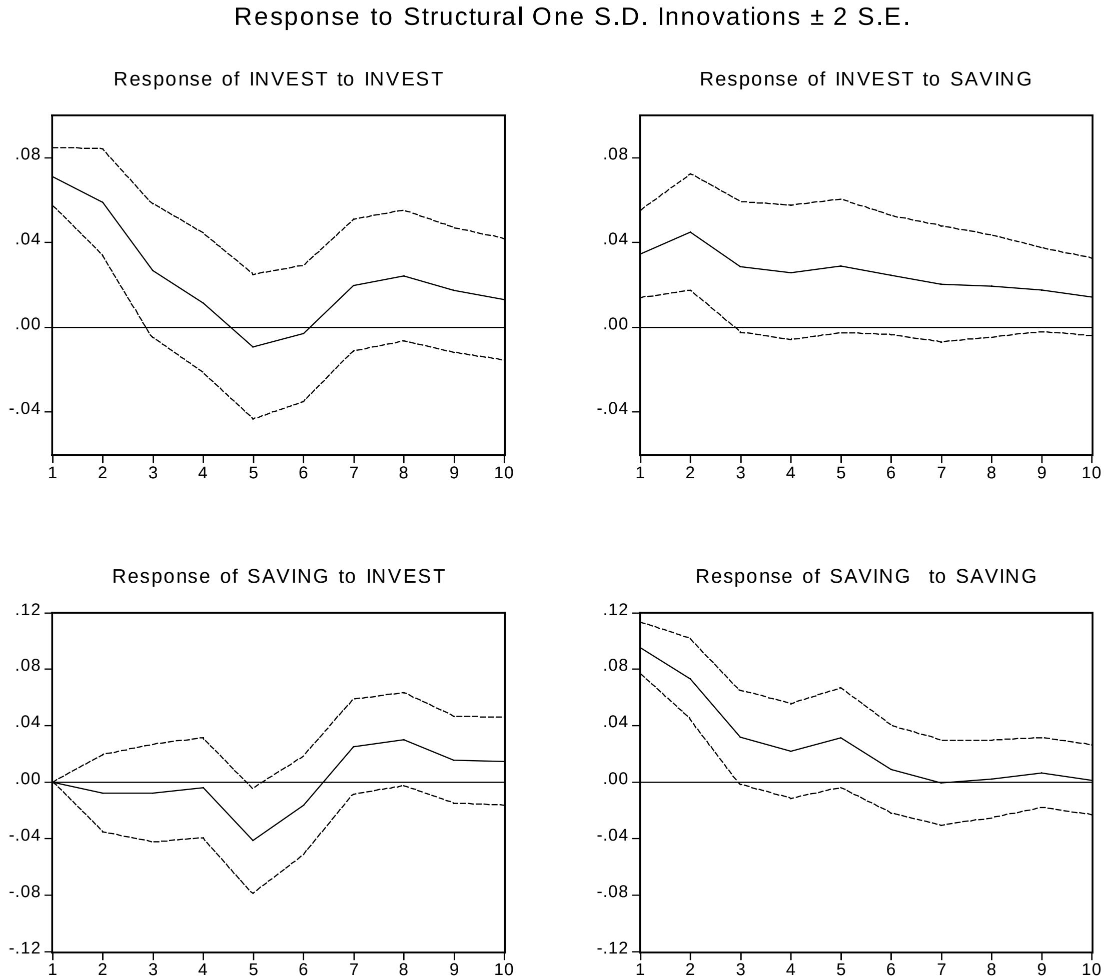


GRAPH 6
N STEP FORECAST TEST: SAVING



APPENDIX C

IRFs-STRUCTURAL VAR



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