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Econometric Analysis of Discrete Reforms

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Abstract

The paper suggests an econometric methodology for testing the effectiveness of reforms implemented in one major step, i.e., discrete reforms. The methodology is based on the exogeneity properties of variables in an econometric model. The paper specifies the preconditions for setting up an appropriate model; suggests an economic interpretation of the tests for weak, strong, and superexogeneity; and illustrates this methodology by applying it to two cases of instantaneous reforms. The exogeneity properties of variables in a correctly specified econometric model may help uncover information on the preparation, implementation, and the outcome of such reforms, which could be useful for future policy advice.

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I. Introduction

"Es irrt der Mensch, solang er strebt"
"Man errs as long as he doth strive"
"Tout homme qui marche peut s'égarer"
"Кто ищет—вынужден блуждать"

Goethe. *Faust*

1. How to test whether a reform has had an expected impact on economic activities? This question has been addressed traditionally by constructing econometric models aimed at capturing the shifts in the macroeconomic parameters of interest in response to an impulse dummy variable representing the reform added to the right-hand side of an equation. Lucas (1976) forcefully pointed out that a policy change can invalidate the model itself, which, consequently, cannot be used for any policy inference, including the assessment of the impact of economic reforms. According to his famous critique, "given that the structure of an econometric model consists of optimal decision rules of economic agents, and that the optimal decision rules vary systematically with changes in the structure of series relevant to the decision maker, it follows that *any change in policy will systematically alter the structure of econometric model.*" Although the empirical evidence in favor of this critique is "weak at best and non-existent at worst" (Ericsson and Irons, 1995), the issue of model constancy in the presence of policy shifts needs to be addressed adequately for the correct evaluation of the impact of any economic reform measure.

2. The **purpose** of this paper is to show how testing for model constancy and for various degrees of exogeneity of variables in econometric models can help assess whether a particular policy measure or reform achieved the targeted outcome. Within the reemerging interest in econometric analysis and forecasting of economic policies, the methodology suggested in the paper can be used for assessing the impact of reforms on macroeconomic performance as a whole. The paper concentrates only on instantaneous or discrete reforms, and illustrates the methodology by applying it to the analysis of exchange rate unification and tax reform in two developing countries. Although these reforms were in fact implemented in early 1990s, the country attribution would be premature at this point, because of the debatable nature of the proposed methodology.

3. The paper is organized as follows. Section II reviews the literature on the existing approaches to testing reforms, summarizes the use of exogeneity-based techniques for economic policy analysis, and suggests a simple testing procedure for ascertaining the effectiveness of reforms. Section III provides a practical application of this testing procedure for the two discrete reforms—the introduction of VAT and exchange rate unification, respectively. Finally, Section IV sets out some conclusions.

II. Exogeneity Approach to Testing Reforms

A. Literature at a Glance

4. The testing of the effectiveness of reforms is one of the most challenging tasks in econometric modeling, be it testing for the effectiveness of a comprehensive reform program or a specific reform. Significant literature has been devoted to **testing a reform program as a whole**, in particular within the context of IMF-supported programs. Khan (1990), and most recently Ul Haque and Khan (1998), cataloged the available options for testing IMF-supported reform programs, assessing the pros and cons of the "before-after," "with-without," the "generalized evaluation estimator," and the "comparison of simulations approaches" and advocating a "counterfactual criteria" for evaluation reform program. The counterfactual approach would compare the macroeconomic outcome under the program with the hypothetical outcome, which would have emerged in its absence. Conway (1998) and several other studies define theoretically and measure empirically the "counterfactual" and thus unobserved outcome, and evaluate program performance against it.

5. Instances of **testing the effectiveness of a specific reform** are even more numerous. Traditional models for studying the dynamics of the impact of reforms on the targeted variables rely generally either on crude data inspection, simple correlation analysis, or multivariate regressions. In most cases, such as Greenaway, Morgan and Wright (1997 and 1998), Sachs and Warner (1996), and Thomas and Nash (1991), the empirical evidence is conventionally based on a behavioral equation representing a regression of the targeted variable, in most cases some variant of real income (real GDP, real GDP per capita, real GDP per capita growth), on a set of independent variables. These variables include some measurements of factors (labor, capital, education, initial level of output, etc.), variables reflecting external influences (exports, terms of trade, effective exchange rate), and a parameter capturing effects of a reform through time. Such a parameter is usually represented either by a dummy variable taking a value of zero in pre-reform years and one in the reform year and thereafter, or by a more sophisticated index designed to reflect simultaneous effect of the impact of the reform on a number of variables, such as nontariff barriers, average tariff levels, voluntary exports restraints, the parallel market exchange rate in the case of a trade reform.

6. A specific reform can be either instantaneous (discrete) or gradual. A vast literature on the dilemma of whether reforms should be **instantaneous or gradual** followed Mussa's (1986) article and was comprehensively surveyed by Rodrik (1994), and most recently by Auernheimer (1997) and Mehlum (1998), mainly in the context of trade reforms. They provided an extensive account of arguments for gradualism versus shocks in policy implementation and opted broadly, as does Dehejia (1997), for a case-by-case approach recognizing that although an instantaneous removal of a distortion remains the preferable policy, the presence of market imperfections often make gradualism a clear second-best option.

7. This paper concentrates only on one-step reforms, i.e., **discrete reforms**. The suggested methodology for testing their efficiency is based on the concept of exogeneity and is applicable only to those reforms that could be reasonably considered discrete, have clearly formulated objective, and implemented without any purposely introduced delays, rather than those designed as multi-objective, gradual, or step-by-step reforms. Thus, the exogeneity-based testing for the efficiency of instantaneous reforms is only possible when the actual reform measure has been implemented, and it is obvious that the current round of the reform is over.

8. The **concept of exogeneity** has drawn the attention of economic policy analysts since the early 1980s. Ericsson (1992), building on Engle, Hendry, and Richard (1983), showed that there must be a proof that a variable is exogenous and can be considered known for the purposes of the modeled relationship, otherwise the assumption of its exogeneity can be invalid and lead to a loss of valuable information, inefficient or inconsistent inference and misleading policy simulation. Accordingly, for distinct purposes of statistical inference, forecasting and policy analysis, Ericsson defined the concepts of weak exogeneity, strong exogeneity, and super exogeneity, and suggested testing procedures for determining the exogeneity properties of variables in the model. Developing techniques based on exogeneity analysis, Hendry and Mizon (1998), studying the impact of U.K. short-term interest rate on monetary aggregates, showed that the existence of a behavioral relation between the target and the instrument variable should be proved empirically, before any valid assessment of the impact of policy instruments on economic developments can be made. Imposing any degree of exogeneity on a variable can lead to invalid policy conclusions, because full and conditional systems respond differently to exogenous shocks. In the same vein, Paroulo and Rahbek (1999) strongly recommend routine testing for the weak exogeneity of parameters before performing any analysis of a conditional model. Finally, Banerjee, Hendry, and Mizon (1996) and Ericsson, Hendry, and Mizon (1998) give a comprehensive overview of conditions for a reliable economic policy analysis with special emphasis on the validity of the exogeneity assumption, which allows the use of simpler modeling strategies and the isolation of invariance in the modeled system. They further show how tests for different degrees of exogeneity, and thus for invariance and causality, help assess the forecasting power of the model, and apply these techniques to rebuff the Lucas critique and to construct a congruent money demand function for the United Kingdom. Further development of the exogeneity-based policy analysis requires streamlining of the existing procedures and agreeing on the interpretation of the econometric results.

B. Concept of Exogeneity in Economic Policy Analysis

9. Consider a model x_t of variables $(Y, X, Z \ldots)$ that characterize the economy at time t, where t=1,2...T. Then, a simplified model x_t of such an economy (called "a full model" hereafter) in times when it undergoes a reform process consists of the following four variables:

$$Y_t = \alpha + \beta X_t + \gamma Z_t + \delta i + \varepsilon_t \quad \textbf{(1)}$$

with $\varepsilon_t \sim IN(0, \sigma^2)$ and $t = 1,2...T$, where:

• Y_t is a *target variable* that is endogenous to the model and is supposed to be influenced and ultimately improved by a reform (such as growth, international reserves, or inflation rate).

• X_t is a vector of *control variables* that are considered to be the prime determinants of the trend in the target variable. For example, if the growth rate has been selected as the target variable for testing the effectiveness of a reform, then capital accumulation, labor force productivity, or some indication of technological improvements could be considered a vector of possible control variables, although, for empirical purposes, such a vector can consist just of one variable.

• Z_t is a vector of *transmission variables* that are most influenced by a particular reform. Examples of such variables could include fiscal revenue or tax collection, if a tax reform in under consideration; real effective exchange rate in an exchange rate reform (such as an exchange rate unification or devaluation); consumer price index or wholesale price index in a price reform; and real interest rate in the case of an interest rate liberalization. Again, in the simplest case, this vector can include only one variable.

• i is a step or an impulse *dummy* designed to capture the time effect of a reform. If the reform has been introduced instantaneously, and relatively consistent efforts along its lines have continued thereafter, then a step dummy taking the value of zero before the reform, and the value of one in the year of the reform and thereafter, can be used. If the reform has been reversed at some later date, then an impulse dummy taking the value of one in the year(s), when the reform was in effect and zero otherwise, may be appropriate.

• ε_t is a white noise random disturbance, with zero mean and fixed variance.

This simplified specification can be easily refined to introduce intertemporal dynamics, additional variables, country specific effects, or estimated in a panel or VAR formulations.[2]

10. The data generating process of (1) is generally unknown but can be approximated by an econometric modeling of a subset of variables in full model x_t conditional on the other variables in x_t. Following Ericsson, et al. (1998), and Hendry and Mizon (1998), without loss of generality, the full model x_t can be partitioned into conditional model y_t and marginal model, z_t i.e. $x_t = (y_t^{'}; z_t^{'})^{'}$

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[2] Regardless of the particular form, in a traditional testing framework, the hypothesis that a reform has had an impact on the target variable is not rejected if δ is statistically significant and the direction of such an impact is determined by the sign of this parameter.

Conditional model of y_t given z_t i.e. $(y_t|z_t)$ is:

$$y_t|z_t = \alpha_0 + \alpha_1 z_t + \upsilon_t \tag{2}$$

where $\upsilon \sim IN(0,\Omega)$.
Marginal model of z_t is

$$z_t = \beta_0 + \beta_1 z_{t-1} + \varepsilon_t \tag{3}$$

where $\varepsilon \sim IN(0,\Theta)$.
The relationship between the conditional and marginal models is

$$F_x(y_t, z_t|x_{t-1}, \theta) = F_{y|z}(y_t|z_t, x_{t-1}, \lambda_1) F_z(z_t \mid x_{t-1}, \lambda_2) \tag{4}$$

where $F_z(x_t, \theta)$ is the joint density of x_t; $F_{z|z}(y_t|z_t;\lambda_1)$ is the conditional density of y_t given z_t; and $F_z(z_t;\lambda_2)$ is the marginal density of z_t. The parameter vector θ is the full set of parameters in the joint process; $\lambda_1 = (\alpha_0, \alpha_1, \Omega)'$ and $\lambda_2 = (\beta_0, \beta_1, \Theta)'$ are the parameters of the conditional and marginal models respectively; and x_{t-1} is a set of original conditions. The reform dummy variable *i* can be included either in the conditional or in the marginal model.

11. The **purpose** of an instantaneous reform is to shift the mean of the target variable Y_t in the conditional model y_t to a desired value or within a desired range by using the instruments Z_t in the marginal model z_t available to governments.[3] Thus, y_t can be viewed as a model of factors ultimately determining Y_t, and z_t as a model of policy instruments affecting Y_t through their impact on y_t. Accordingly, the purpose of econometric modeling is to assess the effects on the data generating process (DGP) from changes in economic policy implemented by the manipulation policy instruments on the path of the partial response of the target variables. Economic reforms typically assume that changes in the instruments in z_t have an impact on the targets Y_t. This implies that the following conditions should hold: (i) variables in x_t must be cointegrated, i.e., there should exist a long-run economic relationship between them; (ii) causal links should lead from instruments X_t to targets Y_t; and (iii) the instruments in the marginal model z_t must be manipulable, suggesting that the governments should be able to set instruments to the desired values.

12. The statistical property of **cointegration** is important because it links the economic notion of a long-run relationship between variables in the full model to an econometric model of these variables, and allows for the test of different levels of exogeneity, which is used here

[3] Variables are shown in uppercase; their models are shown in lowercase. In cases when the variable means a modeled variable, lowercase is used.

as an empirical tool for testing reforms. Following Hendry (1995), a vector equilibrium-correction model of x_t can be presented as:

$$\Delta x_t = \delta + \alpha\beta' x_{t-1} + \Gamma \Delta x_{t-1} + \varepsilon_t \tag{5}$$

with an intercept as the only deterministic variable, and r cointegrating relations $\beta' x_t$ (linear combinations of variables in x_t that are *I(0)*), where β' is a matrix of cointegrating vectors and α is a matrix of weighting elements. Consistently with the conditional and marginal models, as in Ericsson, et al. (1998), in the simplest case all elements in Δx_t model can also be re-parameterized into conditional model

$$\Delta y_t = (\delta_1 - D\delta_2) + (\alpha_1 - D\alpha_2)\beta' x_{t-1} + D\Delta z_t + (\Gamma_1 - \Gamma_2)\Delta x_{t-1} + \varepsilon_{1t} \tag{6}$$

and a marginal model

$$\Delta z_t = \delta_2 + \alpha_2 \beta' x_{t-1} + \Gamma_2 \Delta x_{t-1} + \varepsilon_{2t} \tag{7}$$

13. Such factorization allows testing the system for *weak exogeneity* of the parameters in the marginal model. If weak exogeneity is detected, the conditional model can be analyzed without having to specify exactly how z_t is determined. Because the target variable in y_t depends on the parameters of the conditional model only and z_t is determined exogenously to the model, any parameter of interest ψ can be determined only from the conditional model itself. The variable z_t is weakly exogenous over the sample period for the parameters of interest ψ, only if there exists a re-parameterization of θ as λ, with $\lambda = (\lambda_1', \lambda_2')'$, such that (i) parameters of interest ψ, are a function of conditional model's parameters λ_1 only; and (ii) parameters of the conditional and marginal models (λ_1 and λ_2) be variation free, [4] i.e., the factorization operates a sequential cut.[5] Weak exogeneity can be tested by imposing zero linear restrictions on parameters in the α matrix in the cointegration analysis. A valid exogeneity assumption could comprise any or all of inference, forecasting, or policy. But if such an assumption is invalid, the estimation of the conditional model alone can lead to inefficient or inconsistent inferences, and result in misleading forecasts and policy simulations.

14. The impact of a reform can be considered to go beyond regular statistical inferences and affect conditional forecasting if the parameters of the conditional model are not *strongly*

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[4] Parameter λ_1 in invariant to parameter λ_2 if the parameter space Λ_1 is not a function of the parameter λ_2 and the parameter space Λ_2 is not a function of the parameter λ_1.

[5] The factorization (3) operates a sequential cut if λ_1 and λ_2 are variation free, and are not subject to cross restrictions that is, (λ_1, λ_2) belong to $\Lambda_1 \times \Lambda_2$, the product of their individual parameter spaces (see Ericsson, 1992 for details).

exogenous for the marginal model, i.e., a conjunction of weak exogeneity of y_t and Granger non-causality of z_t onto y_t is not present.[6] At the same time, the presence of strong exogeneity in the conditional model attests to the fact that the policy instruments z_t do not have obvious causal links with the target variables y_t in both DGP and its econometric model. Assuming that the model is adequate (congruent and encompassing), absence of such linkages between instruments and targets suggests that z_t can be treated as fixed. Testing for strong exogeneity requires only a test for Granger causality in addition to testing for weak exogeneity. Policy reforms are often based on the experience in a particular field accumulated through years and thus are likely to include feedbacks from the past adjustment outcomes into current decisions, i.e., Granger causality can run from y_t to z_t. It means that the transmission variables are unlikely to be strongly exogenous.

15. The impact of a reform can be considered persistent and can be simulated from the conditional model alone if *super exogeneity* of the transmission variable holds. Defined as a conjunction of weak exogeneity and invariance, i.e., z_t is weakly exogenous for the parameters of interest ψ, and λ_1 is invariant to changes in λ_2, super exogeneity effectively isolates the conditional process from any non-constancies in the marginal model. The factorization may aim to isolate those non-constancies into the sub vector λ_2 leaving the parameters of the conditional model λ_1 invariant to the changes that have occurred in λ_2. A very appealing aspect of testing superexogeneity is that only a simple marginal model needs to be non-constant. Thus, to verify superexogeneity, it is sufficient to establish the constancy of λ_1 and the non-constancy of λ_2. This proves that λ_1 is invariant to λ_2 and, if weak exogeneity has also been found, that λ_2 is super exogenous to λ_1. Or, alternatively, a marginal model for z_t can be developed until it is empirically constant by adding dummies and/or other variables, and their significance in the conditional model can be tested. If they are not significant, the parameters λ_1 of the conditional model are invariant to fluctuations of λ_2 in the marginal model. Super exogeneity of the transmission variable Z_t means that it affects the target variable directly by entering the conditional model through the path of Z_t in this model than through its parameters λ_1. The parameters of the conditional model are empirically constant, and it alone can be used for reliable policy simulation with no need to model separately the Z_t.

[6] Instrument z_t does not "Granger cause" target y_t if deleting the history of z_t does not alter the distribution of any of the remaining variables y_t.

16. Finally, additional information about the propagation of instantaneous reforms through time can be obtained by analyzing the *impulse response* to a policy regime shift and a transitory shock. Following Hendry and Mizon (1998), shocks to the full system may include unexpected changes in economic policy and can be represented as $(\delta x_{t+h}/\delta\varepsilon'_t)$. Systematic change in y_t may emanate from a reform prompted change in z_t, and thus the partial response of the conditional model y_t can be decomposed into a permanent regime shift in z_t $(\delta y_{t+h}/\delta\upsilon'_t)$ and a transitory change in z_t $(\delta y_{t+h}/\delta\varepsilon'_t)$, where $dy_t = d\upsilon_t + d\varepsilon_t$. A comparison of the impulse response to an orthogonalized shock to the full system x_t and the conditional model y_t, and in particular to a reform shift $\delta y_{t+h}/\delta\upsilon'$, can allow an assessment of the time varying characteristics of the reform. An impulse response is valid for the reform efficiency analysis only if the full model is congruent and encompassing and the conditional model in correctly specified by proving weak exogeneity of z_t.

17. A word of caution is warranted by the **limitations of the exogeneity-based analysis**. First, if the parameters of the conditional model are found to be to some degree exogenous to the marginal model, reforms still affect the conditional model through its variables, rather than through its parameters. Second, neither weak nor super exogeneity imply Granger non-causality. The marginal model can be found super exogenous to the conditional process, whereas obvious Granger causal links could still lead from instruments z_t to targets y_t. Third, while causal links from z_t to y_t are critical for a reform to have an impact on y_t and, thus, on Y_t, parameter constancy of y_t (i.e. its resistance to any shifts in z_t) is essential for the conditional model to have enough predictive power. This helps to refute empirically the Lucas critique if applied to the testing of the effects of reforms by testing exogeneity.[7] Forth, the reform testing procedure implies that y_t is a function of z_t. However, the inversion of the equation does not automatically mean that z_t becomes a conditional model of y_t. Thus, an inversion, although preserving the original direction of causality, can alter the covariance structure of the system, violate weak exogeneity, and break the invariance property of the conditional model. Finally, the arbitrarily imposed orthogonalization for modeling impulse responses can also violate weak exogeneity, distort the invariance of y_t and thus differences in the propagation of shocks will attest to a mere misspecification of the model rather than would be a confirmation of strong exogeneity of the transmission variable.

[7] See Ericsson and Irons (1995) for a comprehensive review of empirical relevance of the Lucas (1976) critique.

C. Testing the Effectiveness of Reforms by Testing Exogeneity

18. The econometric model cannot be expected to coincide with the economic process under consideration, but it should approximate the DGP accurately and should not be mis-specified. The underlying assumption of testing reforms by testing exogeneity is that the relevant econometric model is conditional on the policy instruments that can be used to alter the target variables. Thus, cointegration, exogeneity, causality, invariance, and impulse response are the key elements needed to estimate the impact of changes in a policy regime on any macroeconomic parameters of interest. Table 1 presents possible economic interpretations of the corresponding econometric properties, if they are detected in the process of statistical analysis of the underlying data.

19. The number of steps needed to estimate consistently and interpret meaningfully the above properties depend on the properties of the underlying data and the results obtained at each step. The suggested **estimation sequencing** is the following:

a. Build a congruent full model x_t by selecting relevant variables and the functional form.

b. Check for cointegration of variables in x_t;

c. If the cointegration property is detected, break x_t into y_t and z_t .

d. Test for weak exogeneity of Z_t;

e. Check for the direction of Granger causality between Y_t and Z_t;

f. Check for constancy of λ_1 in the conditional model by Chow test;

g. Construct a congruent ARMA(p,q) model for z_t ;

h. Check for constancy of λ_2 in z_t by Chow test or by Bai and Perron (1998);

i. Augment z_t using dummy variables (including the reform dummy) until it becomes empirically constant;

j. Augment the original model by plugging in the dummies capturing instabilities in the marginal model and check for their significance;

k. Compare impulse response functions of x_t and y_t to check the validity of conditioning;

l. Provide comparative interpretation of the results.

Table 1. Exogeneity Testing: Quick Reference Map

Property	Status	Interpretation
Cointegration	detected	There are long-term co-movements in the full model x_t. The suggested testing procedure can be applied.
	not detected	There are no long-term co-movements in the full mode x_t. The suggested testing procedure cannot be applied.
Weak exogeneity	detected	Policy instruments z_t are set exogenously outside the conditional submodel y_t. The government has full control over these instruments and can effectively manipulate them. Conclusions based on the conditional submodel y_t alone are accurate and valid.
	not detected	Policy instruments z_t are an endogenous part of the full model x_t. They cannot be treated as determined outside the conditional model, and should be modeled as a separate submodel. The government cannot set its policies independently of other developments in the economy or effectively manipulate this policy instrument. Conclusions based on the conditional submodel y_t alone are neither accurate nor valid.
Granger causality	detected	z_t is a potential instrument for changing the target y_t. Policies z_t have effect on target variable y_t. The policies are applicable y_t and z_t must be forecasted together within the full model x_t, one period at a time.
	not detected	z_t is not the right instrument for changing the target y_t. Policies z_t do not have effect on target variable y_t. The policies are not applicable. y_t and z_t can be forecasted separately: first forecasts of z_t over several periods can be constructed and then forecast for y_t can be generated from the conditional submodel alone.
Strong exogeneity = (weak exogeneity + Granger non-causality)	detected	Past history of the reform has no impact on the reform decision taken today. Information on previous attempt of a particular reform can be disregarded.
	not detected	Past history of the reform is important for and is taken into account for the reform decision taken today.
Invariance	detected	Effects of policies z_t on the target variable y_t are as anticipated.
	not detected	Effects of policies z_t on the target variable y_t are other than anticipated.
Super exogeneity = (weak exogeneity + invariance)	detected	The reform has an impact on the target variable through the transmission variable entering the conditional model and does not affect the value of the parameters in that model. The conditional model alone can be used for reliable policy simulation:
	not detected	The reform has an impact on the target variable through both the transmission variable entering the conditional model and its parameters. The path of the transmission variable should be modeled separately. Reliable policy simulation requires simultaneous modeling of the conditional and marginal process.
Differences in **impulse responses** between full and conditional models	detected	May mean incorrect conditioning. If conditioning is proved to be valid, suggests that a shift in the marginal model induced by the reform propagated into the conditional model.
	not detected	Conditioning is valid. Shifts in the marginal model induced by the reform do not propagate into the conditional model.

20. Using the suggested approach, one should not elevate the econometric techniques above economic sense. The exogeneity testing is based on a number of strong **assumptions**: (i) the equation for the target variable is correctly specified and control variables capture all its significant determinants; (ii) the transmission variable is correctly selected to represent the impact of an instantaneous reform; (iii) no other variables, which may be correlated with the transmission variable, are important for the target variable and can be disregarded. The relevant question to ask about these assumptions is not whether they are descriptively "realistic," for they never are, but whether they are sufficiently good approximation for the purpose in hand. This paper asserts that the answer to this question is positive.

III. Applications: Testing Discrete Reforms

A. Data Sources and Description

21. The econometric framework described above has been applied to test the episodes of two structural reforms, the introduction of VAT and exchange rate unification, which could be reasonably considered instantaneous. As the paper is methodological in nature and its conclusions highly preliminary, the paper intentionally has no direct attribution to particular countries, although the episodes tested are actual reforms of the early 1990s. The data for all variables for both countries are annual and cover 1971–97, which represent 27 data points, described in Appendix I. To avoid misspecifications, all time series were checked for stationarity, with the real GDP per capita growth for both countries and real investment in first country found mean-stationary at the conventional confidence level, whereas all other series were not. Stationarity was induced by taking appropriate log-linear transformations of the underlying data. All data are from IMF *WEO* and *IFS* databases and were corrected to the extent possible for omissions and other irregularities with the help of relevant IMF desk economists.

B. Exchange Rate Unification

22. The exchange rate unification in the first country was one of the most important economic reforms in the early 1990s, implemented alongside a series of other macroeconomic and structural reforms, including fiscal adjustment, decontrol of interest rates, productivity-boosting structural measures, and a debt restructuring agreement with the Paris Club. While all these reforms were introduced with the ultimate objective of improving growth and, empirically, it is difficult to distill the relative contribution of each of them, the exchange rate liberalization and unification clearly played an important role. Segregating this structural reform from an array of other reforms and exogenous influences, the exogeneity approach allows for the testing of whether the exchange rate unification by itself was an efficient instrument to induce additional growth.

23. The exchange rate liberalization and unification can be reasonably considered as an instantaneous economic reform that culminated in 1991. Thus, the impact of this reform can be assessed based on the following set of five variables describing the economy: *Y* - real GDP per capita growth (target variable), *I* - ratio of real investment to real GDP (control variable), C - current account balance in percent of GDP (another control variable), *R* - real effective exchange rate (transmission variable), and *D* - 1991 reform step dummy. The log-linear full model includes current or lagged values of the variables suggesting that all of them have had a contemporaneous or a lagged impact of the real GDP per capita growth (Table 1.1.1). The full model looks correctly specified (Table 1.1.2)

24. The cointegration analysis of the full model using the Johansen procedure on the first-order VAR, as selected by the Scwartz and Akaike information criteria, rejects the null hypothesis of no cointegration in favor of at least one cointegrating relationship with one large eigenvalue (0.698) and three small eigenvalues (Table 1.2.1). By putting the corresponding row of the speed of adjustment coefficients in α matrix to zero and under the assumption of one cointegrating vector, the LR-test accepts weak exogeneity of the transmission variable *R* in the conditional model. Thus, R seems weakly exogenous and a disequilibrium in the cointegrating relationship does not feed back into the conditional model. Consequently, the exchange rate can be considered an efficient policy instrument at the disposal and under effective control by the authorities. It is set exogenously from the conditional model and can be used to affect the target variable. Moreover, owing to the exogeneity property of the transmission variable, there is no need to model it separately, because the conclusions derived from the conditional model alone are deemed accurate and valid.

25. Although weak exogeneity of the transmission variable confirms that it is an efficient policy instrument, it—alone—does not attest to the fact that this particular instrument can be operational in affecting favorably the target variable, i.e., real GDP per capita growth. In the case of the reform under consideration, weak exogeneity of the transmission variable is complemented by a strong one-way Granger causality (test with two lags) from *R* to *Y* (Table 1.2.3). It suggests that the exchange rate reforms have had a pronounced impact on real GDP growth. A conjunction of weak exogeneity and Granger causality means that the transmission variable is not strongly exogenous for the conditional model. Thus, the past history of exchange rate reforms, which have been underway since 1987, has had an important impact on the exchange rate unification decision taken in 1991. The parameter constancy of the conditional model has been checked by recursive statistics, including one-step-ahead residuals (forecast error) with an approximate 95 percent confidence interval, the scaled log-likelihood, and the breakpoint Chow statistics (1.2.4). For the whole data set, the estimates are significantly different from zero, and relatively constant over the sample. The recursive plots suggest a reasonable constancy of all parameters, and of the conditional system as a whole, although some marginal values of the tests statistics have been observed for the current account variable C, in particular in 1992, the year immediately following the exchange rate reform.

26. Weak exogeneity of the transmission variable is supplemented by the invariance of the conditional model to the interventions that occur in the marginal process, proving that the parameters of the conditional model are super exogenous for the innovations occurring during the sample period. If the conditional model has constant parameters, but the marginal model does not have constant parameters, then the conditional model parameters cannot depend on the marginal model parameters. A very appealing aspect of testing super exogeneity is that only a simple marginal model needs to be non-constant. The marginal model for R has been specified as a simple univariate ARMA (1.4) (Table 1.3.1). Although the constant term is marginally accepted, the model looks correctly specified (1.3.2), but it does not pass the standard tests for parameter stability (1.3.3). This conjuncture of parameter stability in the conditional model and its instability in the marginal model, together with weak exogeneity property, clearly suggests super exogeneity of R in the conditional model. This property is critical for a reliable policy simulation: the exchange rate reform has had an impact on real GDP growth through the transmission variable entering the conditional model, but not by affecting the value of the parameters in that model.

27. To check the super exogeneity property of R, the marginal model has been augmented (Table 1.4.1) by introducing a number of auxiliary dummy variables, in particular a step 1995 and an impulse 1979 dummies, to induce its empirical constancy. A battery of standard tests have not detected any misspecification (1.4.2). One-step-ahead residual and breakpoint Chow test have shown a recursive constancy of the augmented marginal model (1.4.3) The reform 1991 step dummy has not been found significant for the augmented marginal process. Testing for invariance of the conditional model has been performed by adding the auxiliary variables to see whether they affect its parameters. As the Wald test for liner restriction has clearly indicated (Table 1.1.3), both auxiliary dummies (*E* and *G*) have not been significant, and the hypothesis that the parameters of this subset are jointly zero has also been accepted. Meanwhile, the reform step dummy *(D)* has been found significant in the conditional model. Consequently, super exogeneity of *R* for the parameters of the full model has been confirmed.

28. Finally, the validity of conditioning on *R* can be further tested by comparing the impulse response of variables in the full and the conditional models to orthogonalized shocks administered to the error terms in the corresponding cointegrated VAR models. In the case of first country, the information criteria suggested the selection of the first-order VAR with an intercept. Table 1.5 presents impulse response functions with rows corresponding to shocks to the target, determining, and transmission variables in each equation, and columns represent their impulse responses in the full model (uppercase letters) and the conditional model (lowercase letters). Because the conditional variable (*R*) was not included in the conditional model, although it was present in the full model, the sign and the pattern of impulse response graphs can be different if *R* were not strongly exogenous. Only in one case (response by *Y* to a shock to *I)* the conditioning of *R* had a marked effect, switching both the sign and the pattern of the impulse response. In all other cases, the sign and the propagation pattern of the shocks through time remained unchanged. Such a similarity in impulse responses to orthogonalized shocks supports strong exogeneity of *R* suggesting that the

amplitude and the time profile of potential exogenous shocks will be broadly invariant on the exchange rate regime.

29. Summing up, the following findings stem from the exogeneity analysis of the exchange rate unification: (i) the exchange rate can be considered a useful policy instrument at the disposal of, and under an effective control by, the authorities applicable for achieving a variety of macroeconomic goals (weak exogeneity property); (ii) the exchange rate is the proper policy instrument to use to stimulate the real GDP per capita growth (Granger causality property); (iii) past experience of the exchange rate liberalization and reform was taken into account by the decision makers and was embedded in the reform decision taken in 1991 (strong exogeneity property); (iv) the impact of the exchange rate reform on real GDP growth has been broadly in line with the authorities' expectations (invariance property); (v) an impact of the potential changes in the exchange rate regime on growth can be reliably simulated from the model of the real GDP alone, without a need to model simultaneously the exchange rate (super exogeneity property); and, lastly, (vi) given the adequate policy efforts, the results of the reform can be reasonably expected to be preserved in the future (impulse response property).

C. Tax Reform

30. The second application is based on examining the data on an episode in late 1980s–early 1990s, immediately surrounding the introduction of VAT and a major tax system reform in a developing country. The tax reform was conducted in within a 2-tear time frame and included a revamping the whole tax system through the introduction of the VAT, a new tax code, a single personal income tax, and a new corporate tax. Overall, the tax reform aimed at enhancing the elasticity of the tax system, improving tax equity and administrative efficiency, providing tax incentives for the private sector, streamlining the inadequate system of cascading taxes, and eliminating distortions created by a large number of tax rates.

31. The tax reform can be viewed as an instantaneous economic reform, because its key components were put in place within a very short time period (from mid-1988 until early 1990), and the government has undertaken congruous efforts on reinforcing and preserving its results thereafter. The exogeneity analysis of the impact of this reform is based on a simplified model consisting of just four variables: Y is the real GDP per capita growth (target variable), I is the ratio of real investment to real GDP (control variable), T is the real tax revenue (transmission variable), and *D(90-)* is 1990–97 reform step dummy.[8] The full ARDL

[8]The effect of the revenue-neutral tax reform on growth is thus tested by establishing exogeneity properties of T within the suggested cointegrated framework, rather than by searching for a statistically significant slope coefficient or a reform dummy according to a traditional approach.

model (Table 2.1.1) includes lagged values of the dependent variable and a number of current and lagged values of the independent variable (2.1.1) and looks correctly specified (2.1.2).

32. The rationale for including real tax revenue in the growth equation as a variable transmitting the impact of tax reform on growth is based on ample evidence available in the literature that tax reform may have an impact on growth. Rejecting the influential Harberger's (1974) superneutrality conjecture suggesting that the effect of taxation on growth is negligible, modern endogenous growth literature (Lucas, 1990; Rebelo, 1994) shows that growth depends on the net rate of return from investment, which, in turn depends on the tax rates, suggesting that the tax policy can actually influence the growth rate. Moreover, in some cases, long-run growth rates are explained by differences in tax systems. Advances in econometric techniques allow for the testing of the impact on growth of individual elements of fiscal policy, such as expenditure and taxation, and even more disaggregated by types of expenditure and shifts in composition of taxes. For example, Kim (1997) examines the impact of the revenue-neutral tax reform on growth in the United States and finds that shifts in the relative tax structure, while keeping the general tax level unchanged, have had a substantial positive impact on growth. Decomposition of the tax system into individual instruments allowed for the establishment of the impact of changes on growth in each of them. The testing of the tax reform described below shows the way of solving the dispute between Harberger and endogenous growth economists, thus answering the question of whether this particular tax reform was the right instrument to spur growth. This testing is based on establishing the exogeneity properties of a tax variable, rather than on a traditional testing of the reform through a dummy variable.

33. The cointegration analysis using the first-order VAR, as selected by the Scwartz and Akaike information criteria, supports the existence of at least two cointegrating relationships between the variables in the full model (2.2.1). By putting the corresponding row of the speed of adjustment coefficients in α matrix to zero and under the assumption of two cointegrating vector, the LR-test rejects weak exogeneity of the transmission variable T in the conditional model (2.2.2). Therefore, this tax reform should be viewed as a policy action that is endogenous for the economy as a whole: the government cannot set its tax policies independently of other developments in the economy; these policies cannot be treated as determined outside the conditional model and should be modeled separately; conclusions based on the conditional model alone are neither accurate nor valid, as any disequilibrium in the cointegrating relationship feeds back into the conditional model. Tax policy is endogenous for the conditional model, and its capacity to affect economic growth depends on the authorities' ability to effectively manipulate this policy instrument.

34. The testing of Granger causality did not detect causality between the target and the transmission variable in any direction, confirming a specific character of the tax reform (2.2.3).[9] It broadly supports the Harberger's conjuncture of a negligible impact of a tax

[9]Lack of causality does not contradict the presence of cointegration between variables, because cointegration is a property of contemporaneous variables integrated of the same

(continued)

reform on growth, because it was originally designed as revenue neutral and did not have growth acceleration as an immediate target. It does not mean that the tax reform cannot be considered the appropriate instrument to promote economic growth; it just suggests that such a reform—even with improved tax structure—by itself was not sufficient to boost growth and should have been supplemented by additional adjustment measures. Absence of weak exogeneity of the transmission variable, even if supplemented by Granger non-causality, does not allow for a meaningful analysis of the strong exogeneity property of the model. Although, it attests indirectly that the history of tax reform has had virtually no impact on the decisions to introduce the VAT or approve a new tax code taken in 1988–90. Rather, these reforms have been an integral part of a "fresh start" in the adjustment strategy aimed at improving resource allocation and dismantling excessive controls. Therefore, the information about earlier attempts to reform the tax system can be considered broadly irrelevant to the analysis of the tax reform of 1988–90. A parameter constancy test suggests that the estimated parameters are significantly different from zero, and relatively constant over the sample (2.2.4).

35. The only empirical value of testing for invariance, when *T* is not weakly exogenous for the conditional model, is to check indirectly whether the impact of the reform on the target variable has been as anticipated by the authorities. The marginal model for *T*, set as a simple ARMA (1, 3) process (Table 2.3.1), looks correctly specified (2.3.2), but does not pass the standard tests for parameter stability (2.3.3). The conjuncture of parameter stability in the conditional model and their instability in the marginal model parallel to the rejecting of weak exogeneity of *T* does not allow for the establishment of the super exogeneity property of the transmission variable. Nevertheless, it means that the tax reform has had an impact on real GDP growth through both the transmission variable entering the conditional model and its parameters. A reliable policy simulation requires simultaneous modeling of growth determinants, including a tax-related variable (such as *T*), as well as the path of the tax-related variable itself.

36. The simplest way of modeling *T* implies augmenting the marginal model until it becomes empirically stable by introducing a reform step dummy D(90-) and a step dummy E(80-), capturing the non-constancy of the model (Table 2.4.1). Note that the reform D(90-) dummy is significant for the augmented marginal process. Although, normality is marginally rejected, all other tests for misspecification look favorable (2.4.2), and the parameters of the model are empirically constant (2.4.3). When the auxiliary dummies are added to the full model, each of them separately and both taken together are not significant (2.1.3). Insignificance of the reform dummy in the full model conventionally means that the tax reform has not had an immediate impact on growth, whereas its clear significance in the augmented marginal model suggests that the tax revenues have been positively affected by the tax reform. This result can be seen only if *T* is modeled independently of the growth

---

order, whereas Granger causality relates variables, which are distant in time and can be of different order of integration.

equation, thus adducing additional evidence that the tax reform has been viewed as an integral part of a broader reform effort, rather than as just a straight growth inducing step.[10]

37. On the whole, the above analysis of the tax reform leads to the following conclusions: (i) the tax reform was an integral part of a broader reform package, and its impact on economic growth depended on the authorities' ability to effectively preserve its results (absence of weak exogeneity); (ii) the tax reform by itself was not sufficient for improving growth performance and needed supplementary adjustment measures to induce growth (Granger non-causality); (iii) the accumulated information about earlier attempts of tax system was not important for the tax reform of 1988–90, which can be considered a "fresh start" (absence of strong exogeneity); (iv) the tax reform was one of the determinants of growth in terms of both levels of tax collection and its elasticity (invariance property); (v) the impact of tax reform on growth can be quantified only by modeling simultaneously the growth determinants, including the tax-related variable and the path of the tax-related variable itself (absence of super exogeneity).

IV. Conclusions

38. The analysis presented in the paper builds on recent theoretical literature on the use of econometric techniques for economic policy evaluation and forecasting in the presence of structural breaks and regime shifts. Explicitly recognizing that any econometric model or technique is, at best, a crude approximation of reality, the paper suggests a new way of testing for the effectiveness of reforms using the exogeneity property of variables in correctly specified econometric models. It sets the preconditions for using the testing techniques (instantaneous type of the reform under consideration and cointegration of variables in the full model); suggests the interpretation of the results from the standard tests for weak, strong, and superexogeneity, useful for assessing the preparation, implementation, and outcome of such reforms; and applies these testing procedures for instantaneous reforms undertaken and interprets their results.

39. The exogeneity-based approach allows for the establishment, with a high degree of confidence, of whether the economic policy instruments the government has used for introducing a particular reform have really been under its effective control and whether they could have been manipulated efficiently enough to affect the targeted variable and bring about the desired macroeconomic outcome; whether the choice of policy instruments was correct; whether the impact of the reform was consistent with the expectations; and whether the econometric model of the reform process can be used for future policy simulation, analysis, and forecasting, or implementation of the reform has changed the DGP, and the model should be re-estimated.

[10] Because conditioning on T is not supported empirically, there is no practical value in analyzing the impulse responses.

40. The suggested technique has obvious **limitations**: (i) the issue of omitted variables has not been solved satisfactorily. Ramey RESET test run for each equation detects only functional form misspecification, while all unidentified factors which affect growth are lumped in the constant term. (ii) The exogeneity testing is largely a comparative static technique, which shows the impact of a unit change in the control variable on the target variable, assuming all other variables are kept unchanged. Although this a legitimate analytical approach, in the real world the new equilibrium is always an outcome of multiple dynamic forces. (iii) The suggested techniques assume that the particular instantaneous reform was the only factor affecting the transmission variable in the specified time period. This assumption is plausible only if, at the same time, there were no other reforms, which could potentially affect the transmission variable. If such a reform overlapped in time with other reform of the same sector, the impact of a particular reform may not be distinguishable.

41. The above conclusions and interpretations should be treated only as suggestive. The econometric literature on economic policy analysis is in its infancy, reemerging after several years of silence stemming from the general fatigue from trying to explain the poor performance of macro models. Substantial additional work—both theoretical and empirical—is needed before conclusions based on the testing for exogeneity could be considered reliable. In particular, the following **extensions** and refinements seem fruitful: (i) introducing the concept of testability of reforms along the lines of the concepts of predictability and forecastability, suggested in Clements and Hendry (1998); (ii) allowing the testing of econometric models of economic reforms with non-stationary variables building from the concept of joint stationarity within a cointegrating framework, as in Hendry (1999); (iii) conducting a comprehensive specification search through a multi-step model reduction to ensure model congruence, i.e., that it embodies all available information on a particular reform; (iv) development of a formal testing procedure to distill control variables from transmission variables, because each plays its specific role in the suggested procedure; (v) assessing whether the exogeneity-based testing dominates other available means for testing for effectiveness of a particular reform and thus uncover its encompassing ability; and (vi) applying, after inevitable refinements, these techniques to assessing results of instantaneous reforms in countries benefiting from IMF financial resources, technical assistance, and policy advice.

Definitions of Variables

Variables		Definition	Symbol	Construction	Sources
Country 1	Real per capita GDP growth rate	Index. Real GDP divided by total population	Y	ln (Wcountry codeRGDPRPC) index	WEO line POILAVGW
	Real investment	Ratio of real investment (deflated by WPI. 1990=100) to real GDP	I	level	WEO line Wcountry codeGGB and Wcountry codeRGDP
	Current account balance	Current account divided by nominal GDP in U.S. dollars.	C	level	WEO line Wcountry codeBCA and WCountryCodeN GDPD
	Exchange rate	Real effective exchange rate	R	As calculated by WRS	
	Reform dummy	Step dummy	D	Zero in 1971-90, one thereafter	
Country 2	Real per capita GDP growth rate	Index. Real GDP divided by total population	Y	ln(WCountryCod eRGDPRPC) index	WEO line POILAVGW
	Real investment	Ratio of real investment (deflated by WPI. 1990=100) to real GDP	I	ln index real investment to real GDP	WEO line Wcountry codeGGB and Wcountry codeRGDP
	Tax revenue	Log nominal tax revenue deflated by CPI (1990=100)	T	ln(WCountryCod eRGDPRPC) index	
	Reform dummy	Step dummy	D	Zero in 1971-90, one thereafter	
	Stability inducing dummy	Step dummy	E	Zero in 1971-79, one thereafter	

1.1. Full Model Analysis

1. Full model for Y

Variable	Coefficient	Std.Error	t-value	t-prob	PartR^2
Constant	-0.34455	0.13572	-2.539	0.0200	0.2533
I_2	-0.0019473	0.00083578	-2.330	0.0310	0.2222
C_1	-0.0039409	0.0011941	-3.300	0.0038	0.3644
R	0.084044	0.027891	3.013	0.0071	0.3234

```
R^2 = 0.551806  F(3,19) = 7.7975 [0.0014]  \sigma = 0.0242404  DW = 1.81
RSS = 0.01116436249 for 4 variables and 23 observations
```

2. Tests for mis-specification

```
AR 1- 1 F( 1, 18) =  0.0025109 [0.9606]
ARCH 1  F( 1, 17) =    0.37972 [0.5459]
Normality Chi^2(2)=     1.3792 [0.5018]
Xi^2    F( 6, 12) =     1.0162 [0.4594]
Xi*Xj   F( 9,  9) =     0.7169 [0.6860]
RESET   F( 1, 18) =    0.19445 [0.6645]
```

3. Augmented full model. Wald test for linear restrictions:

```
on D(91-): F( 1, 18) =     5.0608 [0.0372] *
on E(85-): F( 1, 17) =    0.71019 [0.4111]
on G(79) : F( 1, 17) =     2.8793 [0.1080]
on subset of E(85-) and G(79): F( 2, 17) =  1.5413 [0.2426]
```

Variables:

Y - real GDP per capita growth (the target variable)

I - ratio of real investment to real GDP (control variable)

C - current account balance in percent of GDP (control variable)

R - real effective exchange rate (transmission variable)

D - 1991 reform step dummy

E - 1985-97 step dummy

G - 1979 impulse dummy

1.2. Conditional Model Analysis

1. Test for cointegration for conditional model (VAR with one lag)

```
Ho:rank=p  -Tlog(1-\mu)   using T-nm    95%  -T\Sum log(.)  using T-nm    95%
 p ==  0       28.99**      24.16*     23.8      42.79*       35.65     39.9
 p <=  1        7.677        6.398     17.9      13.79        11.49     24.3
 p <=  2        6.105        5.088     11.4      6.114         5.095    12.5
 p <=  3        0.008312     0.006927   3.8      0.008312      0.0069    3.8
standardized \beta' eigenvectors
         Y            I            C           R
      1.0000      0.0017393    0.0061063 -0.00039887
     47.704       1.0000      -7.7691     -0.35530
   -292.76        2.2541       1.0000     -0.35606
    1465.7       40.396       39.236       1.0000
standardized \alpha coefficients
 Y              -0.7665  -0.0002588   -0.0000005 -0.00000001
 I              -3.1889  -0.032382    -0.072794  -3.5220e-006
 C             -23.896    0.056055     0.0093395 -1.9279e-005
 R             202.41    -0.10362      0.27204   -0.00018197
```

At least one cointegrating vector

2. Test for weak exogeneity of D (one cointegrating vector)

```
standardized \beta' eigenvectors
            Y            I            C            R
      1.0000    0.0015319    0.0055634 -0.00037040

standardized \alpha=A\theta coefficients
 Y             -0.86632
 I              4.5206
 C            -10.984
 R              0.00000

LR-test, rank=1: Chi^2( 1) = 2.3618 [0.1243]
```

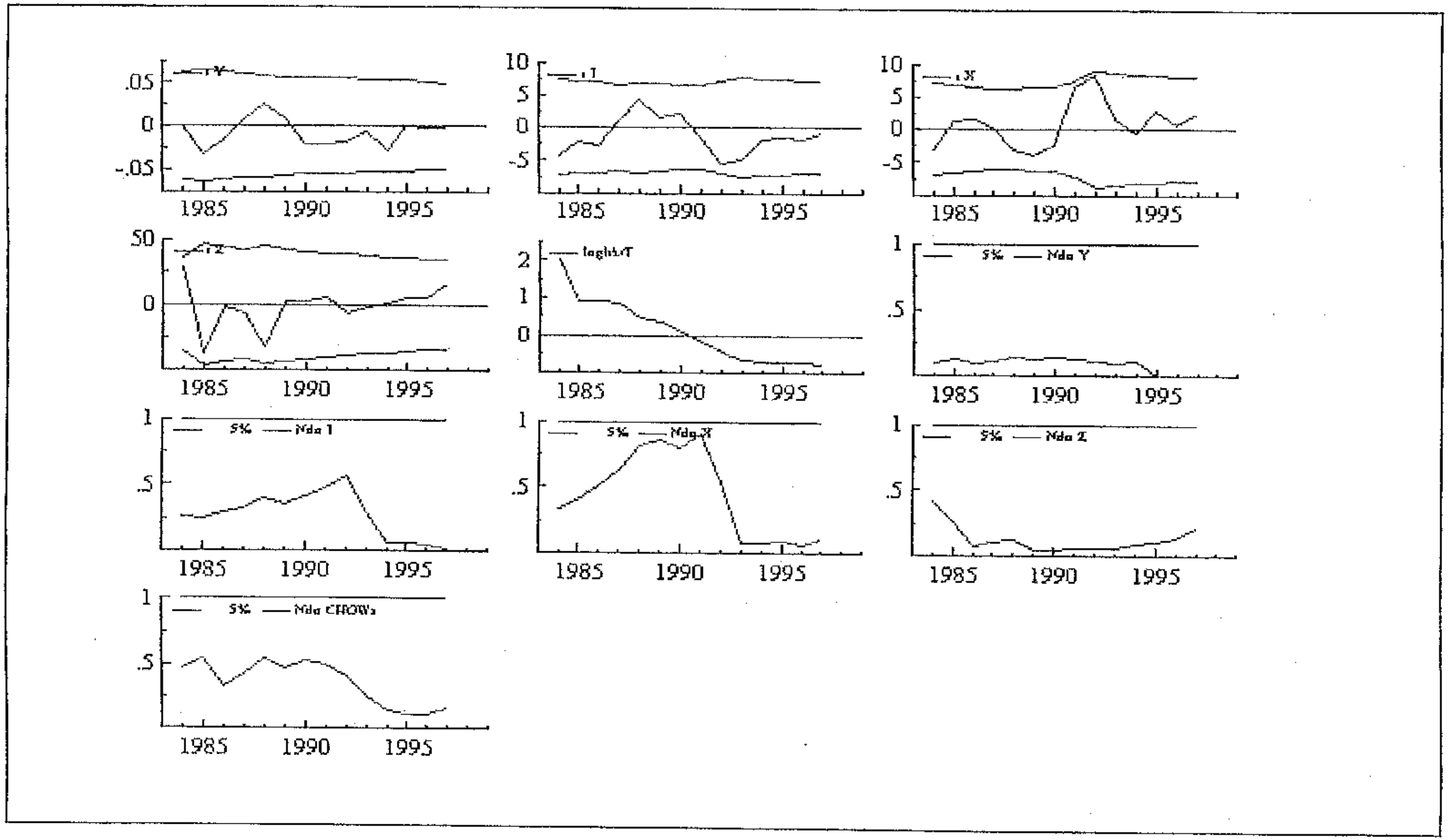
R is weakly exogenous

3. Test for Grander causality

Null Hypothesis:	Obs	F-Statistic	Probability
R does not Granger Cause Y	22	5.69568	0.00781
Y does not Granger Cause R		0.73736	0.61095

Granger causality from R to Y, no causality in the opposite direction

4. Tests for stability of λ_1



Recursive estimations for Y, B, I, and R: one-step ahead residuals $0+/-2\sigma_t$, scaled log-likelihood, and breakpoint Chow statistics for each equation and for the marginal model as a whole rescaled by their one-off 5 percent critical value.

1.3. Marginal Model Analysis

1. ARMA (1.4) model for R

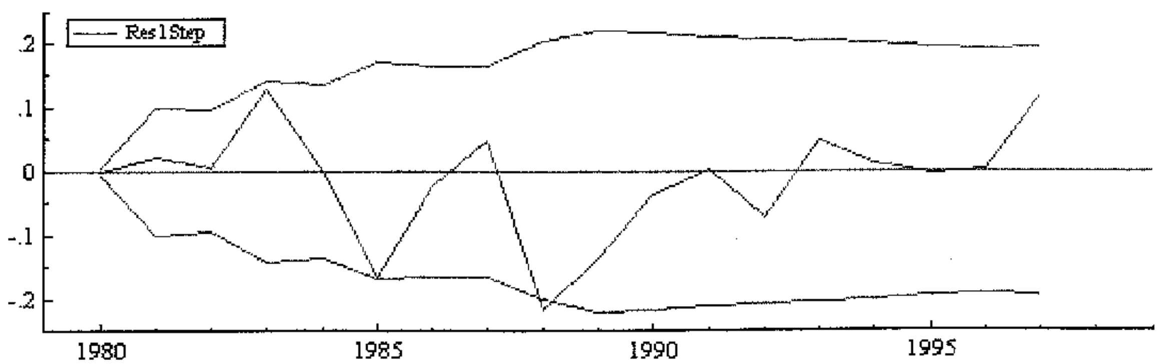
Variable	Coefficient	Std.Error	t-value	t-prob	PartR^2
Constant	0.78961	0.47347	1.668	0.1084	0.1039
AR(1)	0.83651	0.096694	8.651	0.0000	0.7572
MA(4)	-0.71324	0.17043	-4.185	0.0003	0.4219

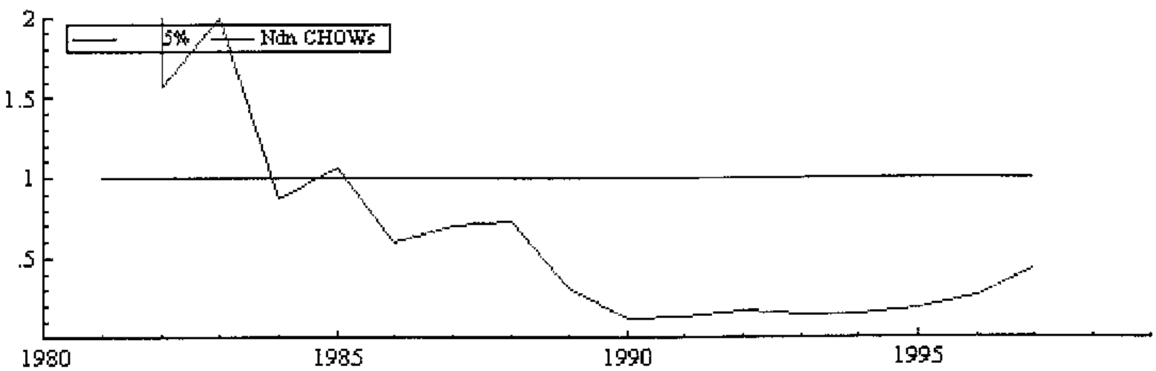
```
R^2 = 0.752844  F(2,24) = 36.552 [0.0000]  \sigma = 0.0971494  DW = 1.87
RSS = 0.2265120009 for 3 variables and 27 observations
```

2. Tests for mis-specification

```
ARCH 1    F( 1, 22) =      2.249 [0.1479]
Normality Chi^2(2)=      1.6748 [0.4328]
AR 1- 2 F( 2, 22) =    0.58346 [0.5664]
Xi^2      F( 4, 19) =      1.611 [0.2125]
Xi*Xj     F( 5, 18) =     1.3042 [0.3060]
```

3. Tests for stability





Recursive estimations for R: one-step ahead residuals $0+/-2\sigma_t$, and breakpoint Chow statistics for each equation and for the marginal model as a whole rescaled by their one-off 5 percent critical value.

1.4. Augmented Marginal Model Analysis

1. ARMA (1.4) model with a step dummy (1985) and an impulse dummy (1979)

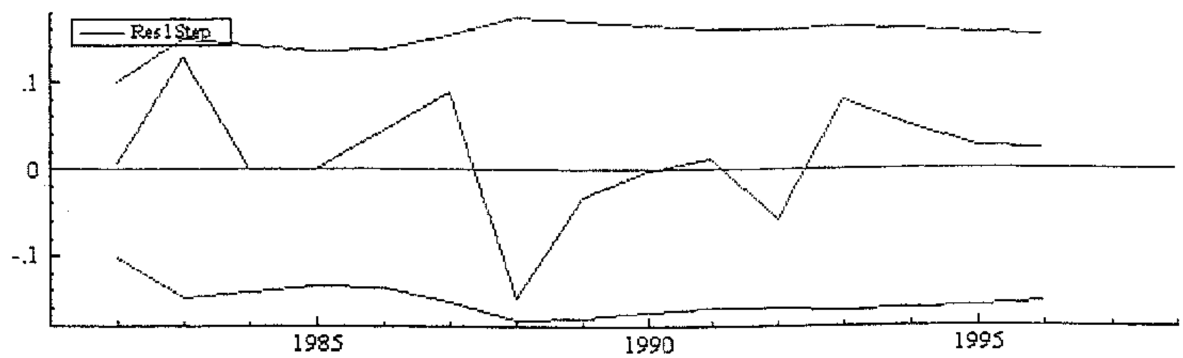
Variable	Coefficient	Std.Error	t-value	t-prob	PartR^2
Constant	2.7649	0.82745	3.342	0.0030	0.3367
AR(1)	0.44220	0.16524	2.676	0.0138	0.2456
MA(4)	-1.1319	0.25538	-4.432	0.0002	0.4717
E(85-)	-0.099186	0.045232	-2.193	0.0392	0.1794
G(79)	0.15011	0.036172	4.150	0.0004	0.4391

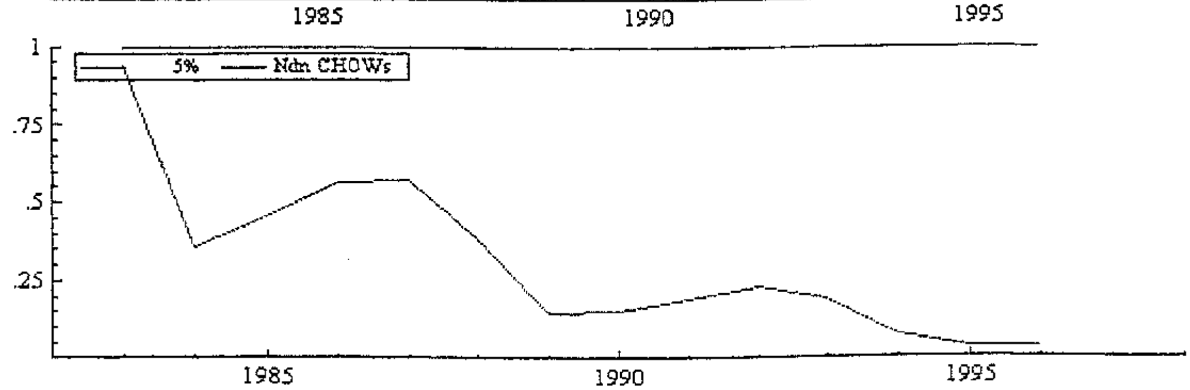
```
R^2 = 0.854212   F(4,22) = 32.226 [0.0000]   \sigma = 0.0779309   DW = 1.55
RSS = 0.133611089 for 5 variables and 27 observations
```

2. Tests for mis-specification

```
ARCH 1   F( 1, 20) =    0.027037 [0.8710]
Normality Chi^2(2)=     0.49822 [0.7795]
AR 1- 2 F( 2, 20) =     0.92076 [0.4145]
Xi^2     F( 8, 13) =      1.8662 [0.1526]
Xi*Xj    F(14,  7) =      1.9451 [0.1905]
```

3. Tests for stability

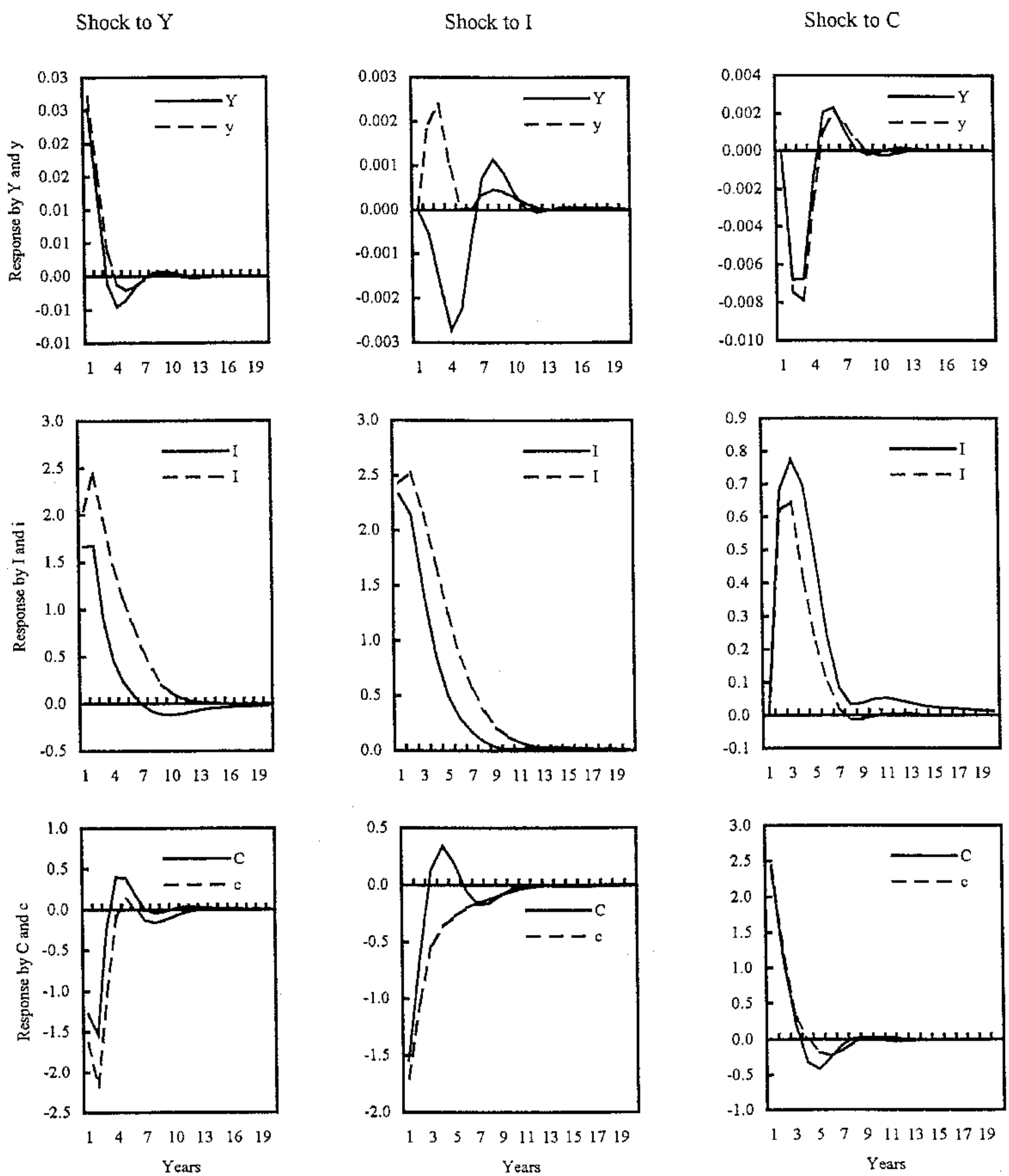




Stable. E(85-) and G(79) dummies induce stability, D(91) reform dummy is not significant.

1.5. Impulse Response Analysis

(Full model and the model conditional on R)



Source: Staff estimates.

Note: Y, I, C are the variables of the full model; y, i, c are the corresponding variables of the model conditional on R.

2.1. Full Model Analysis

1. Full ARDL model for Y

Variable	Coefficient	Std.Error	t-value	t-prob	PartR^2
Constant	0.038601	0.0093926	4.110	0.0008	0.5135
Y_1	-0.48957	0.22600	-2.166	0.0457	0.2268
Y_2	-0.51038	0.22372	-2.281	0.0366	0.2454
I	0.15701	0.045129	3.479	0.0031	0.4307
T_2	-0.22821	0.068117	-3.350	0.0041	0.4123
T_5	0.083256	0.040773	2.042	0.0580	0.2067

```
R^2 = 0.507707  F(5,16) = 3.3002 [0.0308]  \sigma = 0.0233499  DW = 2.37
RSS = 0.008723488225 for 6 variables and 22 observations
```

2. Tests for mis-specification

```
AR 1- 2 F( 2, 14) =     2.2997  [0.1369]
ARCH 1  F( 1, 14) =     0.30637 [0.5886]
Normality Chi^2(2)=     1.2621  [0.5320]
Xi^2    F(10,  5) =     0.38369 [0.9074]
RESET   F( 1, 15) =     1.403   [0.2547]
```

3. Augmented full model. Wald test for linear restrictions:

```
on D(90-): F( 1, 14) =     2.1264 [0.1668]
on E(80-): F( 1, 14) =     0.46669 [0.5057]
on subset of D(90-)and E(80-): F( 2, 14) = 1.0661 [0.3707]
```

Y - real GDP per capita growth (the target variable), I - ratio of real investment to real GDP (control variable), T - real tax revenue (transmission variable); D(90-) - 1990-97 reform step dummy; E(80-) - 1980-97 stability inducing step dummy.

2.2. Conditional Model Analysis

1. Test for cointegration for conditional model (VAR with one lag)

```
Ho:rank=p Tlog(1-\mu)   using T-nm   95%  -T\Sum log(.)  using T-nm   95%
 p ==  0       41.97**       36.94**  21.0       61.86**       54.43**  29.7
 p <=  1       17.11*        15.06*   14.1       19.88*        17.5*    15.4
 p <=  2        2.775         2.442    3.8        2.775         2.442    3.8
standardized \beta' eigenvectors
            Y            I            T
       1.0000     -0.039432    0.019058
      -3.3361      1.0000     -1.2836
      -1.3242     -1.6281      1.0000
standardized \alpha coefficients
 Y               -1.0061     0.029757     0.024972
 I                0.86368    0.076790     0.12395
 T                0.28148    0.22220      0.017351
```

At least two cointegrating vectors

2. Test for weak exogeneity of C (2 cointegrating vectors assumed)

```
standardized \beta' eigenvectors
         Y            I            T
       1.0000     -0.031709    0.031793
       0.082897    1.0000     -0.75901

standardized \alpha=A\theta coefficients
 Y               -0.94730    -0.065878
 I                0.80162    -0.26099
 T                0.00000     0.00000

LR-test, rank=2: Chi^2( 2) = 14.903 [0.0006] **
```

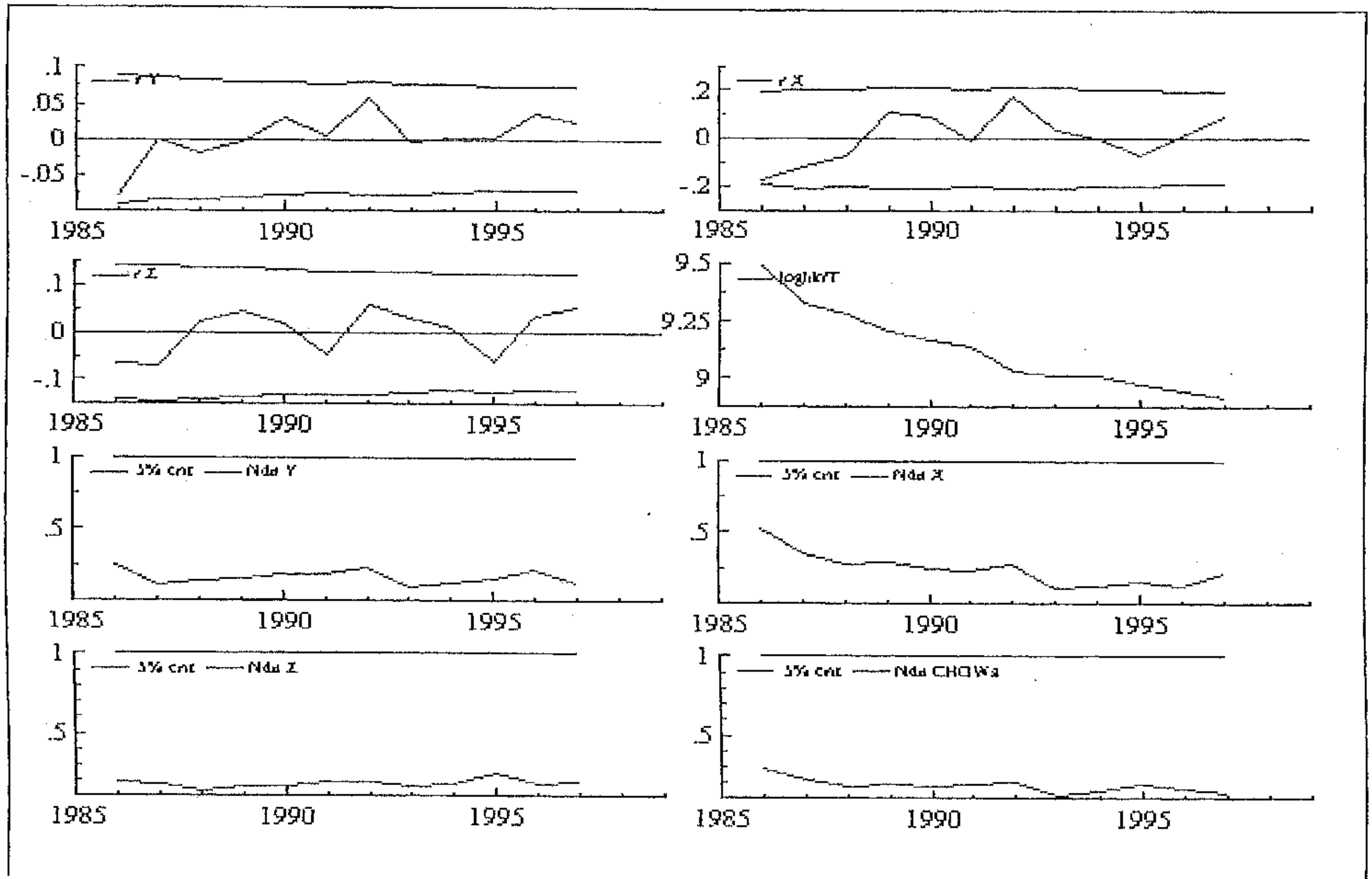
T is not weakly exogenous

3. Test for Granger causality (5 lags)

```
Null Hypothesis:                Obs F-Statistic Probability
  T does not Granger cause Y     22     0.47147      0.79017
  Y does not Granger cause T            0.58460      0.71199
```

No Granger causality in any direction

4. Tests for stability of λ_1



Recursive estimations for Y, I, and T: one-step ahead residuals 0+/-2σ_t, scaled log-likelihood, and breakpoint Chow statistics for each equation and for the marginal model as a whole rescaled by their one-off 5 percent critical value.

2.3. Marginal Model Analysis

1. ARMA (1.3) model for T

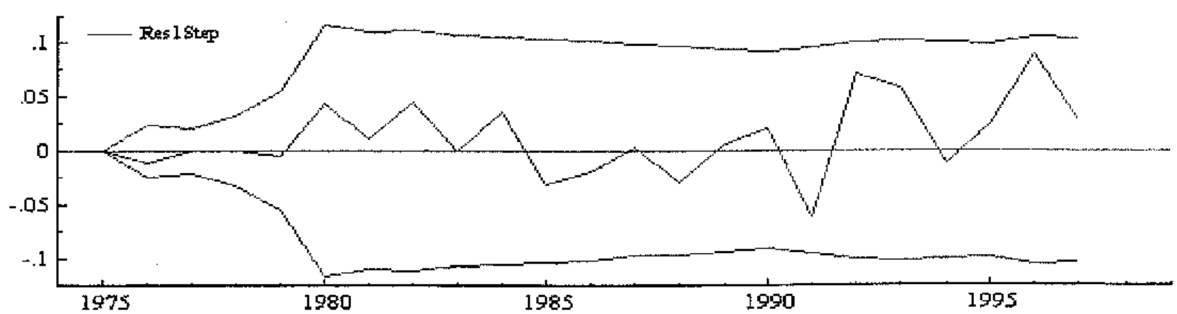
Variable	Coefficient	Std.Error	t-value	t-prob	PartR^2
Constant	0.02555	0.005825	4.386	0.0002	0.4450
AR(1)	0.85670	0.015232	56.243	0.0000	0.9925
MA(3)	-0.82582	0.16292	-5.069	0.0000	0.5171

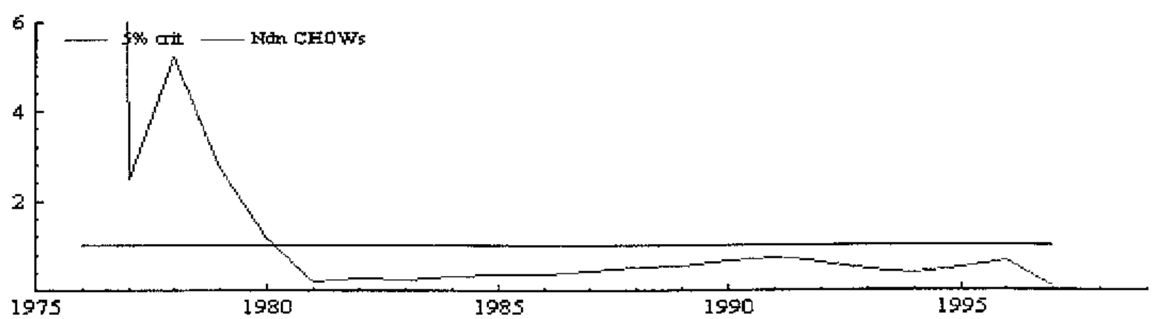
```
R^2 = 0.991  F(2,24) = 1321.4 [0.0000]  \sigma = 0.051801  DW = 2.06
RSS = 0.06440021716 for 3 variables and 27 observations
```

2. Tests for mis-specification

```
ARCH 1   F( 1, 22) =      1.3193  [0.2630]
Normality Chi^2(2)=       2.2198  [0.3296]
AR 1- 2 F( 2, 22) =       0.17158 [0.8435]
Xi^2     F( 4, 19) =      0.80077 [0.5396]
Xi*Xj    F( 5, 18) =      0.63736 [0.6741]
```

3. Test for stability





2.4. Augmented Marginal Model Analysis

1. ARMA (1.3) model with step dummies (1990) and (1980)

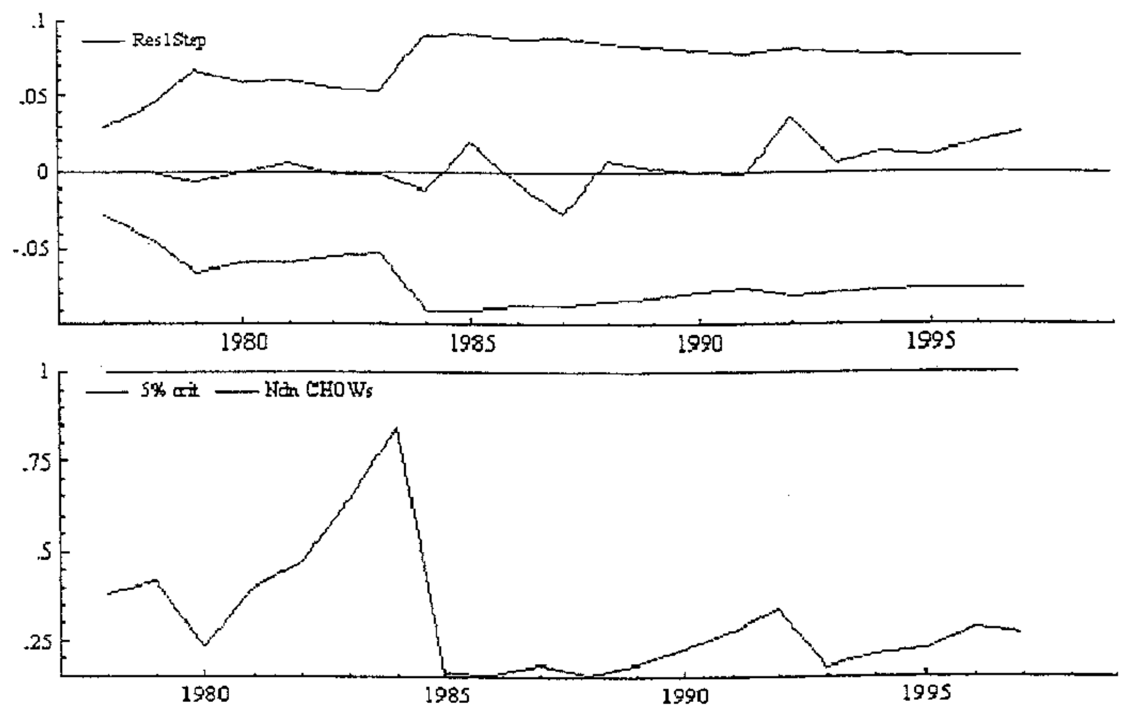
Variable	Coefficient	Std.Error	t-value	t-prob	PartR^2
Constant	-0.099096	0.010547	-9.396	0.0000	0.8005
AR(1)	0.72895	0.0084858	85.902	0.0000	0.9970
MA(3)	-1.4251	0.063016	-22.615	0.0000	0.9588
D(90)	0.049101	0.020378	2.409	0.0248	0.2088
E(80)	0.10211	0.017975	5.681	0.0000	0.5946

```
R^2 = 0.995525  F(4,22) = 1223.6 [0.0000]  \sigma = 0.0381515  DW = 2.11
RSS = 0.03202174873 for 5 variables and 27 observations
```

2. Tests for mis-specification

```
ARCH 1   F( 1, 20) =    0.031936[0.8600]
Normality Chi^2(2)=    6.0037   [0.0497] *
AR 1- 2 F( 2, 20) =    0.18178 [0.8351]
Xi^2     F( 8, 13) =    0.14402 [0.9950]
Xi*Xj    F(14,  7) =    0.25591 [0.9856]
```

3. Tests for stability



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